UWI
ST. AUGUSTINE CAMPUS

FACULTY OF ENGINEERING

BOOK OF ABSTRACTS

The International Conference on Emerging Trends in Engineering & Technology (IConETech-2020)

June 1st – 5th, 2020

Edited by: Boppana V. Chowdary

SPONSORS AND PARTNERS:

ansa McAL GROUP OF COMPANIES

THE NATIONAL GAS COMPANY OF TRINIDAD AND TOBAGO LIMITED

WE LOVE LEARNING.ca

HMIC INSTITUTE OF TECHNOLOGY "TRAINING FOR INDUSTRY"

PHOENIX PARK GAS PROCESSORS LIMITED

LAURISTON LEWIS ASSOCIATES LTD. CONSULTING ENGINEERS Established 1970

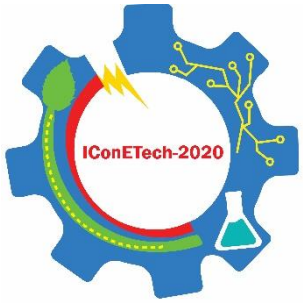
UWI
ST. AUGUSTINE CAMPUS

FACULTY OF ENGINEERING

BOOK OF ABSTRACTS

The International Conference on Emerging Trends in Engineering Technology (IConETech-2020)

June 1st – 5th, 2020



Edited by: Boppana V. Chowdary

Published and Printed by: Faculty of Engineering,
The University of the West Indies,
St. Augustine, Trinidad & Tobago, West Indies

CONFERENCE ORGANIZING COMMITTEES

Conference Chair

Professor Boppana V. Chowdary, Professor of Mechanical Engineering &
Deputy Dean (Research & Postgraduate Studies),
Faculty of Engineering, The UWI, St. Augustine, Trinidad & Tobago

Chief Patron

Professor Brian Copeland, PVC & Campus Principal, The UWI, St. Augustine

Patron

Professor Edwin I. Ekwue, Dean – Faculty of Engineering, The UWI, St. Augustine

Technical Chairs

- Professor Raffie Hosein, Faculty of Engineering, The UWI, St. Augustine, Trinidad & Tobago
- Dr. Trevor Townsend, Faculty of Engineering, The UWI, St. Augustine, Trinidad & Tobago
- Dr. Fasil Muddeen, Faculty of Engineering, The UWI, St. Augustine, Trinidad & Tobago
- Dr. Michael Sutherland, Faculty of Engineering, The UWI, St. Augustine, Trinidad & Tobago
- Dr. Jacqueline Bridge, Faculty of Engineering, The UWI, St. Augustine, Trinidad & Tobago

Conference Secretariat

- Mr. Jainarine Bansee
- Ms. Ambika Koonj Beharry
- Ms. Janae Dassyne
- Mr. Muhammad Ali
- Mr. Naseef Ali-Mohammed

Communications, Marketing & Sponsorship

- Ms. Paula Wellington-John, Faculty of Engineering
- Mr. Kishore Jhagroo, Mechanical and Manufacturing Engineering
- Mr. Jainarine Bansee, Mechanical and Manufacturing Engineering
- Ms. Wendy Maynard, Marketing and Communications

Presentations

- Dr. Victor Job, Faculty of Science and Technology
- Dr. Alana Sankar-Ramkarran, Faculty of Science and Technology
- Ms. Ambika Koonj Beharry, Faculty of Engineering
- Dr. Letetia Addison, Faculty of Science and Technology
- Mr. Jagadesh Ramnanan, Faculty of Science and Technology

Programme & Logistics

- Dr. Keith Miller, Geomatics Engineering and Land Management
- Dr. Sanjay Bahadoorsingh, Electrical and Computer Engineering
- Dr. Sean Rocke, Electrical and Computer Engineering
- Dr. Anthony Adeyanju, Mechanical and Manufacturing Engineering
- Ms. Theresa Lee, Chemical Engineering
- Mr. Azim Abdool, Electrical and Computer Engineering

Organizing

- Dr. Richard Bachoo
- Dr. Anthony Ademola Adeyanju
- Dr. Keeran Ward
- Ms. Theresa Lee
- Dr. Sanjay Bahadoorsingh
- Dr. Sean Rocke
- Dr. Lee Leon
- Dr. Dexter Davis
- Dr. Earl Edwards
- Professor Indrajit Ray
- Professor Hazi Azamathulla
- Mr. Jainarine Bansee
- Ms. Ambika Koonj Beharry

Regional/Local Advisory

- Professor Andrew Jupiter, The UWI, St. Augustine, Trinidad & Tobago
- Dr. Richard Clarke, The UWI, St. Augustine, Trinidad & Tobago
- Dr. Vincent Cooper, The UWI, St. Augustine, Trinidad & Tobago
- Dr. Sreedhara Rao Gunakala, The UWI, St. Augustine, Trinidad & Tobago
- Dr. Vernon Paltoo, President, National Energy Corporation, Trinidad & Tobago
- Mr. Mark Loquan, President, National Gas Company, Trinidad & Tobago
- Professor Prakash Persad, The University of Trinidad and Tobago, Trinidad & Tobago
- Dr. Ray J. Furlonge, Transportation Consultant, Trinidad & Tobago
- Mr. Mark Rattansingh, bpTT, Trinidad & Tobago
- Dr. Paul Aiken, The UWI, Mona, Jamaica
- Professor Noel Brown, Caribbean Maritime University, Jamaica
- Dr. Nagarani Ponakala, The UWI, Mona, Jamaica
- Ms. Michelle St. Clair, Lands and Surveys Department, Barbados

International Advisory

- Professor Udaya Halabe, West Virginia University, USA
- Professor Devdas Shetty, University of the District of Columbia, USA
- Professor Nageswara Rao Posinasetti, University of Northern Iowa, USA
- Professor P. Rathish Kumar, National Institute of Technology, India
- Professor T. S. Ravi, Wichita State University, USA
- Professor Kishore Pochiraju, Stevens Institute of Technology, USA
- Professor Abid Halem, Jamia Millia Islamia University, India
- Professor Pengcheng Jiao, Ocean College, Zhejiang University, China
- Dr. Konstantinos Kopsidas, University of Manchester, UK
- Dr. Ronald Dyer, University of Sheffield, UK
- Dr. John Wang, Pennsylvania State University, USA
- Dr. Turgay Eterkein, Pennsylvania State University, USA
- Professor Angappa Gunasekaran, California State University, USA
- Professor Geoff Syme, Edith Cowan University, Australia
- Professor Donatella Termini, University of Palermo, Italy
- Professor S. G. Deshmukh, Indian Institute of Technology Delhi, India
- Professor Leslie Montplasir, Wayne State University, USA
- Professor Rajiv Kumar Garg, National Institute of Technology Jalandhar, India
- Dr. Floyd Chadee, Stancorp Financial Group, USA
- Dr. T.V. V. L. N. Rao, SRM Institute of Science and Technology, India
- Dr. Fernando, Yudi, Universiti Sains Malaysia, Malaysia
- Associate Professor Rameshwar Dubey, Montpellier Business School , France
- Dr. Osama Mohammed Alia, University of Tabuk, Kingdom of Saudi Arabia
- Professor Prasanta Kumar Dey, Aston University, UK
- Professor Jairo R.Montoya-Torres, Universidad de La Sabana, Colombia
- Professor Md Azlin Md Said, Universiti Sains Malaysia, Malaysia
- Professor Kee-hung Lai, The Hong Kong Polytechnic University, Hong Kong
- Professor Marta Ormazabal, University of Navarra, Spain
- Professor Kwai-Sang Chin, City University of Hong Hong Kowloon, Hong Kong, China
- Dr. Albert H.C. Tsang, Hong Kong Polytechnic University, Hong Kong, China
- Professor Adelino Ferreira, University of Coimbra, Portugal
- Mr. Uday Sunkara, Daikin Australia PTY. Limited, Australia

Publications

- Mrs. Paula Wellington-John
- Mr. Jainarine Bansee
- Ms. Ambika Koonj Beharry
- Ms. Janae Dassyne
- Mr. Muhammad Ali
- Mr. Manoj Kollam
- Mr. Arshad Mohammed
- Dr. Simone Primus

Facilities Management

- Dr. Mwasha Abrahams
- Mr. Dayanand Powdhar
- Mr. Adedotun James Akingbala

Event Management

- Mrs. Charmain Subero-Salandy
- Mrs. Nikeisha Plato-Robinson
- Ms. Tianna Lewis
- Ms. Megan Alexander
- Mrs. Precious Clement
- Ms. Nikesha James
- Ms. Elisabeth Mohammed
- Mrs. June Charles-Noray
- Ms. Nicole Soomai

Engineering Exhibition

- Mr. Jainarine Bansee
- Mr. Kishore Jhagroo
- Mr. James Akingbala
- Mr. Sheldon Lancaster
- Mrs. June Charles-Noray
- Mr. Steve Ramoutar

Budgeting & Accounting

- Mr. Navneet Boodhai
- Ms. Julie Kublalsingh
- Ms. Tanya Aberdeen

Technical Support Team

- Mrs. Paula Wellington-John
- Mr. Dwayne Caberrea
- Ms. Kristal Gosine
- Mr. Garth Wilson
- Mr. Nicholas Buchoon
- Mr. Dentan Clarke
- Mr. Anthony Lamb

SPONSORS AND PARTNERS

- The School for Graduate Studies and Research, The UWI
- ANSA McAL Group of Companies
- The National Gas Company of Trinidad & Tobago Limited
- We Love Learning Canada Inc.
- The Metal Industries Company
- Phoenix Park Gas Processors Limited
- Lauriston Lewis Associates Limited
- The Association of Professional Engineers of Trinidad and Tobago

WELCOME MESSAGES

MESSAGE FROM CONFERENCE CHAIR

Boppana V. Chowdary
Conference Chair
Professor & Deputy Dean (Research and Postgraduate Studies)
Faculty of Engineering,
University of the West Indies, St. Augustine Campus.

The International Conference on Emerging Trends in Engineering & Technology (*IConETech-2020)* is hosted by the Faculty of Engineering of The University of the West Indies, St. Augustine, Trinidad and Tobago on 13th -15th March 2020**, in collaboration with engineering firms such as The ANSA McAL Group of Companies, and The National Gas Company of Trinidad and Tobago Limited (NGC).**

This conference aims at bringing together leading academics, innovative engineers, government officials, and environmental policy makers to share their experiences on fundamental developments in science and engineering concepts and their contemporary applications in technological advancements in the 21st century. ***IConETech-2020*** focuses on providing a platform for researchers and practitioners to present their findings in various disciplines such as Advancing the Chemical, Food & Petroleum Sectors, Sustainable Built Environment, Smart & Intelligent Systems, Applied Spatial Information Systems, Innovative Mechanical and Manufacturing Systems as well as Entrepreneurial Approaches in Engineering Education.

The conference organising committee has received 110 full papers and 50 abstracts. Over 20 of them have been submitted from other countries including USA, India, Nigeria, Ethiopia, France, and Portugal as well as other Caribbean nations. All peer reviewed papers will be published on the university website as post conference proceedings, so it may be accessible to all. Subsequently, the information shared in the conference will be disseminated through various publications including peer reviewed special issues journals. The best of the paper submissions will be awarded Innovative Engineering Prizes.

In addition to the special research outputs to be presented in five parallel sessions, the conference also features several keynote addresses from distinguished international speakers. The conference also includes poster presentations, plenary sessions, engineering exhibition and island tours.

I would like to thank all the Booth Sponsors and the other partners of the conference as well as the Technical Chairs, Organizing Committees, Paper Reviewers, and International, Regional & Local Advisory members for their support and value addition to the conference. My special thanks to the Chief Guest and all international, regional and local speakers for spending their valuable time and adding great value to the conference. I hope that ***IConETech-2020*** will be beneficial and enjoyable to all participants.

MESSAGE FROM CONFERENCE PATRON AND DEAN, FACULTY OF ENGINEERING

Professor Edwin I. Ekwue
Conference Patron
Dean, Faculty of Engineering,
The University of the West Indies, St. Augustine Campus.

It is with gladness that I present this introduction to the Book of Abstracts as Dean, Faculty of Engineering, the Faculty that is hosting this Conference. This Conference aims to bring together leading professionals involved in engineering, environment and other ancillary aspects of engineering including research scientists, engineers, and other experts so that they will have a forum to share their experiences, research results and methods and developments in science and engineering concepts and their contemporary applications as we move ahead in this 21st Century. The Book of Abstracts portrays the synopsis of the papers of these great contributors to the Conference.

Our Faculty of Engineering at St. Augustine, Trinidad offers many courses resident in five departments: Chemical Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, Geomatics Engineering and Land Management and Mechanical and Manufacturing Engineering. Programmes offered include Bachelor's, Diploma, Master's, Master of Applied Science, Master of Philosophy and Doctor of Philosophy, representing all levels of university education. Our Faculty also is involved in carrying out meaningful research, development and innovation. Our Faculty strives at all times to be relevant to industry and the country generally. We are deeply involved in examining ways of improving our innovation and entrepreneurial strides in all our programmes and activities.

Thanks to all members of the Organising Committee of this relevant and all-important Conference. I commend them for leading the drive towards this conference. Thanks also again to all our Faculty members, the sponsors, you the distinguished participants and all who have contributed papers to this conference. This Book of Abstracts is a prelude to the Conference Proceedings. I wish all of us happy deliberations at this all-important conference.

MESSAGE FROM PRO-VICE CHANCELLOR FOR GRADUATE STUDIES & RESEARCH

Professor Stephan Gift
Pro-Vice Chancellor for Graduate Studies and Research
Faculty of Engineering,
The University of the West Indies, St. Augustine Campus.

On behalf of The University of the West Indies, I welcome everyone to this International Conference organised by the Faculty of Engineering here at St. Augustine. The conference has as its main theme *"Emerging Trends in Engineering Technology"*. Technology today is advancing at an increasingly rapid rate and a conference that identifies and examines these trends will provide important information for the attendees as well as other researchers and professionals. We especially welcome visitors from outside of Trinidad and Tobago and hope that your stay here in Trinidad and Tobago is a pleasant and rewarding one. The University of the West Indies actively promotes high-quality research as we recognise its importance to our well-being as an internationally accredited tertiary institution as well as the impact such research can have on the region we serve. We have also been promoting innovation and entrepreneurship among our staff and students with the goal of making our University more entrepreneurial. In this way we can both increase opportunities for our graduating students as well as develop new ideas and intellectual property that would allow us to influence these emerging trends in technology.

The presence of local and international scholars will no doubt contribute to meaningful discussions over the 2 days of the conference and we look forward to the many presentations. It is my hope that everyone, especially our young researchers, will benefit from this experience and can develop fruitful collaborations with our visiting colleagues. I offer my best wishes for a successful conference.

MESSAGE FROM THE DIRECTOR
SCHOOL FOR GRADUATE STUDIES & RESEARCH

Professor Hariharan Seetharaman
Director, School for Graduate Studies & Research,
Chair, Campus Committee for Graduate Studies & Research
The University of the West Indies, St. Augustine Campus.

The School for Graduate Studies & Research, UWI, St. Augustine is extremely delighted to note the release of a Book of Abstracts coinciding with the Faculty of **Engineering's International Conference on Emerging Trends in Engineering & Technology *(IConETech-2020)*** to be held from March 13th through 15th, 2020.

The objective of this Conference is to bring together many disciplines to promote science, technology and engineering concepts, as well as entrepreneurship and economic sustainability in an attempt to emphasize the interdisciplinary approach of resolving contemporary issues. There is an immediate need for increasing such awareness among the practising professionals in multiple disciplines.

I am confident that the research papers to be presented in this Conference will comprise a lot of local research undertaken in the subject matter.

I wish the Conference organizers and the Faculty of Engineering every success and also implore them to take science and engineering in the Caribbean to newer heights.

MESSAGE FROM THE CHIEF GUEST

Mr. Anthony Sabga III
Chief Executive Officer
ANSA McAL Group of Companies

Greetings.

Allow me to thank the organizers of this important Conference for giving me the privilege of being the Chief Guest for the International Conference on Emerging Trends in Engineering & Technology (IConETech-2020). For me it is an honor and pleasure.

Engineers play a key role in the development of countries. They contribute to and enable initiatives that drive economic progress and inspire the changes that improve our quality of life. Currently, the manufacturing industry is facing unprecedented challenges due to globalization and as a result, the business environment is characterized by complexity and continuous change.

As such, this Conference is timely and an excellent opportunity for stakeholders to establish meaningful collaborations around the world. I look forward to an excellent meeting with great engineering minds from the Caribbean, sharing exciting and innovative presentations and ideas.

I take great pride in welcoming all participants of the Conference and I am sure that each one of you will identify subjects of his/her interest and will benefit from many fruitful and enriching interactive discussions.

Let me thank the local organizing committee, participants, session chairs, keynote and plenary speakers for what promises to be an exciting conference program.

I wish for inspiring and successful ideas.

MESSAGE FROM INTERNATIONAL KEYNOTE SPEAKER

Devdas Shetty, Ph.D., P.E.
Dean, School of Engineering and Applied Science
Professor of Mechanical Engineering
University of the District of Columbia
4200 Connecticut Ave. NW, Washington, DC 20008
Email: devdas.shetty@udc.edu

Welcome to the **International Conference on Emerging Trends in Engineering & Technology *(IConETech-2020)*** in Trinidad and Tobago. This is a special event that provides opportunities for sharing technical expertise and first-hand knowledge of the latest development trends and innovations in the emerging area of the 21st century.

This unique conference brings together people who are passionate about innovation. An important part of continuous improvement motivates all of us to work together and this conference provides opportunity to talented students, educators and industry leaders. Fundamentally, ***IConETech-2020*** is about sharing and connecting with participants who are dedicated to this objective fundamentally.

The theme of this conference reminds us that the world is changing rapidly- and that we must be ready to adapt. Global competitiveness in in STEM field had been never been more crucial than it is today. Today, business environments increasingly require engineers who can design and deliver to customers not only basic design, but complete products and solutions involving complex integrated systems. Product design is no longer solely concerned with the design of a manufactural product, it also focusses on innovation, entrepreneurship and services that will benefit individuals and society. With the important need of an interdisciplinary approach to resolve the issues, the goal of the conference is to provide a platform to researchers in varied disciplines to attain the highest sustainable economic growth and employment and a rising standard of living, while maintaining financial stability nationally and globally. The conference addresses wide ranging issues starting from advances in petroleum sector and, includes sustainable development, intelligent systems, manufacturing, Industry 4.0 and covers areas in I.T. and engineering education.

Many thanks to all the experts and delegates attending ***IConETech-2020***. I am also grateful to the sponsors for their support. I really applaud the leadership of the Faculty of the Engineering, The University of the West Indies, St. Augustine for their dedicated service towards the organization of this important conference. I encourage you to take full advantage of your participation. I wish you a purposeful and comfortable stay at the University of the West Indies, Trinidad during ***IConETech-2020***

TABLE OF CONTENTS

Theme A

Advancing the Chemical, Food, and Petroleum Sector

SHELF LIFE STUDY, SENSORY EVALUATION AND NUTRITIVE VALUE OF WHEAT FLOUR/ DASHEEN (*COLOCASIA ESCULENTA* (L.) SCHOTT) TARO/COCOYAM FLOUR SWEETBREAD

Maltee R. Rampat[1], Marsha Singh[2] and Neela Badrie[3*]

[1,2,3]Faculty of Food and Agriculture, The University of the West Indies, Trinidad

[1]Email: malteerampatm@gmail.com, [2]Email: marsha_ggghotmail.com

[3]Email: neela.badrie@sta.uwi.edu *(Corresponding author)

Abstract*:* The purpose of this study was to develop three variations of taro/dasheen sweetbread with varying percentages of taro flour to replace wheat flour and determine shelf life study, sensory evaluation and proximate composition. Four sweetbread treatments were prepared using wheat flour and taro flour in the ratios W-100: T-0, W-70: T-30, W-60: T-40 and W-50: T-50. Each treatment was subjected to a shelf life study for ten consecutive days, test for colour, pH, water activity, total plate count and to physically observe the two treatments used in the sensory evaluation at air condition 20°C for ten consecutive days. To analyse the results Descriptive Statistics and statistical tests were used to explore means ± and Standard deviations (SD). Significant difference was established at ($P<0.05$). It was concluded that the treatment containing 100% wheat flour was more preferred than the sweetbread made with 30% taro flour to replace wheat flour. However, ratio W-70: T-30 can produce higher nutritive value than sweetbread made with 100% wheat flour with similar sensory characteristics. Participants did rate wheat/taro treatment with an affinity of acceptance. The microbiological analysis revealed that sweetbread made from the ratio W-70: T-30 can have a shelf life of approximately one week without growth of bacteria, yeast and moulds. The foregoing ratio of taro flour supplementation can produce sweetbread of acceptable levels to be a viable product on the market.

Keywords: *Taro/Dasheen, Sweetbread, Shelf Life, Food Microbiological test, Chemical Food Tests*

PHASE INVERSION AND VISCOSITY IN PIPE FLOW

Laura Edwards[1], Dhurjati Prasad Chakrabarti[2*]
[1,2]Department of Chemical Engineering, The University of the West Indies, St Augustine, Trinidad and Tobago.
Email[1]: laur_edwards@hotmail.com;
Email[2]: dhurjati.chakrabarti@sta.uwi.edu *(Corresponding Author)

Abstract: This project is primarily aimed at determining the phase inversion of oil water dispersion from a three-phase mixture comprising of an oil-water emulsion at different oil percentages and air at varying liquid and gas flowrates through a horizontal pipe. Parameters affecting phase inversion were investigated such as liquid-side pressure drop, viscosity and flow regimes. The liquid-side pressure drop was estimated and predicted from existing as well as developed correlations. The results obtained were tabulated and represented graphically. Viscosity measurements were taken at the different oil percentage values. At inversion, the mixture's continuous phase switched from water to oil as indicated by a vast increase in viscosity. A significant increase in pressure drop was noted for all correlations used beyond the point of phase inversion. It was also found that the occurrence of phase inversion affected the flow regimes of the mixture causing a shift from a plug dominant flow to a more slug-type flow pattern.

Key words: *three phase flow, emulsion, horizontal pipe, phase inversion, oil-water.*

DISSOLVED OXYGEN IN GASOLINE AND TANK CORROSION

Preya Ramdeen[1], Dhurjati Prasad Chakrabarti[2*]
[1,2]Department of Chemical Engineering, The University of the West Indies, St Augustine, Trinidad and Tobago.
[1]Email: preyaramdeen@gmail.com
[2]Email dhurjati.chakrabarti@sta.uwi.edu *(Corresponding Author)

Abstract: The quantity of gaseous oxygen dissolved in water is generally known as Dissolved Oxygen. However, the presence of dissolved oxygen is possible in other liquids. To determine the concentration of Dissolved Oxygen in Gasoline a probe was used to carry out oxygen concentration at different experimental conditions. Comparing the experiments performed on Gasoline and Deionized Water it was found that for gasoline, the equilibrium point was reached earlier, while for the Deionized Water it took generally a long time for the initial reading to be attained after purging. In determining the mass transfer coefficients of Gasoline and Deionized Water it was found that Gasoline displayed a higher mass transfer coefficient value than Deionized Water. It is concluded that the increase in stirring speed, increases, the mass transfer coefficient and it is more prominent for gasoline. From extensive research it was reckoned that the Dissolved Oxygen and free water present in the Gasoline in storage, could result in electrochemical corrosion over a period of time.

Key words: *tank corrosion, gasoline, dissolved oxygen, electrochemical, oil-water interface.*

THE NATIONAL FOOD CONTROL SYSTEM IN GUYANA: EVALUATION OF THE CURRENT REGULATORY FRAMEWORK FOR FOOD CONTROL SYSTEMS

Maya A. Phillips[1*]

[1]Faculty of Food and Agriculture, The University of the West Indies, Trinidad

[1]Email: maya.phillips@my.uwi.edu; phillips_maya@rocketmail.com *(Corresponding author)

Abstract*:* The national food control system in Guyana is fragmented. It is a multiple agency system where multiple governmental agencies across various Ministries of Government are responsible for different aspects of food control. Overlaps in responsibilities arise from agencies sharing the responsibility for a particular industry or sharing food related legislation and/or regulations. Gaps in the food control system include the skills gap, the lack of a database to share information between agencies, slow surveillance system for foodborne diseases, largely paper based documentation system, poor harmonization of national standards with international standards, lack of adequate quarantine facilities, and the lack of a robust traceability system from farm to table. Outdated legislation and weak communication pathways are major weaknesses in the current regulatory framework for food control in Guyana.

Guyana needs to address the overlaps, gaps, and weaknesses in the current national food control system. It is recommended in the short term that Guyana establishes formal channels of communication such as Memoranda of Understanding (MOU) between agencies responsible for food in Guyana, expand Guyana's human resource capacity by training personnel in various aspects of food control, and design and implement Public Service Announcements (PSAs) for food safety and food quality.

In the medium term, it is recommended that Guyana establishes a Ministry of Food Production, develops accompanying Regulations for the new Food Safety Legislation (Act) following the passage of the Draft Food Safety Bill 2016, Bill no. 22 of 2016, designs a national policy for genetically modified (GM) foods, certifies public abattoirs, establishes quarantine facilities and regulations to govern operations, and develops a database with baseline data for heavy metals in the water supply.

In the long term it is recommended that the country establishes a Food Safety Authority, and improves laboratory infrastructure and capabilities.

Keywords: *National Food Control Systems, Food Legislation and Regulations, Guyana.*

MICROBIAL FUEL CELL – AN ALTERNATIVE ENERGY SOURCE FOR T&T

D Ramganase[1], R Ramoutar[2], J M Intosh-Abdool[3], A Bleasdell[4], J Rooplal[5] and D P Sharma[6]*

Faculty of Science & Technology, The University of the West Indies, Trinidad
Email: Davinder.Sharma@sta.uwi.edu *(Corresponding author)

Abstract*:* The microbial fuel cell (MFC) is a bio-electrochemical system that uses bacteria from wastewater to convert organic molecules directly into electrical energy under anaerobic conditions. In the present study we used a dual chamber MFC for electricity generation and performance improvement. The performance of the MFC was optimized by: (a) setting up five MFC's using different combinations of electrodes of varying surface areas, (b) using wastewaters from different locations within Trinidad & Tobago and (c) providing additional supply of oxygen in the cathode chamber. Aluminum mesh and Platinum/Carbon 40% (PtC40%) cloth of different ratios were used as electrodes whereas Nafion-212 was used as the ion exchange membrane inside of an MFC reactor with capacity of 150 ml per chamber. Samples collected from various site in Trinidad i.e. Cascadoux, Nariva swamp, Caroni swamp, Guaracara River and a cow farm located at Cunupia, were tested for their electrical capabilities. The highest voltage of 850 mV was achieved from the cow farm sample using a cylindrical shaped aluminum mesh electrode of ratio 6:1. The PtC40% with ratio 2:1 for the cow farm had the best stability. The results were very attractive and demonstrated that wastewater containing animal faeces, urine or chemical pesticides are ideal for energy generation. This supports that an MFC is an option as an alternative source of electrical energy.

Keywords: *Microbial fuel cell, Dual chamber, Alternative energy source, Wastewater.*

THE PRODUCTION OF A DRIED AVOCADO (PERSEA AMERICANA) POWDER

Saheeda Mujaffar[1*] and Tsai-Ann Dipnarine[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: saheeda.mujaffar@sta.uwi.edu [*](Corresponding author)
[2]Email: tsaiann1@hotmail.com

Abstract*:* This work investigated the technique of vacuum freeze drying of avocado pulp (*Persea americana* var. Pollock) to produce a dried cake which could be blended into a powder to be used in various food applications. Frozen, mashed avocado pulp samples were dried in a Benhay SB-4 vacuum freeze dryer. For comparison, fresh pulp samples were also oven-dried in a Unitemp drying cabinet at 60°C. Samples were dried until constant weight was achieved after which they were blended into powders and analysed. Analyses included determination of moisture content, water activity, pH and total soluble solids content, colour assessment, proximate analyses, physical properties, rehydration behaviour and a preliminary storage assessment. Drying data was used to generate rate and Moisture Ratio (MR) curves and thin layer models applied to the MR data. The moisture content and water activity values of the fresh pulp averaged 3.16 g H_2O/g dry matter (76.0% wet basis) and 0.889, respectively. Samples were successfully dried in the freeze dryer to an average moisture content of 0.02 g H_2O/g dry matter (2.1% wet basis) after 72h, and a final average water activity of 0.356. Drying occurred in the falling rate period and the drying rate constant (k_1) averaged 0.2496 1/h. The Verma model was found to best fit the Moisture Ratio (MR) data. Compared with oven-dried samples, the freeze-dried samples dried to lower equilibrium moisture values, did not show any signs of browning and was higher in protein and fat content. The freeze-dried 'cake' was easier to blend to a light, free-flowing powder which easily rehydrated to a form which closely resembled fresh avocado puree. Freeze drying is therefore an attractive option to produce a high-quality Pollock avocado powder, without the use of heat or the application of chemical preservatives to preserve colour.

Keywords: *Avocado, Freeze-drying, Oven-drying, Drying kinetics, Curve fitting*

FOAM MAT DRYING OF CARAMBOLA (*AVERRHOA CARAMBOLA* L.) PUREE

Saheeda Mujaffar[1*] and Racine Robertson[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: saheeda.mujaffar@sta.uwi.edu *(Corresponding author)
[2]Email: racine.robertson@gmail.com

Abstract: The carambola (*Averrhoa carambola* L.) is a tropical dessert fruit, oblong or elliptical in shape, with five prominent longitudinal ribs which give rise to a cross section that resembles a five-pointed star. Because of its unique shape, the fruit is commonly known as the five-finger or star-fruit. The carambola fruit has a thin, waxy skin and smooth brown seeds, and its flesh and skin are juicy and crisp, with minimum fibre. Foam mat drying is a relatively simple and inexpensive process to produce dried powders from raw materials, such as fruits and vegetables, that are heat-sensitive and high in sugars. Fruit and vegetable powders are convenient, easy to store and can be used in various food applications including beverages and baked goods. During foam mat drying, the material is first converted to a stable foam through whipping with a suitable foaming and/or stabilizing agents followed by air drying of a thin, porous sheet (or mat) of the foam and blending of the dried foam to a fine, free-flowing powder. The objective of this study was to develop a method for the foam mat drying of carambola fruits of the "Sweet type". Following pasteurization, the strained puree was whipped to a foam using food grade Methocel®F50 as the foaming agent with Maltrin®M150 maltodextrin for foam stabilization and flavour encapsulation. The fruit foam was then dried at 60°C. Foam characteristics assessed included foam density, drainage, expansion and overrun. Dried powder assessment included moisture content, water activity, colour, pH, total soluble solids and titratable acidity. The physical properties of the dried powder included bulk and tapped density, water solubility and oil holding capacity. Drying data was collected, and drying mechanism elucidated. The final product was an attractive, free flowing powder with intense carambola flavour and characteristic sweet-sour taste, which rehydrated easily to produce a carambola drink.

Keywords: *Carambola, Foam mat drying, Drying kinetics*

DRYING BEHAVIOUR OF CASSAVA (*MANIHOT ESCULENTA*) CHIPS

Saheeda Mujaffar[1*] and Amanda Lalla[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: saheeda.mujaffar@sta.uwi.edu*(Corresponding author)
[2]Email: alakshmil@gmail.com

Abstract: Drying of cassava (*Manihot esculenta* Crantz) chips of two sizes (S1 3 x 2 x 1cm and S2 0.8 x 0.6 x 0.4 cm) was carried out in a natural convection (<0.5 m/s) cabinet type dryer at 60°C. The moisture content of chips was reduced from 1.69 g H_2O/g DM (62.8% wb) to 0.07 g H_2O/g DM (6.2% wb) and the rate of decline in moisture was significantly affected by piece size. Equilibrium moisture values were attained after 15h for the larger chips (S1) and within 8h of drying for the smaller chips (S2). Drying to a safe moisture content of 13% (wb) could be achieved after 8h for the larger chips and 3.5h for the smaller chips. Drying of all samples occurred in the falling rate period only and drying described through the drying rate constants (k_1). Curve fitting of the moisture ratio (MR) data resulted in the development of mathematical models to predict the extent of drying with respect to drying time. The composition of the dried chips was assessed, and the cyanide content of the dried chips was well below the maximum acceptable limit. While size did not affect overall appearance and quality of the dried product, the smaller chip size would be recommended for cassava export based on the rapid drying.

Keywords: *Cassava chips, Drying kinetics, Thin layer models*

TWO-DIMENSIONAL MATHEMATICAL MODEL OF FLOWS IN THIN FILM COMPOSITE MEMBRANES

Aatma Maharajh[1], Prakash Persad[2], Denver Cheddie[3], and Edward Cumberbatch[4]

[1,2,4] Design and Manufacturing Systems, The University of Trinidad and Tobago, Trinidad and Tobago
[3] Utilities Engineering Group, The University of Trinidad and Tobago, Trinidad and Tobago
[1]Email: aatma.maharajh@utt.edu.tt *(Corresponding author)
[2]Email: prakash.persad@utt.edu.tt
[3]Email: denver.cheddie@utt.edu.tt
[4]Email: edward.cumberbatch@utt.edu.tt

Abstract*:* Mathematical modelling of reverse osmosis membranes has evolved from simplified one-dimensional simulations to complex three-dimensional simulations using CFD based techniques. These models have been useful in simulating solute and solvent flows across the membrane, the development of the concentration polarisation layer and the effects of spacer and spacer geometry as some examples. Various simplifying assumptions are, however, made in the modelling process that limit their extension to the specific application of directly-coupled wave powered desalination. These include the treatment of the membrane and use of rejection coefficients for solute transport. The model presented in this paper addresses some of the limitations imposed currently on available models. Fully coupled mass-momentum equations are specified for the hydrodynamics within the feed, membrane and permeate channels. Semi-empirical relationships are developed to account for the effects of inlet pressure, cross-flow velocity and inlet concentration on solvent and solute flows across the membrane. The model is validated against published experimental data and the predicted errors for simulations of solvent and solute flows were found to be 0.6% and 0.7% respectively. The effects of three feed spacer types, submerged, cavity and zigzag, on solvent and solute flows are then considered. Larger wall shear stress was seen for the submerged type spacer than for either cavity or zigzag types.

Keywords: *Computation Fluid Dynamics, Concentration Polarisation, Diffusion Coefficients, Reverse Osmosis, TFC membranes*

DEVELOPING NETWORK MODELS OF INDUSTRIAL SYMBIOSIS

Thérèse G. Lee Chan[1], Venessa K.K. Bhagwat[2] and David A. Janes[3*]
[1,2,3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: therese.lee@sta.uwi.edu
[2]Email: venessa.bhagwat@my.uwi.edu
[3]Email: david.janes@sta.uwi.edu *(Corresponding author)

Abstract*:* This study aimed to examine whether industrial symbiosis (IS) could be applied on the Point Lisas Industrial Estate (PLIE) in Trinidad and Tobago for the reuse of process carbon dioxide (CO_2) within the estate. To acquire optimal networks, initially simplified petrochemical complexes were posed as transportation-type problems and solved with linear programming and mixed integer linear programming techniques. Network models were developed in which process CO_2 was optimally allocated between existing ammonia (sources) and methanol plants (sinks) on the PLIE. Multiple scenarios were considered including possible restrictions on CO_2-transfers from sources or to sinks. The functionality of the developed network models was confirmed with three test cases. Multi-objective optimization (MOO) was applied to a fourth model, with a secondary objective of minimising operational network costs. In the second stage, an enterprise input-output (EIO) model was developed from both process engineering and economic data. It incorporated performance indicators, which had been proposed in the literature, to calculate the level of industrial symbiosis and benefits - based on "the three pillars of sustainability" - realized in the representative industrial network. On the representative petrochemical network, 17% of the process CO_2 emissions were reused in chemical manufacturing and the eco-connectance, which is one measure of the level of IS, was determined as 1.33. This demonstrates the presence and level of IS in the industrial park. Furthermore, optimized flow networks were created, with and without a CO_2-reusing propylene carbonate plant. MOO was used to determine how to add the CO_2-reusing plant to the industrial network to minimize both CO_2 emissions and implementation costs. The addition of a CO_2-reusing plant reduced the CO_2 emissions by 1.1%, demonstrating there is scope for improving the existing IS network.

Keywords: *Industrial symbiosis, Carbon dioxide utilization, Multi-objective optimization.*

SUSTAINABLE APPROACHES FOR COLLECTION AND VALORIZATION OF SARGASSUM BIOMASS IN THE CARIBBEAN

Jayaraj Jayaraman[1*], Omar Ali[2], Adesh Ramsubhag[3], Indar Ramnarine[4] and Bopanna Chowdary[5]

[1,2,3,4] Faculty of Science & Technology, The University of the West Indies, Trinidad
[5]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: jayauwi@gmail.com*(Corresponding author)
[5]Email: Boppana.Chowdary@sta.uwi.edu

Abstract: Deposition of large quantities of Sargassum seaweed on beaches across the Caribbean in recent years has become rampant and is projected to steadily increase due to global warming effects. This has negatively affected tourism and fishing industries as well as marine and coastal ecosystems in the Caribbean region. Conservative estimates show approx. US$150 million will be needed yearly to execute Sargassum seaweed beach clean-up exercises across the Caribbean. The challenge grows further in the absence of proper approaches and technologies to utilize or transform the seaweed biomass into safe value-added products. Although reports of preliminary studies are available, there is very little research or effort on utilization of Sargassum in this region. For such biotransformation or industrial uses, collection of clean and uncontaminated biomass is a prerequisite. At present, most of the biomass is collected at the shores and beaches which are of inferior quality. The ideal collection strategy should focus on harvesting in the sea, before the Sargassum reaches the shore, which will need mechanized approaches. Commercial use of biomass also requires appropriate and rapid processing to minimize oxidation of contents. Methods are being proposed for efficient and low cost collection, drying and storage of seaweed biomass for further processing. The biomass collected would serve as a feedstock for a range of applications including extraction of phytostimulants and elicitors, polysaccharides and compounds of potential pharmaceutical value, preparation of feed supplements, composts, building materials and biofuel. All such propositions for use of biomass and transformation require interdisciplinary research and actions. The research team at UWI-STA comprising members from multiple faculties is currently envisaging the action plan on the above objectives in order to utilize the otherwise wasteful Sargassum biomass for commercial uses.

Keywords: *seaweed*

MICROBIAL DEPENDENT BIORESOURCE TECHNOLOGY FOR SUSTAINABLE VEGETABLE PRODUCTION

Duraisamy Saravanakumar[1]*, Marisa Khan[2] and Augustus Thomas[3]
[1,2,3]Department of Food Production, Faculty of Food and Agriculture, The University of the West Indies, St. Augustine.
[1]Email: duraisamy.saravanakumar@sta.uwi.edu *(Corresponding author)
[2]Email: marisanalima@gmail.com
[3]Email: Augustus.thomas@sta.uwi.edu

Abstract: An intensive use of synthetic fertilizers and pesticides in agriculture over sixty years has posed serious negative impacts on human and environmental health. Emerging consciousness of consumers demand the supply of pesticide free food, which further relies on the availability of environment friendly agricultural practices. Therefore, the development of reliable technology for chemical free practices in agriculture assume greater significance in the era of increasing pest population and changing climate conditions. Such holistic plant health technology could be accomplished with microbes being a reservoir of genes, enzymes and bioactive compounds. Aligning with this prelude, the current research aimed (i) to isolate, characterize and identify the microbes suitable to enhance the growth and protect plants from diseases (ii) to develop the microbe based formulations and (ii) to standardize the application technology. The study has employed sequencing of 16S rRNA gene to understand the microbial diversity of tropical rhizosphere soils. The diversity and antagonistic studies showed that *Bacillus amyloliquefaciens*, a rhizobacterium has greater potential for promoting growth and suppressing diseases in vegetable crops. PCR studies has further confirmed that the presence of lipopeptide gene(s) viz., iturin, bacillomycin, bacilysin, fengycin, surfactin and zwittermycin in *B. amyloliquefaciens* were responsible for suppression of pathogens affecting vegetable production. The testing of purified lipopeptide compounds has exhibited greater inhibition to the wide range of fungal, bacterial and oomycete pathogens. The development of various microbe based formulations, shelf life, testing and its feasibility for production of pesticide free vegetables would be discussed during this presentation.

Keywords: Bioformulation, Lipopeptides, Microbial diversity, 16S rRNA gene, PCR.

OPTIMISATION OF THE SUPERCRITICAL FLUID EXTRACTION OF EXTRACTS FROM VETIVER ROOTS

Sharad Maharaj[1*], Marian Watson[2], David McGaw[3], Shawn Thomas[4] and Shivani Sonilal[5]

[1,3,4,5]Faculty of Engineering, The University of the West Indies, Trinidad
[2]Faculty of Engineering, University of Trinidad and Tobago, Trinidad
[1]Email: Sharad.Maharaj@sta.uwi.edu *(Corresponding author)
[2]Email: marian.watson@utt.edu.tt
[3]Email: drmcgaw@gmail.com
[4]Email: shawn.thomas23@hotmail.com
[5]Email: shivanisonilal@gmail.com

Abstract*:* The market projections for growth in both the essential and oleoresins market demonstrate a unique opportunity for Trinidad and Tobago to enter the business. Since an established bay tree plantation in Tobago cannot provide the raw material to operate a natural extracts plant for an entire year, the operation could be supplemented by the production of vetiver oil using vetiver roots that are grown and supplied by Tobago farmers. The chosen extraction technique is Supercritical Fluid Extraction (SFE) using carbon dioxide solvent since SFE was found to be more efficient and versatile than the traditional technique of Steam Distillation Extraction (SDE). To determine the optimum process conditions, a laboratory scale SFE programme was implemented using indigenous vetiver roots. The interactive effects of the operating parameters of pressures, temperatures and flowrates with respect to the oil yield were ascertained using Design of Experiments (DOE) which entailed the execution of 11 experimental runs. An ANOVA test produced an R^2 value 0.9864 and the optimum conditions were found to be – 220 Bar at 50 ^oC at an exit CO_2 flow rate of 2ml/min. The yield at this optimum condition was 4.75 wt. % which was considerably higher than yields reported in the literature. An initial evaluation of the economic viability of the project indicated an IRR of 28%, making the project well worthy of further development towards potential commercialisation.

Keywords: *vetiver, SFE, DOE*

BIOENGINEERING OF A JAMAICAN PLANT TO EFFECT CELL CYCLE ARREST IN PROSTATE CANCER CELLS AND ITS POTENTIAL USE IN GREEN NANOPARTICLES SYNTHESIS.

S Wright *[1] W Aiken[2], M. Adeyeye[3] O. Sadik[4] and H. Asemota [5]

[1]Faculty of Engineering, University of the West Indies, Mona [2]Faculty of Medical Sciences, University of the West Indies, Mona [3]National Agency for Food and Drug Administration and Control, Nigeria. [4] New Jersey Institute of Technology, USA [5]Biotechnology Centre, University of the West Indies, Mona

[1]Email: sashagay.wright@uwimona.edu.jm *(Corresponding author)
[2]Email: william.aiken@uwimona.edu.jm
[3]Email: cm.adeyeye@nafdac.gov.ng
[4]Email: omowunmi.sadik@njit.edu
[5]Email: helen.asemota@uwimona.edu.jm

Abstract: Prostate cancer is the most frequently diagnosed malignancy and is the leading cause of cancer related deaths among Caribbean men. Current treatment options have proven useful to kill cancer cells however they concomitantly cause damage to normal cells as well. Research has shown that plants possess secondary metabolites that provide therapeutic effects in a multiplicity of diseases. These plants are also renowned for their reduced side effect which makes them very attractive for research. This study therefore sought to first, phytochemically screen a specific Jamaican plant (*Dioscorea cayenensis*), investigate possible cytotoxic effects on prostate cancer cells and then to further decipher a possible mechanism of action of the extract through cell cycle analysis and chemiluminescent techniques. The results showed that the extract had a cytotoxic effect on the prostate cancer cells that was dosage and time dependent. Further investigations showed that this was effected through cell cycle arrest and a decrease in cyclin D expression, a principal regulator of G1/S phase transition in the cell cycle, was observed. This supports research that indicates that cyclin D could be a therapeutic target in cancer. The anti-cancer effects and purported mechanism of action of the yam extract against the prostate cancer cells as well as the phytochemicals present, makes it an ideal alternative for the formulation of green nanotechnology for targeted therapy.

Keywords: *Plants, Bioengineering, Green-nanoparticles and Prostate cancer*

UNSTEADY MHD POISEUILLE FLOW THROUGH A POROUS CHANNEL UNDER AN OSCILLATING PRESSURE GRADIENT AND UNIFORM SUCTION/INJECTION

Jennilee Veronique [1*], Sreedhara Rao Gunakala[2] and Victor M. Job[3]
[1,2,3]Faculty of Science and Technology, The University of the West Indies, Trinidad
[1]Email: judith.balkissoon@my.uwi.edu *(Corresponding author)
[2]Email: Sreedhara.Rao@sta.uwi.edu
[3]Email: victor.job@sta.uwi.edu

Abstract*:* The unsteady magnetohydrodynamic Poiseuille flow of a viscous, incompressible, hydromagnetic fluid through a porous channel, bounded by two horizontal plates under an oscillating pressure gradient, is studied. The Brinkman's equation is used to model the flow and the Galerkin Finite Element Method is used to solve the governing equations. The values of Hartmann number (Ha), frequency of oscillation (ω), suction/injection parameter (S), the permeability parameter (α), time (t) and the amplitude of the pressure gradient (A) are discussed. The results obtained are in good agreement with the existing literature.

Keywords: *MHD Poiseuille Flow; Suction/Injection; Oscillatory flow; Brinkman Equation; Finite Element Analysis.*

UNSTEADY HYDROMAGNETIC COUETTE FLOW UNDER AN OSCILLATING PRESSURE GRADIENT AND UNIFORM SUCTION AND INJECTION

Jennilee Veronique[1], Sreedhara Rao Gunakala[2*], Victor M. Job[3]
[1,2,3]Faculty of Science and Technology, The University of the West Indies, Trinidad
[1]Email: jennilee.veronique@my.uwi.edu
[2]Email: Sreedhara.rao@sta.uwi.edu *(Corresponding author)
[3]Email: victor.job@sta.uwi.edu (Corresponding author)

Abstract*:* In this paper, we consider the unsteady hydromagnetic Couette flow of a viscous incompressible flow between two infinitely-long horizontal parallel plates under an oscillating pressure gradient. We apply a constant magnetic field which is perpendicular to the plates, and there is uniform suction and injection through the plates. The governing equation for fluid motion within the channel is discretized with the help of the Galerkin Finite Element Method. The effects of the Suction parameter S, Hartmann number Ha, Reynolds number Re, the amplitude of the pressure gradient k and the oscillation frequency of the pressure gradient ω on the velocity distribution are investigated.

Keywords: *Couette Flow; Finite Element Analysis; Hydromagnetics; Oscillatory Flow; Flow with Suction and Injection.*

COMBINED HEAT AND POWER (CHP) SYSTEM OPTIMIZATION USING ENERGY, EXERGY AND THERMODYNAMIC ANALYSIS ALUMINA REFINERY POWER PLANT OPTIMIZATION – TWO CASE STUDIES

Quamie N. Mortley[1], Winston A. Mellowes[2]
[1]Chemical Engineering and Energy Consultant, Kingston, Jamaica
[2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: qnmortley@yahoo.com
[2]Email: wamello@yahoo.com

Abstract: The conventional energy analysis evaluates the performance of a thermodynamic system generally on its quantity only. It gives no information about the effect of irreversibilities on performance that occurs inherently during any thermodynamic process. On the other hand, exergy analysis, based on the second law of thermodynamics recognizes magnitudes and locations of the losses due to these irreversibilities. This paper deals with the improved energy performance of two-alumina refineries in Jamaica. One refinery produces alumina from Jamaican bauxite ore, using the Bayer process. The first process includes the digestion of bauxite with sodium hydroxide at 135 deg.C, (low temperature digestion). The second process includes the digestion of bauxite with sodium hydroxide at 245 deg.C. Hence, the requirement for both steam and power. Steam is generated using heavy fuel oil. There is auxiliary power from Internal Combustion Engines, Gas Turbine Engine and the Power Grid. The engine (the machine) produces mechanical work and then electrical power. According to the Second Law of Thermodynamics, the machine gives back heat (a part of the useful energy delivered by CHP) to a cold sink (low temperature sink), before rejecting the remaining heat to the environment at the reference temperature. Losses to the low temperature sink is minimized. This resulted in daily fuel savings of 400 barrels of Heavy Fuel Oil (HFO) and an annual savings of 146,000 barrels of Heavy Fuel Oil.

Keywords: *combined heat and power, energy, exergy analysis.*

INDUSTRIAL RECYCLE TOWARDS ZERO DISCHARGE ALUMINA REFINERY CASE STUDY

Quamie N. Mortley[1], Winston A. Mellowes[2]
[1]Chemical Engineering and Energy Consultant, Kingston, Jamaica
[2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: qnmortley@yahoo.com
[2]Email: wamello@yahoo.com

Abstract: Water management at alumina refineries and associated power plants is a major concern, especially if water resources are scarce and liquid discharges are not permitted. This paper describes the case of one such plant in Jamaica recovering 350 m^3/h of digester regenerative condensate. The steam and power for the alumina refinery is supplied by a cogeneration facility, which has to use a mix of well water and return condensate from the steam users in the alumina production process. The refinery produces alumina from Jamaican bauxite ore, using the Bayer process. This process includes the digestion of bauxite with sodium hydroxide at 135 deg.C, hence the requirement for both steam and power. In the course of this extraction, large quantities (350 m^3/h) of digester and evaporator condensate are produced. In view of the limited liquid discharges permitted from the site, this condensate was stored on site in large ponds, and reused in the process. Pressured from three sides, with a limitation on raw water abstraction from the wells by the Water Resource Authority, a requirement for minimized liquid discharge of wastewater, and high cost of energy there was a need to utilize the regenerative condensate from the digesters and the evaporators as boiler feedwater. Studies carried out by international water treatment companies had concluded that Total Organic Carbon (TOC) would not allow condensate re-use as boiler feedwater, with an attached US$10 million cost for the removal of TOC. Extensive laboratory work and thermodynamic analysis were carried out and the condensate are used as boiler feedwater, without treatment. The avoided cost was US$10 million and energy savings of US$3 million realized.

Theme B

Sustainable Built Environment

PAVENERGY RESEARCH PROJECT – RESULTS ALREADY ACHIEVED AND NEW DEVELOPMENTS PLANNED FOR THE YEARS TO COME

Adelino Ferreira[1*]

[1]Research Centre for Territory, Transports and Environment, Department of Civil Engineering, University of Coimbra, Portugal

[1]Email: adelino@dec.uc.pt *(Corresponding author)

Abstract*:* This paper presents the PAVENERGY research project, which has carried out at the University of Coimbra, in Portugal, since June 1st, 2016 and will end on April 30th, 2020. The following results have been achieved so far: one startup has been created (PAVNEXT); one prototype has been constructed; one pilot plant has been installed; one patent has been submitted, and which is in the final stage of approval; eleven innovation and entrepreneurship prizes have been won, five at national level and six at international level; one PhD thesis has been finished; ten articles have been published in Web of Science journals; seventeen articles have been presented in international conferences; one article has been presented in a national conference. This paper describes what was planned, what has already been done, what will be done in the next few months and what is planned for the years to come.

Keywords: *clean energy, energy harvesting, road pavement, vehicle road interaction.*

ADOPTION AND DEVELOPMENT OF ALTERNATIVE FUEL VEHICLES IN TRINIDAD AND TOBAGO

Kohan Dolcy[1] and Trevor Townsend[2*]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: kohan.dolcy@sta.uwi.edu
[2]Email: Trevor.Townsend@sta.uwi.edu* (Corresponding author)

Abstract*:* The transport sector has been identified as one of the highest contributors to greenhouse gas emissions in Trinidad and Tobago owing to the increase in the number of vehicles and the inherent traffic congestion. The vehicles are mainly fuelled by conventional fuels with relatively few being alternative fuel vehicles (AFVs), primarily in the form of compressed natural gas (CNG) vehicles. This research explores the current situation with the development and adoption of AFV technology in Trinidad & Tobago. In Trinidad, the natural gas supply is already well-established, refuelling stations are in operation and up to 18 original equipment manufacturer CNG vehicles are available on the market, supplemented by the option of vehicle conversion. The opposite is true for electric vehicles, with only one recognized dealer offering electric vehicles and public charging stations, and only one related market incentive in effect. Despite the number of initiatives geared toward CNG development, the 2018 vehicle conversion targets have not been realized and it would require a very aggressive approach to achieve those figures by 2020. The authors have identified the key impediments to successful attainment of the targets. They note that few of the ongoing fiscal incentives, measures or pilot projects by the government ministries that are associated with renewable energies are directly linked to the transportation sector. Additionally, since measures of effectiveness for sustainability are not being monitored, the country cannot adequately determine its progress towards sustainability. The authors propose measures towards achieving sustainable development in transportation and to overcome the constraints of data availability, perceived barriers to AFV adoption and the notion of affordability over sustainability.

Keywords: *Alternative fuel vehicle, Compressed natural gas, Transportation, Trinidad and Tobago, Sustainability*

TRANSPORTATION SUSTAINABILITY FRAMEWORK

Kohan Dolcy[1] and Trevor Townsend[2*]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: kohdolcy@gmail.com
[2]Email: Trevor.Townsend@sta.uwi.edu *(Corresponding author)

Abstract*:* Previous research highlighted that the necessary indicators of effectiveness for sustainability are not being measured by the respective stakeholders in Trinidad and Tobago. As with other small island developing states, the country cannot effectively determine its progress towards or away from sustainability. The authors have developed an impact-based hierarchal framework comprising the triple bottom line – economy, environment, and society – and applied it to the local transportation system. Bearing in mind the confines of limited resources and data availability for the Trinidad and Tobago case, the selected indicators were aligned with those used by national, regional and international bodies to monitor sustainability progress, making the framework more useful to stakeholders. Three requirements, nine criteria and 22 indicators were incorporated into the transportation sustainability framework. The authors propose that integrating the necessary data collection and monitoring processes with established tasks already under the purview of the various line ministries can reduce the overall costs of evaluating sustainability progress. Local transportation engineering professionals were surveyed to establish a relative weighting for the key sustainability requirements. They were of the view that the social, environmental and economic sustainability requirements should be weighted at 50%, 33.3% and 16.7% respectively. The professionals also saw potential applications like determining the overall status of and setting targets for improvement to the transportation system, assessing the suitability of proposed alternatives and making decisions about investments in the transport sector. The analytical hierarchy process structure employed in the development of the framework also permits the user to apply their preferred multi-criteria decision making technique based on the alternatives arising and the tolerable degree of compromise.

Keywords: *Framework, Indicators, Sustainability, Transportation, Trinidad and Tobago*

THE RELATIONSHIP BETWEEN VALUE OF TRAVEL TIME AND WAGE RATE IN TRINIDAD AND TOBAGO

Jevan Stephen[1*] and Trevor Townsend[2]

[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: jevan.stephen@gmail.com *(Corresponding author)
[2]Email: trevor.townsend@sta.uwi.edu

Abstract*:* The value of travel time is a key component in evaluating the potential impacts of projects aimed at improving the transportation system. In particular, the evaluation of the feasibility of projects such as toll roads is often premised on the assumed benefits that drivers perceive from saving travel time and their willingness to pay for such benefits. In Trinidad and Tobago there is no historical information which could inform valuation. This study utilized stated preference methods to determine the local value of travel time. A questionnaire was developed that incorporated a stated preference survey involving binary choices between faster, expensive travel options and slower, cheaper ones and also captured socio – economic data and work trip characteristics of the respondents. It was administered using convenience sampling via the WhatsApp mobile messaging app. To develop the survey, a preliminary estimate of value of travel time was made based on both national Gross Domestic Product and average income data. A binary logistic regression model was developed utilizing the maximum likelihood method to determine the parameters of travel time and travel cost. Based on the analysis, the overall value of travel time estimate obtained was found to be 71% of the income wage rate and 48% of the wage rate calculated using Gross Domestic Product. The GDP base rate is consistent with estimates from other jurisdictions.

Keywords: *binary logistic regression; stated preference survey; value of travel time*

ON THE FORCHHEIMER COEFFICIENTS FOR UNSATURATED FLOWS

Anton Ali[1]* and Deborah Villarroel-Lamb[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: anton_1991@live.com*
[2]Email: deborah.villarroel-lamb@sta.uwi.edu

Abstract: The Darcy- Forchheimer equation is the most common model used in describing porous media flow. Many CFD pre-packaged platforms offer this model via the modified Navier- Stokes equations and typically implement the model under a penalization scheme. Although the theoretical basis of the Darcy-Forchheimer equation is unquestionable, its use is dependent on introduced coefficients which vary with practical applications. Despite a general range of values, the selection of these coefficients is somewhat subjective in saturated cases. For transient unsaturated flow cases, the selection of these coefficients may even be further complicated. This research experimentally investigated the inherent nature of these Darcy-Forchheimer coefficients for unsaturated flows in naturally occurring porous media. The results suggest variability of these coefficients with the transient nature of this flow regime. Thus, highlighting the invalidity of a single combination of coefficients across the entirety of unsaturated flows in natural porous media.

Keywords: *Darcy- Forchheimer coefficients, Natural porous media, Unsaturated flows*

A SWASH-ZONE SEAWARD BOUNDARY CONDITION FOR IMPERMEABLE BEACHES

Anton Ali[1]* and Deborah Villarroel-Lamb[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: anton_1991@live.com*(Corresponding author)
[2]Email: deborah.villarroel-lamb@sta.uwi.edu

Abstract: Numerical Modelling of the swash-zone has received considerable attention in recent years in an effort to better predict the hydrodynamics of this coastal zone subsection. State of the art numerical models typically employ the well-known Navier-Stokes equations or one of its variations. Consequently, suitable boundary conditions are needed for such models to ensure that real-life applications are simulated whilst also reducing the computational effort. This paper presents an empirically derived sea-ward boundary condition at the initial still water line position of the zone. The boundary condition is developed via laboratory experiments which simulate regular linear incident wave climates upon impermeable and variable beach slopes. The developed boundary condition favorably mimics experimental data and better predicts swash flow depths and velocities at the initial still water line when compared to more well-established models.

Keywords: *Impermeable beach, Seaward boundary condition, Swash-zone, Wave climate*

TRANSPORTATION ENGINEERING: MARKETING AND MEASURING IN A MODERN WORLD

Katherine Agong[1]*
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Katherine.Agong@sta.uwi.edu *(Corresponding author)

Abstract: There's always the need to communicate to members of the public about the initiatives and projects that are being planned and implemented. Quite often engineers design and implement projects and then are surprised, disappointed and annoyed by the response from members of the public. This paper will examine the role of marketing in the success of transportation engineering projects especially in today's world of social media. The paper will focus on sustainable transportation engineering projects and will examine how marketing to members of the public contributed to project success as it relates to buy-in and feedback.

Research will provide empirical evidence and be of a qualitative and quantitative nature. Interviews with keys experts in marketing and transportation engineering will be undertaken to gather relevant information and data. In addition, actual marketing media for relevant projects will be examined. It is hoped that the findings of the research will guide engineers and policy makers where expectations of success as measured by the public perception of their projects is concerned.

The paper will discuss the various marketing methods used nowadays in promoting sustainable transport projects to members of the public post final design and pre- and during implementation. The marketing methods will be described including:

- Definition of the project
- Goals of the communication with members of the public
- Overview of the communication
- Details of the communication plan/ was social media used and how
- Definition of preferred results of the communication plan
- Research to support the communication of the project
- Determination of target audience
- Time taken/ timeline to implement the communication plan

The findings will be based on the cross examination of the outcome/ success of these projects against the marketing methods used to look for patterns.

Keywords: *sustainable transport, marketing, transportation, engineering*

A REVIEW OF RECYCLED CONCRETE AGGREGATES AS A SUSTAINABLE CONSTRUCTION MATERIAL

Rekha Rampit[1*], Jovanca Smith[2] and Indrajit Ray[3]
[1,2,3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Rekha.Rampit@sta.uwi.edu*
[2]Email: Jovanca.Smith@sta.uwi.edu
[3]Email: Indrajit.Ray@sta.uwi.edu

Abstract*:* The recent increase in structural developments worldwide, has given rise to the consumption of natural aggregates and energy hence generating a vast amount of construction and demolition waste. Natural aggregates occupy 60-75 percent in volume of the concrete matrix. It is beneficial to recycle construction and demolition waste, for construction activities. One such material retained from construction sites is waste concrete, which can be used to produce recycled concrete aggregates (RCAs). Recycling waste concrete produces a substitute to natural aggregates and preserves the environment by reducing waste disposal at landfills and conserving energy. The use of recycled concrete aggregates has piqued the interest of many researchers by utilization of a full or partial substitution to that of natural aggregates in concrete mixtures. Over the last decade, a significant volume of literature has been published discussing the properties and microstructure of recycled concrete aggregates and its response when used in a new concrete mix. This paper summarizes and critically analyses some of the important research findings pertaining to physical, mechanical, durability properties together with the treatment methods specific to coarse recycled concrete aggregates. Different experimental conditions used in the investigation of RCAs such as replacement ratio of coarse recycled concrete aggregates, saturation state and curing methods was also considered in detail.

Keywords: *microstructure, porosity, recycled concrete aggregate, residual mortar*

INFLUENCE OF ACID TREATMENT ON THE RESIDUAL CEMENT MORTAR OF COARSE RECYCLED CONCRETE AGGREGATES

Jovanca Smith[1*], Rekha Rampit[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: jovancals@gmail.com*
[2]Email: rekharampit@hotmail.com

Abstract: Investigations on methods to improve the overall quality of the recycled concrete aggregate has been a major concern to researchers. Recycling waste concrete promotes savings in natural resources and landfill space. The inferior quality of the recycled aggregate often limits its utilization to low grade applications such as road fillers and low grade concrete. The presence of the attached cementitious mortar on the surface of the recycled concrete aggregate is the prime reason that contributes to the lower strength and mechanical performance of concrete made with recycled aggregates. This residual mortar results in a lower density, higher porosity and water absorption rates as compared to natural aggregates. The recycled concrete aggregate also has an additional interfacial transition zone (ITZ) which lies between the residual mortar and new mortar matrix forming another weak region due to the poor bonding. Pre-soaking acid treatment of recycled concrete aggregates over a period of 24-hours is performed in an attempt to reduce the quantity of the residual mortar attached on the surface of recycled concrete aggregate. Different replacement levels of the treated recycled concrete aggregates were incorporated within the new concrete mix to determine the effects on mechanical strengths and porosity and compared to a conventional concrete mixture.

Keywords: *recycled aggregate concrete, porosity, water absorption, pre-soaking treatment, residual mortar.*

REDUCING CHRONIC DISEASE THROUGH TRANSPORTATION AND BUILT ENVIRONMENT IN HIGH CRIME COUNTRIES: A REVIEW OF THE LITERATURE

Katherine Agong[1]*, Debra Bartholomew[2] and Dawn Goddard-Eckrich[3]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[2]Ophthanologist Resident, Trinidad
[3]Associate Research Scientist, School of Social Work, Columbia University, United States
[1]Email: Katherine.Agong@sta.uwi.edu*(Corresponding author)
[2]Email: deb25bie@gmail.com
[3]Email: dg2121@columbia.edu

Abstract*:* Trinidad and Tobago has the third highest diabetes deaths, the highest rates of kidney failure in the world and is listed as one of the top countries where citizens have a fear of crime. There is a large body of research that has proven that there is an association between physical activity, fear of crime, health outcomes and built environment. However, most scientific research around urban design, physical activity, planning and transportation have been conducted in developed counties. However, there have been few studies in developing countries, particularly Trinidad and Tobago, which is facing both high crime and chronic disease. To evaluate the literature on physical activity, chronic disease and the built environment, we conducted a review of the literature through a systematic search and also analyzed research gaps and implications. Future studies should develop a multidisciplinary research on physical activity, fear of crime, transportation and the interactive effects of the built environment that can help improve chronic disease health outcomes and better understand the social and environmental influences of barriers to physical activity in Trinidad and Tobago.

Keywords: *built environment, crime, chronic disease, physical activity, Trinidad & Tobago.*

DEVELOPMENT OF ATTENUATED ENERGY SPECTRUMS AT X-RAY ENERGIES OF 60 KEV AND 150 KEV USING CONCRETE MANUFACTURED WITH ELECTRIC ARC FURNACE SLAG AGGREGATES

Davatee Maharaj[1*], Abrahams Mwasha[2] and Nikolay Zyuzikov[3]
Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: devimaha1222@hotmail.com *(Corresponding Author)
[2]Email: Abrahams.Mwasha@sta.uwi.edu
[3]Email: Nikolay.Zyuzikov@sta.uwi.edu

Abstract*:* This paper provides a simplified method to deduce the attenuated energy spectrum of X-ray radiation when it traverses through concrete made with 100 % electric arc furnace slag aggregates. Electric arc furnace slag is a by-product of the steel making process and in this study, it was utilized as an aggregate in the concrete. The attenuation of the radiation through the concrete is attributed to possible absorption and scattering of X-ray photons. Typically, X-ray procedures are conducted within the energy settings of the X-ray machines in the range of 60 keV to 150 keV. As such, the lowest and the highest energy settings were considered in evaluating the degree of attenuation attained at these values. The concrete shielding partitions of thicknesses of 15 cm, 17 cm, 19 cm and 22 cm were constructed and exposed to X-ray energies of 60 keV and 150 keV respectively. The calculated X-ray spectrum through the concrete partitions describing the energies of the photons was compared with the spectrum incident on the concrete partition. The overall reduction of the energies of the photons is attributed to the interaction processes between the X-ray photons and the atoms as they traverse through the concrete partition.

Keywords: *attenuated, X- ray spectrum, electric arc furnace slag, concrete, photons.*

INVESTIGATING THE INCLUSION OF COCONUT COIR IN CONCRETE MIX

Shereece Hosein[1], Robert A. Birch[2*], Edwin Ekwue[3] and David Mercury[4]
[1,2,3,4] Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Shereece.hosein@my.uwi.edu
[2]Email:Robert.birch@sta.uwi.edu *(Corresponding author)
[3]Email: Edwin.ekwue@sta.uwi.edu
[4]Email: david.mercury@my.uwi.edu

Abstract: An investigation was conducted on the inclusion of coconut coir in plain cement concrete mix. A trial mix was initially performed to obtain the maximum amount of coir that can be added until failure occurred or zero workability. Further investigations resulted in varying coir contents being derived and used in plain cement concrete mix. Multiple samples were then cured and tested for compressive and tensile strength at 7 days.
Our findings showed that the addition of coconut coir to the concrete mix increased the strength of the mixture and promoted an unusual failure pattern for concrete having a coir content between 6 to 12%. After 7 days the mean maximum compressive strength at 6 % coir was 40.7 MPa while the mean maximum tensile strength at 12% coir content was 4.2 MPa. Further, concrete with 6 to 12 % coir present had a reduction in the concave failure pattern under compressive loads and improved post peak load strength under tensile loading. Such results would be significant information in the design of sustainable concrete structures.

Keywords: *Coconut Coir, Concrete, Failure, Compressive and Tensile*

TOWARDS AN OPTIMAL ROAD ACCESS FOR UWI ST. AUGUSTINE SOUTH GATE

Rae J. Furlonge[1*]
[1]Managing Director/Principal, LF Systems Ltd Consulting, Trinidad
[1]Email: info@ccost.org *(Corresponding author)

Abstract: The primary access to the University of the West Indies, St Augustine Campus is located directly off the Churchill-Roosevelt Highway (CRH), an east-west four-lane divided urban arterial road. This access is known as the South Gate and is set back 180 metres from the CRH but is made difficult by the crossing east-west Watt Street, a collector road that services primarily pass-by traffic between the residential, commercial and school activities and the CRH. The high level of pass-by traffic comprises trips entering the area/intersection on the way from an external origin to an external destination, and includes through-traffic, as well as drop-off and pick-up of passengers. The morning and afternoon peak periods are particularly congested with the combined north-south UWI motorists and the east-west Watt Street traffic, including the associated turning flows. The situation is exacerbated by the apparent limited land space availability, such as (1) the extremely close proximity of the UWI perimeter road to Watt Street, (2) some of the Engineering Faculty buildings constructed very near the existing UWI perimeter road, and (3) the layout configuration of the current road entry and exit as well as the associated green space, all complicate any approach to readily suggest the provision of a grand campus access and frontage. As the country's premier university in an urban environment, it is important that the campus emphasises its presence and visibility. In other words, the entire area should be reconfigured into a Campus Precinct. The constraints identified above have been taken into account in the assessment using SIDRA intersection traffic analysis software, and the resultant access tested with AIMSUN traffic simulation software.

Keywords: *Double-lane roundabout, Intersection traffic analysis, and Traffic simulation modelling*

FROM A NOBEL INTENT TO SOCIAL III –DILIGENCE DUE TO PUBLIC SECTOR CONSTRUCTION MANAGEMENT

Aaron A Chadee[1*], Indrajit Ray and Hector Martin[3]
[1,2,3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: aaron.chadee@sta.uwi.edu *(Corresponding author)
[2]Email: indrajit.ray@sta.uwi.edu
[2]Email: hector.martin@sta.uwi.edu

Abstract: Recent studies on management of construction projects has made minimal improvements in delivering public sector social development projects. Challenges from meeting established project targets to delivering the intended benefits to the public still pervades project professionals. While research in this area has made significant contributions in reducing the performance shortfalls on social development projects, it does not adequately explain the consequences and societal symptoms in continuing with a futile course of action on failed projects. To address this shortcoming, we analyse a case study of a public housing development to understand the causal linkages between escalating political vulnerability influencing the project management process. The analysis of the case study presents a context specific nomological framework, based on the concepts of stakeholder embeddedness and social contracting, to manage the dichotomous results realised by projects of increased political vulnerability.

Keywords: *Construction management, Public Housing, errors, political cycles, stakeholder embeddedness, social contracting.*

EVALUATING THE EFFECTIVENESS OF THE JOB HAZARD ANALYSIS AND RISK ASSESSMENT REPORTS FOR CIVIL WORKS ASSOCIATED WITH BUILDING SERVICES INSTALLATION.

Gino Hosein[1*] and Indrajit Ray[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: ginohosein@yahoo.co.uk *(Corresponding author)
[2]Email: IndrajitRay29@gmail.com

Abstract*:* Excavating and backfilling trenches along the roadway to accommodate the installation of building services are common to the local industry. These services include electricity, water, telecommunications and data. The job hazard analysis (JHA) and risk assessment (RA) documents are typical forms prepared before the execution of these works to ensure health and safety. However, due to the hazards associated with the works, there are cost impacts which almost always affect the labour, materials and equipment resources. The main reasons for these are scope creep and the unforeseen nature of what to expect when breaking ground. This results in either the client or the contractor absorbing the additional unforeseen expenditure. The purpose of this research is to improve the efficiency of preparing and administering JHA and RA documents to help reduce unforeseen expenditures. This includes identifying and analysing all typical hazards and risks associated with labour, materials and equipment and the respective potential cost impacts. The data was collected by means of a population survey and validation of the results was achieved by means of a case study analysis of typical projects. The results revealed the main hazards associated with JHA and RA. It also identified some of the barriers to implementation such as lack of specific training, the need for more academic research, the use of more technology and for regulatory authorities to be more proactive. It was recommended that further research into this topic be done.

Keywords: *Building Services; Civil Works; Cost Impact; JHA; RA*

EFFECTS OF AIMS COARSE AGGREGATE ANGULARITY CLASSFICATIONS ON LABORATORY MECHNICAL BEHAVIOUR OF DENSE GRADED ASPHALT MIXTURES

Lee P. Leon[1*]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: leepleon@gmail.com *(Corresponding author)

Abstract*:* Aggregates are 80 – 92 % of the total volume of asphalt concrete (AC) thus having significant influence on the serviceability and performance of flexible pavements. Estimation of the effects of the classifications of aggregate angularity on mechanical properties of asphalt concrete is understudied because of its complexity. This paper identifies the limitations of aggregate angularity and mix performance in existing studies and present experimental results of the influence of coarse aggregate angularity (CAA) on the mechanical behaviour of dense graded asphalt mixtures. Four mixtures of different classes of coarse aggregate angularity (rounded, sub-rounded, sub-angular, angular) were designed and compacted to cylindrical heights of 63, 100 and 150 mm each. Geometric characterization of the particle angularity have been evaluated using Aggregate Imaging System (AIMS). Additionally, indirect tensile stiffness modulus (ITSM), uniaxial compression test (UCT), static creep test (SCT) and repeated axial load creep test (RLAT) have been evaluated at three tropical temperatures (25, 35 and 45 ^{o}C). Principle results of the study demonstrated that tangential modulus, compressive strength, static and repeated load elastic, viscoelastic and viscoplastic properties are highly influence by the classes of coarse aggregate angularity and other factors such as temperature and sample heights. The resilient stiffness modulus and recovered (elastic) creep strain however, were not significantly influence by changes in coarse particle angularity. The influence of a particular angularity classification maybe useful to road engineers when evaluating the mechanical behaviour, mix designs, field quality control and assurance as well as the performance prediction of asphalt concrete.

Keywords: *AIMS, Aggregate angularity, Asphalt concrete, Mechanical behaviour, Pavement performance*

SCOURING AROUND PIER UDER SUBMERGED CONDITION

Manish Pandey[1], Prashant Birbal[2] and H Md Azamathulla[3]
[1] Faculty of Engineering, VIT Vellore India,
[2,3]Faculty of Engineering, University of the West Indies, Trinidad,
[1]Email:manishpandey3aug@gmail.com
[2]Email: birbal.prashant58@gmail.com
[3]Email: mdazmath@gmail.com

Abstract: Present study deals with scouring around pier under submerged condition. Bridges that become partially or totally submerged during flood in that case flow of water through over bridge deck or below bridge deck drastically changes the scour depth in comparison to free surface flow. In the case of partially submerged bridge deck the flow below the bridge deck converted into free surface flow into pressure flow. In the present study an emphasis was given to conduct the experiments to calculate the scour depth at different submergence ratio. A series of clear water scour experiments has been conducted with three different diameters of circular cylinder and different discharges. The finding of experiments is used to describe the effect of submergence ratio on equilibrium scour depth under clear water condition. During the experimentations, scouring process occurs initially at faster rate and then the rate of scouring reduced after one hour and after that decreases constantly at five hours' equilibrium states. Some experiments were also conducted for non-submerged case to study the effect of non-submergence.

Keywords: *Scour, Pier, Bridge*

EVALUATION OF WAVE RUN-UP PREDICTIONS FROM PARAMETRIC MODELS ON TRINIDAD BEACHES

Shani Brathwaite[1*], Deborah Villarroel-Lamb[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Shani.Brathwaite@sta.uwi.edu *(Corresponding author)
[2]Email: Deborah.Villarroel-Lamb@sta.uwi.edu

Abstract*:* The comprehension of wave run-up is essential to coastal engineering. It is required to obtain an understanding of beach profile changes, beach recovery and the interaction of waves on coastal structures. Several empirical expressions have been defined to predict extreme wave run-up positions through the comparisons of offshore wave parameters, beach slopes and synchronous run-up observations. This paper assesses the accuracy of wave run-up formulae on three Trinidad beaches. Run-up data were collected using Traditional Surveying Techniques and statistically analysed to determine both the maximum run-up and the 2% run-up exceedance. Observed values of wave run-up were compared to values predicted by four (4) field wave run-up models. All models were found to over predict wave run-up on the three beaches.

Keywords: *Wave run-up, Swash zone, Swash Infiltration*

BEHAVIOUR OF HIGH PERFORMANCE FIBER REINFORCED CONCRETE BEAM JOINTS UNDER SEISMIC LOADING

B. Pandu Ranga Rao[1*], Prof. K. Rama Mohana Rao[2] and Srinivas Tanuku[3]

[1] Research Scholar, JNTU College of Engineering, Hyderabad; General Manager in National Council for Cement and Building Material, New Delhi, India

[2]Professor in Civil Engineering, Jawaharlal Nehru Technological University, Hyderabad, India

[3]Senior Manager-Tower Assessment, RAMBOLL India Private Limited, Hyderabad, India

[1]Email: pandu5270@yahoo.com*(Corresponding author)

[2]Email: rkunapareddy@gmail.com

[3]Email: srinit@ramboll.com

Abstract*:* The strength and ductility of structures primarily depend on proper detailing of reinforcement in beam-column joints. Under seismic excitations, beam-column joint region is subjected to high horizontal and vertical forces whose magnitude is much higher than those within the adjacent beams and columns. Beam-column joints have been recognized as critical element in seismic design of reinforced concrete (RC) frames. Conventional concrete loses its strength after formation of multiple cracks. Fiber reinforced high performance concrete (FRHPC) can be utilized to sustain for cyclic loading. Present study is aimed at investigating structural behaviour of beam-column joints using normal strength concrete (NSC) and FRHPC based beam-column joints utilizing steel fibers in varied aspect ratios, types and fiber contents. Beam-column joint of a multi-storeyed building has been modelled and scale down model experimented considering the scaling effect. Fifteen specimens of beam-column exterior joint were cast and tested using FRHPC in different fiber contents to study load-deformation behaviour, failure pattern, stiffness degradation and ductility associated parameters. The typical results illustrate significant increase in compressive, tensile and flexural strength values in HPFRC based control specimens. Beam-column joints corresponding to different grades of HPFRC with varied fiber content and aspect ratio & shape has been observed to give maximum load carrying capacity, energy absorption capacity and resilience. An optimum fiber contents corresponding to this value may therefore be utilized to provide significant dimensional stability, integrity, strength and ductility to beam- column joints subjected to cycle loading and can be substituted for conventional transverse reinforcement thereby allowing for relaxation in ties and stirrups in beam column joints.

Keywords: *beam-column joint, high performance concrete, cyclic loading, stiffness degradation*

LINKING SUSTAINABLE TRANSPORT AND COMMUNITY DEVELOPMENT: TRANSPORTATION 2.0 IN THE SMALL ISLAND OF TOBAGO

Julia Kotzebue[1*]

[1]Email: Julia.kotzebue@uni-hamburg.de *(Corresponding author)

Abstract*:* Worldwide the UN is promoting sustainable transport that requires the engagement of communities to make it context and community sensitive. To better engage the community, governments started to use web-based social geo-communication tools in urban areas. The use of these tools is increasing; however, it can be critically questioned to what extent they can support sustainable transport development in rural areas in Trinidad and Tobago. To respond to this question, the paper presents preliminary results of an ongoing pilot study in Charlotteville Tobago. The paper suggests an analytical framework to investigate the spatial governance process that is inherit of the sustainable transport solution development. Results reveal that the majority depends on sharing mobility, which already is more environmentally friendly than individual car use. However, the digital literacy in the village is low which hampers the capacity to participate in an increasingly digitizing society.

Keywords: *Sustainable transport, Community-building, Social geo-communication, Spatial governance*

SUBSIDIARY PROJECT PLAN REQUIREMENTS FOR PUBLIC CONSTRUCTION PROJECTS IN TRINIDAD AND TOBAGO

Amrita Baal[1] and Derek Outridge[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: amritabaal@hotmail.com
[2]Email: derek.outridge@sta.uwi.edu

Abstract: In 2010, the Commission of Enquiry into the Construction Sector of Trinidad and Tobago found that Public Construction Projects (PCPs) in Trinidad and Tobago suffered significant schedule overrun due to a lack of project planning, specifically at the design stage, which costed the country several millions of TT dollars. The Enquiry's revelation prompted this study, to assess the significance of the Subsidiary Project Plans (SPPs) at the design stage of PCPs. The assessment of the impact of SPPs on project schedule, based on its level of production, was executed via statistical analyses, in the Statistical Package for the Social Sciences, utilizing 62 questionnaire responses. The relationship between the level of production of each SPP and project schedule was investigated via a correlation analysis revealing that SPPs are not significantly produced at the design stage of PCPs in Trinidad and Tobago which in turn adversely affected project schedule. Further statistical analysis on each SPP revealed that only 22% of the total number of SPPs that can be produced were done, at 51% adequacy.
This significant finding in the study highlighted its impact on and importance to project schedule and by extension, project cost. A minimum set of SPPs to be produced, at the design stage of Public Construction Projects in Trinidad and Tobago, is recommended for standardisation as it is expected to substantially reduce the probability of project delays and cost overruns. The findings will educate construction project professionals and stakeholders on the SPPs' importance and its contribution to project success and sustainable construction standards.

Keywords: *Construction Industry, Project Design, Project Planning, Project Schedule, Subsidiary Project Plans, Design Management, Sustainable Construction.*

MODE CHOICE MODELLING OF PARATRANSIT MODES IN TRINIDAD

Leah Wright[1*], Trevor Townsend[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: leahwright05@gmail.com *(Corresponding author)
[2]Email: trevor.townsend@sta.uwi.edu

Abstract*:* The objective of this research was to develop a mode choice model in a small island developing states (SIDS), specifically the island of Trinidad. The public transportation system of Trinidad is dominated by paratransit modes, which have developed out of necessity due to the inadequacy of the state-owned bus service. Most modal choice models, calibrated from data in developed countries, do not consider the impacts of such para-transit modes in the choice behaviour of commuters. This research develops a discrete mode choice model based on the revealed preferences of commuters and their subjective assessment of the characteristics of the modes. The results from a nested logit model showed that in-vehicle travel time was a significant factor for the sample, while travel cost, was unimportant in the travellers' mode choice. Large mode-specific constants were estimated in the utility equation when compared to the other variables. This indicated a bias by individuals toward specific modes. This can be due to the current status of the public transportation system. Results highlighted that travellers, consider the illegal "PH" Taxis share more similarities to the private vehicle than to other public transportation modes. This is a significant result that can dictate the development of future policies. This research has shown the importance of incorporating paratransit modes in the mode choice models of SIDS. Future work should consider integrating latent class variables in the model analysis.

Keywords: *Mode choice models, SIDS, Travel behaviour*

DELAYED PAYMENTS IMPACTS ON PLANNED CASH FLOW OF SMALL AND MEDIUM CONTRACTORS FOR A SPECIAL PURPOSE COMPANY

Shawn Bissoon[1] and Derek Outridge[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: shawnbissoon@hotmail.com
[2]Email: derek.outridge@sta.uwi.edu

Abstract*:* The FIDIC suite standard forms of contracts used for executing projects in Special Purpose Companies contain contractual and administrative provisions regarding payments. However, payment delays remain inundated in the construction industry to date. Delay payments generally have an adverse effect on a company's cash flow, leading to extensions on overdraft facilities, ultimately increasing their borrowing. Late payment of commercial debt adversely affects the liquidity of contracting companies sometimes leading to insolvency.

This study examined the impact of the contractual payment period and payment process on the cash flow of contractors executing projects for the Special Purpose Company (SPC) E. The sample population chosen for this research consisted of 100 small and medium contractors within the SPC-E to illustrate the varying effects of the payment delays on the contractors mostly affected. A review of previously published literature along with a questionnaire survey distributed, determined the objectives of the paper. Statistical analysis using IBM SPSS software further analyzed the data collected using Cumulative Means, Relative Importance Index, Spearman's Rank Correlation and Analysis of Variance (ANOVA) to test the hypothesis.

The complicated bureaucratic payment process utilized by the SPC-E resulted in the cascading adverse effects on the contractor's cash flow. The findings also indicated that there has been no significant improvement to the delayed payment issue over the past decade. The implementation of Prompt payment legislation or statutory adjudication is recommended to ensure the sustainability of small and medium contractors.

Keywords: *Delayed payments, Planned Cash flow, Contract payment periods, Prompt Payment Legislation.*

RESIDUAL STRENGTH AND POST-CRACKING BEHAVIOUR OF GLASS WOOL FIBRE-REINFORCED CONCRETE EMBEDDED WITH STEEL REINFORCEMENT

Olutoge Festus[1*] and Ogundeji D. Oluwaseun[2]
[1]Faculty of Engineering, The University of the West Indies, Trinidad and Tobago
[2]Faculty of Technology, University of Ibadan, Nigeria
[1]Email: festus.olutoge@sta.uwi.edu *(Corresponding author)
[2]Email: oluwaseunogundeji@gmail.com

Abstract*:* This study aims to experimentally investigate and present the impact of glass wool fibre (GWF) on the residual flexural strength (RFS) for conventionally reinforced concrete elements by carrying out RFS test on concrete prism specimens. Additional tests, compressive and splitting tensile strength tests were also conducted on cube and cylinder specimens respectively to further examine the effect of the fibre on concrete. Twenty cubes of size 100 by 100 by 100mm, twelve cylinders of size 100 by 200mm and two sets of twelve prisms of size 100 by 100 by 400mm each with and without steel reinforcement (SR) were cast and then cured by water immersion for 28 days after which they were made to undergo compressive, splitting tensile and RFS test (using 3-Point Bending). The GWF content added ranges from 0.00% to 1.00% for four different mixes used.

The results showed a significant percentage increase of 20.83% in tensile strength with 0.50% fibre content and marginal increase of 0.26% in compressive strength with 0.25% fibre dosage. The study also showed that combination of conventional SR and GWF in concrete resulted in enhanced residual strength. It was observed that the average RFS of glass wool fibre-reinforced concrete (GWFRC) with and without SR increased with increasing fibre contents up to 0.50% before a decline in the strength was observed with 1.00% fibre dosage.

It was evident that the effect of SR dominated that of GWF in concrete but the combined effect in terms of post-cracking behaviour and strength was favourable to the long-term performance of concrete. Hence, the use of both SR and GWF in concrete should be given more consideration in concrete industry because of the possibility of improved residual flexural strength and as their synergic tensile properties could have positive impact on service life of concrete structures.

Keywords: *Glass wool fibre, Concrete structures, Residual flexural strength, Postcracking behaviour, Service life.*

CONCEPTUAL FRAMEWORK FOR THE ANALYSIS OF SHEAR DAMAGE IN FOAMED BITUMEN STABILISED MATERIALS

Laurence Bridgemohan[1*]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: laurence.bridgemohan@my.uwi.edu *(Corresponding author)

Abstract: The road building and rehabilitation industry worldwide utilises quality virgin natural aggregate materials, for the construction and maintenance of critical road infrastructure. Depleting natural deposits and limited supplies of high quality aggregates have prompted global emphasis on material selection. The foamed bitumen stabilisation technique offers the industry a sustainable and economical pavement engineering solution. Increased applications involving the enhancement of reclaimed pavement materials and wide range of locally available aggregate materials require pavement practitioners to possess adequate knowledge of its properties, behaviour and performance. Its shear characteristics and damage response have been identified as significant influential factors in determining long term performance. Notwithstanding these, an analysis of existing guidelines and mix design methodologies establish emphasis on stiffness and strength properties, for material characterisation and classification, highlighting the need for further research in modelling performance characteristics. The conceptual framework includes the use of dissipated energy in determining the effect of varying binder and active filler contents on FBSM behaviour and performance. This paper highlights significant factors of the study which contribute to the understanding of FBSMs and determination of optimal foamed bitumen stabilised material (FBSM) mix formulations.

Keywords: *bitumen stabilised materials, damage dissipated energy, foamed bitumen stabilisation, shear characteristics*

TO ACCESS THE IMPACT OF TOLL ROADS ON SMALL ISLANDS DEVELOPING COUNTRIES: A CASE STUDY JAMAICA

Yuwiyl Le Gendre Scott[1*] and Trevor Townsend[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: yuwiylscott@gmail.com *(Corresponding Author)
[2]Email: trevor.townsend@sta.uwi.edu

Abstract: Toll roads are implemented to address traffic congestion and generate revenues, which contributes to economic development in many countries worldwide. Despite numerous successful implementations of toll roads in many first world/developed nations, there is still limited information about the factors which affect the implementation of Toll Roads in small islands developing countries hence growing traffic congestion and reliance on fuel subsidies. Using Independent Samples T-Test, Factor and Regression Analyses this paper analyses the critical factors required for the successful implementation of toll roads in small islands developing countries. An evaluation of 46 respondents (users and non-users) revealed two factors affecting the implementation of toll roads in small islands developing countries; these are Service (Travel Time) and Economic (Urbanization). The Independent Sample T-Test shows that the two facts, has an impact on both the users and non-users. A main limitation of the Independent Sample T-Test is that it does not reveal the direction of the impact whether it's positive or negative. The Logistic Regression shows that travel time for non-users increased with the introduction of the Toll Road. The findings of this study are expected to guide government agencies, policy makers when reflecting on their strategic plan for developing and implementing road networks. This research provides knowledge for the successful implementation of toll roads in small islands developing countries to reduce traffic congestion and reliance on fuel subsidies.

Keywords: *Toll Roads, Traffic Congestion, Small Islands*

THE UNDERWATER TRAJECTORY BEHAVIOUR OF HEAVY OIL JET IN CROSS-FLOW FROM A BROKEN SURFACE PIPELINE

Portia Felix[1*]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: portiafelix30@gmail.com *(Corresponding Author)

Abstract*:* Oil spill occurrences continue to raise varying questions and concerns about their impact on and behaviour in the marine environment as they have the potential to cause unfavourable environmental, economic and social impacts. Understanding the behaviour of oil interactions with the ocean and nearby coastal environments is crucial in maintaining a reasonable relationship between relevant stakeholders. For this purpose, oil spill numerical models are useful for predicting the movement and distribution of oil in any receiving marine environment. As a first attempt, this paper presents a very crude oil plume model to simulate the underwater behaviour of a heavy crude oil which originates from an injection point source protruding the water surface discharging heavy oil into a receiving water body of shallow water depth. Most of the existing surface oil spill models do not cater for spills that initially behave as a jet at the water surface which is an essential feature of this hypothetical oil spill scenario. The study sets a specific focus on simulating the underwater suspension and horizontal movement of an oil plume originating from a spill initially behaving as a positively buoyant jet. The model is based on a two-dimensional modified form of the classical Navier-Stokes equations and discretized using the Projection method. The model is applied in a rectangular domain with suitable boundary conditions and parameterizations to observe the underwater oil trajectory behaviour. The model is verified using a benchmark fluid flow problem and its results show reasonable relationship of specific gravity with depth. The ultimate contribution of the study can provide insights necessary for oil spill cleanup decisions as oil behaviour of this nature may pollute the underlying water.

Keywords: *Underwater Oil Trajectory Behaviour, Oil Plume Model, Projection Method*

SOCIODEMOGRAPHIC CHARACTERISTICS AS IT RELATES TO TRAVEL BEHAVIOUR IN SIDS: A CASE STUDY IN TRINIDAD

Leah Wright[1*], Trevor Townsend[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: leahwright05@gmail.com *(Corresponding author)
[2]Email: trevor.townsend@sta.uwi.edu

Abstract*:* The objective of this research was to analyse the relationship between sociodemographic characteristics and the travel behaviour of Trinidadians. Many studies have shown that a relationship exists between the socio-economic and socio-demographic characteristics of an individual and their travel patterns. A better understanding of this relationship can influence transportation policy decisions and therefore, aid in improvement to the overall transportation structure. This understanding of travel behaviour is of particular importance in developing countries and SIDS, where there is limited geographical space, economic constraints and an influx of competitive unregulated paratransit modes into the transportation system. Trinidad, like other developing countries and SIDS, has a public transportation system that is dominated by paratransit modes. More notably, there is increasing penetration of illegally operated paratransit modes, that are aggressively competing in the market and gaining a lot of traction. Data was collected in January 2018 using a revealed preference survey of commuters' work-based tours in, Trincity, a middle-income housing area with good highway and public transportation access. Results showed that income, age, distance from workplace and gender all affect the likelihood of public transport usage as a primary mode of a work tour and there were gender-based differences in the incidence of walking as part of the tour. Additionally, although most public transportation users considered the government bus service as the safest and illegal para-transit services as the least safe, the usage of such services was more than five times that of the bus. The research points to important service and policy actions which need to be taken to encourage and support shifts to more sustainable modes.

Keywords: *SIDS, Sociodemographic, Travel behaviour*

A COMPARISON BETWEEN TRADITIONAL AND MACHINE LEARNING MODELS IN TRAVEL BEHAVIOUR

Leah Wright[1*], Trevor Townsend[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: leahwright05@gmail.com *(Corresponding author)
[2]Email: trevor.townsend@sta.uwi.edu

Abstract: Mode choice models have traditionally used the Multinomial Logit (MNL) model for analysis. The MNL is based on consumer theory and uses utility maximisation, which boasts its power to replicate human behaviour. However, despite its consistent use and favourable results the logit model has faced criticism about its predictive power, leading researchers to search for new techniques. More recently, several studies have used various machine learning techniques in mode choice models with success. These machine learning models have outperformed the MNL model in different cases. This paper reviews the different techniques used for mode choice models. The study compares both traditional and machine learning models from different aspects. Though machine learning techniques perform well in predictive power, these models are incapable of performing behavioural analysis while the logit model is a power behaviour analysis tool. Therefore, the purpose of the study should determine the model type used. Future research should focus on creating hybrid models of the traditional logit models and different machine learning techniques to create powerful predictive and behaviour analysis models.

Keywords: *Consumer Theory, Machine Learning, Mode choice models, Travel behaviour*

COMPARATIVE STUDY ON ANALYSIS OF TELECOM TOWER USING INDIA AND AMERICAN STANDARDS

Srinivas Tanuku[1*], Prof. K. Rama Mohana Rao[2] and B. Pandu Rangarao[3]

[1,] Senior Manager – Tower Assessment, RAMBOLL India Private Limited, Hyderabad, India
[2,] Professor, Dept. of Civil Engineering, Jawaharlal Nehru Technological University, Hyderabad, Telangana, India.
[3]Research Scholar, JNTU College of Engineering, Hyderabad; General Manager in National Council for Cement and Building Material, New Delhi, India
[1]Email: srinit@ramboll.com *(Corresponding author)
[2]Email: rmkunapareddy@gmail.com
[3]Email: ncbtpqi@gmail.com

Abstract*:* Self-supporting lattice tower are being effective structural system by considering simple, light weight, easy fabrication and installation for supporting telecom equipment at elevated heights. With increase in demand of lattice towers, a critical review on approach for analysis is highly essential to ensure reliable and safe structures. In this paper, a comparative study is taken up on methodologies followed in both national standards (India, America) for assessment of wind loads on bare tower, linear accessories, discrete accessories along with design resistance of members and connections for Two different configurations – Square angular tower, Triangular Hybrid Tower. From the detailed analysis, it is concluded that, American standard (ANSI/TIA-222H) is using Ultimate windspeed for calculation of wind loads based on risk category of structure along with strength reduction factors based on criticality of components compared to Indian Standards (IS 875(Part 3)-2015, IS 802) which resulted lesser wind load on structure i.e., 30% in Square Tower (Oblique wind direction) and 23% in Triangular Hybrid Tower using ANSI/TIA-222H. Also, no major difference observed for calculation of member capacity and connection. Therefore, it is concluded that Tower weights approximately reduces by 10-15% based on Tower configuration using ANSI/TIA-222H compared to Indian Standards

Keywords: *Analysis, Hot-Rolled Steel Angles, Self-Supporting Lattice Towers, Wind Loads*

MITIGATING CONTRACTOR PROBLEMS EXPERIENCED IN THE CONSTRUCTION INDUSTRY OF TRINIDAD AND TOBAGO

Roshan Patel[1] and Derek Outridge[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: roshan.patel176@gmail.com
[2]Email: derek.outridge@sta.uwi.edu

Abstract: The construction industry of Trinidad and Tobago has been, for decades, a direct indicator of national development and contributor to economic growth. However, projects within the industry have continuously associated problems experienced by contractors which negatively impact their overall performance and as a result, adversely affect the success of the projects and the sustainability of construction.

This study identified the most common problems experienced by contractors and assessed these to determine their level of significance and importance to projects. Employing a survey questionnaire and analytical methods in the Statistical Package for the Social Sciences, 43 problems were identified and classified into seven (7) factor groups; Financial, Managerial, Environmental, Labour Based, Resource Based Owner Based and Project Based that were ranked on their level of significance and importance. The top ten (10) problems were found to be delay of payments, design, scope and material changes, working in high risk areas, lack of feasibility and brief, corruption, lack of contractor's experience, bureaucracy, geological problems, contractor's finances and cash flow. These problems represent the Financial, Managerial, Environmental, Project Based and Owner Based factor groups with financial factors being the highest rated group of adverse effect and significance.

Highlighting the findings of this study, the preferred solutions to mitigate against the adverse impact indicative of the construction problems experienced were presented. These solutions can be implemented to reduce the adverse effects on projects, promoting sustainable construction practices in the construction industry of Trinidad and Tobago.

Keywords: *Construction Industry, Construction Problems, Contractor Problems, Project Overruns, Project Irregularities*

A SUSTAINABLE APPROACH TO THE CONSTRUCTION OF COASTAL FACILITIES THROUGH THE INCORPORATION OF BEACH SAND & BRACKISH WATER IN CONCRETE PRODUCTION

Imran H.R. Khan[1*], Daniel White[2] and Jenelle Mieus[3]
[1,2,3]Faculty of Engineering, The University of Trinidad & Tobago, Trinidad
[1]Email: imran.hayden-khan@utt.edu.tt *(Corresponding author)
[2]Email: daniel.white@utt.edu.tt
[3]Email: jenellemieux@yahoo.com

Abstract*:* Advances in reinforcement technology has facilitated the transition from traditional steel rebar to non-metallic rebar in reinforced concretes. Consequently, chloride content can be dramatically increased without worry for the deterioration of the encased reinforcement in reinforced concretes that utilizes composite rebar and polymeric/ceramic fibres. The production of one tonne of concrete releases 900 kg of CO_2 emissions. Reductions in CO_2 emissions from concrete production can be achieved through the production of 'greener' cements, and utilization of localized aggregate sources. Construction of structures along the coastline provides a unique opportunity for the utilization of beach-sand and brackish water that together can improve the sustainability prospects for construction in these environments. The incorporation into concrete of beach-sand that has been previously excavated is a simple means of reducing reliance on traditional sources of fine aggregate for concrete production. Additionally, the use of brackish water from a nearby estuary has the added benefit of reducing the requirement for potable water. Compressive strength tests were conducted on sixteen (22) groups of specimens at 7-days, 28-days and 42-days. Water-to-cement ratios (w:c) of 0.37, 0.39, 0.43 and 0.45 were employed. Analysis showed that at 0.37 w:c, batches that utilized beach-sand and brackish water, beach-sand and potable water, concreting-sand and brackish water were comparable to those produced with concreting-sand and potable water at about 40MPa.

Keywords: *beach-sand, brackish water, concrete, sustainability*

LEAN CONSTRUCTION IN JAMAICA

Leighton A. Ellis[1*], Ashley Mattis[2], Elisabeth Stanley[3], Joshua Swaby[4], Henel Vidal[5], and Marcello Berry[6]

[1-6]Faculty of Engineering, The University of the West Indies, Jamaica
[1]Email: leighton.ellis@uwimona.edu.jm *(Corresponding author)
[2]Email: tabbymattis@gmail.com
[3]Email: e.stanley876@gmail.com
[4]Email: jaswaby1@gmail.com
[5]Email: henelvidal@outlook.com
[6]Email: marcello.berry@gmail.com

Abstract: Lean construction plays an integral role in the sustainability of the construction industry. The principles of this phenomenon seeks to maximize efficiency, in all stages of construction. With maximum efficiency, the major constraints of a project such as: cost, quality and time, would improve drastically. Significant research and analysis has been done in developed countries such as the USA and the UK, regarding this topic. However, lean construction concerning developing countries such as Jamaica is virtually non-existent. As such, this study seeks to ascertain and analyse information on the aforementioned topic and determine the most suitable means of implementing the principles of Lean Construction in Jamaica. The instrument of data collection used, was a questionnaire. The questionnaire was specifically design for persons of the occupation: Architect, Engineer and Contractor. The questionnaires were disseminated and collected in person. From the data gathered, information was gleaned about: the general understanding of what Lean Construction means, its application, the degree of use of its techniques by individuals in daily operations, the issues encountered through its use, previous attempts at implementing lean construction, the methods used and the results thereof. If implemented correctly, Lean construction can create exceptional growth in Jamaica's construction industry. Consequently, this would require the collective effort and participation of all parties in the industry.

Keywords: *(Sustainability, Lean Construction, Caribbean)*

SUSTAINABLE CONSTRUCTION IN TRINIDAD & TOBAGO

Leighton A. Ellis[1*]
[1]Faculty of Engineering, The University of the West Indies, Jamaica
[1]Email: Leighton.ellis@uwimona.edu.jm *(Corresponding author)

Abstract*:* In developing countries, given the rapid rate of urbanization and the depletion of limited resources, there is a greater need to implement sustainable construction practices while these built environments are being constructed rather than after. There is a limited window of opportunity to avoid the problems currently faced by developed countries by basing all future developments on the principles of sustainability.

The Government of Trinidad and Tobago (T&T) has made strides towards promoting sustainable development by publishing policy documents, as well as being a signatory to several conventions, protocols, and agendas for sustainable development, climate change, and environmental conservation. However, T&T's heavy dependence on hydrocarbons is a deterrent in this effort. Sustainable development, and by association sustainable construction, are still at the conceptual stage and will require collaboration among all stakeholders.

In this paper, the perceptions of the key project participants in the Construction Industry with regards to the state of sustainable construction in T&T were examined using the Agenda 21 for Sustainable Construction in Developing Countries (A21 SCDC). The A21 SCDC is a framework which was used to identify the local barriers, drivers, enablers, and actions based on those identified by other developing countries. A web-based questionnaire was distributed via email to the target groups, and the mean-ranks were analyzed using statistical analysis software, Statistical Package for the Social Sciences (SPSS). The highest ranked barriers, drivers, enablers, and actions were identified, and differences in opinion among the target groups were highlighted. Also, based on the findings, recommendations for further research to advance sustainable construction in T&T were presented.

This study aims to fill a knowledge gap with regards to sustainable construction particularly in T&T and may be used as a guide to conduct similar research in other developing countries.

Keywords: *Sustainability, Construction, Trinidad and Tobago, Developing Countries.*

BIM IMPLEMENTATION IN THE PRACTICE OF ARCHITECTURE IN TRINIDAD AND TOBAGO

Leighton Ellis[1*], Hector Martin[2] and Marlon Charles[3]
[1]Faculty of Engineering, The University of the West Indies, Jamaica
[2, 3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: leighton.ellis@uwimona.edu.jm *(Corresponding author)
[2]Email: hector.martin@sta.uwi.edu
[3]Email: imarloncharles@gmail.com

Abstract*:* Although, the majority of Architects are aware of the benefits of BIM, they are hesitant to use it due to factors, both internal to individual architecture firms, for example the cost of training; as well as external factors such as the construction market and customer requirements. The findings of this study provide context for understanding how BIM is used in the practice of Architect in Trinidad and Tobago (T&T). It can be used as a starting point to develop future research into how this technology can be effectively implemented in the practice of Architecture in the global construction industry. The findings of the study highlight the need to formulate a strategy for the implementation of BIM and the creation of an appropriate supportive environment for its use in the local construction industry. This requires collaboration from all stakeholders, private and public, to invest and support the development of the necessary policy and standards for BIM implementation, including technical training in the use of software and training in the management of its processes in practice.

Keywords: *Building Information Modelling, BIM, Architecture, Construction Industry, Virtual Model*

A REAL-WORLD ENERGY AND COST COMPARISON BETWEEN AN ELECTRIC VEHICLE AND A PETROL VEHICLE IN THE TRINIDAD AND TOBAGO CONTEXT

Bhopendra S. Maharaj[1]* and Graham King[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: bhopendra.maharaj@my.uwi.edu
[2]Email: graham.king@sta.uwi.edu*(Corresponding author)

Abstract: This paper compares actual and predicted energy use and running costs for an internal combustion engine vehicle (ICE) and an electric vehicle (EV) in typical Trinidad and Tobago driving conditions. Globally, attention has been placed on electric vehicles for sustainable transportation due to their lower carbon footprint than ICE vehicles and the elimination of all tailpipe emissions.
Driving and detailed fuel/energy flow data was collected from both vehicles that was used to parameterise representative MATLAB/Simulink models of each. Simulations were performed using the same representative driving cycle as an input for both vehicle models and parameters such as fuel flow rate and rate of energy transfer were recorded. Another data set was used for validation of the models.
It was shown that energy used by the EV over the driving cycle was approximately 20% of that used by the ICE. The analysis was extended to consider Well to Wheel energy use and CO2 emissions by combining the model results with published data, showing that both energy and CO2 emissions from the EV are approximately 50% of those produced by the ICE. Further, it was estimated based on the findings that if 10% of the vehicle fleet was displaced by EVs, this would provide a 3% contribution to the Trinidad and Tobago Paris Agreement Nationally Determined Contribution (NDC) by 2030. This could be significantly increased if renewables generating sources were to be added to the electrical grid.

Keywords: *Electric vehicles, MATLAB/Simulink modelling, energy analysis, emission research, comparative study.*

THE COMPARISON BETWEEN ELECTRIC VEHICLES VS CONVENTIONAL PETROL VEHICLES AND THEIR IMPACT ON TRINIDAD AND TOBAGO.

Bhopendra S. Maharaj[1*] and Graham King[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: bhopendra.maharaj@my.uwi.edu
[2]Email: graham.king@sta.uwi.edu *(Corresponding author)

Abstract: This paper aims to compare an internal combustion engine (ICE) and an electric vehicle (EV) to assess its impact on Trinidad and Tobago. Globally, attention have been placed on electric vehicles for sustainable transportation. This research undergoes comparisons on energy, emissions, cost and performance in Trinidad and Tobago. These components were answered with the aid of a representative driving cycle for the region thus making these results distinct to Trinidad and Tobago. A methodology was proposed to collect data from both vehicles for modelling, validation and a direct comparison of energy used. Reference models of both vehicle type were developed in MATLAB /Simulink. Simulations were done with both vehicle models using the representative driving cycle as an input and parameters such as flow rate and rate of energy transfer were recorded. The difference in energy used by the ICE and EV model with the driving cycle were found to be 15.511 kWh. The key impact of this research was the emission findings from a well to wheel analysis which utilized data in this research as well as other published data. Therefore, this indicated that if a certain amount of the driving population switched from an ICE to an EV, Trinidad and Tobago would meet its goal for the Paris Agreement pledge by 2030.

Keywords: *Electric vehicles, MATLAB/Simulink modelling, energy analysis, emission research, comparative study.*

ALTERNATIVE FOUNDATION DESIGN FOR TEMPORARY HOUSING UNITS

Omar S. Thomas[1*], Georgeann Henry[2], Kordel Bishop[3], Kymani Francis[4] and Ajene Binns[5]

[1,2,3,4,5]Faculty of Engineering, The University of the West Indies, Mona Campus, Jamaica
[1]Email: omar.thomas@uwimona.edu.jm *(Corresponding author)
[2]Email: george.ann.h1997@gmail.com
[3]Email: kordelbishop@yahoo.com
[4]Email: kymanifrancis1@gmail.com
[5]Email: ajene_binns@gmail.com

Abstract: The Food for the Poor provides hundreds of thousands of temporary housing in the Americas and the Caribbean for persons in need of a shelter. These temporary houses provide a space in which many persons can live. Although these spaces are meant to be temporary, in many cases due to the lack of financial wherewithal, these temporary houses serve as a medium to long-term housing for those who receive them. The topographical and geotechnical environment in which these houses are built not only vary across the Americas and the Caribbean but varies within a single country. This study analyses the current foundation designs used by Food for the Poor in the country of Jamaica, taking into consideration Jamaica's unique hilly terrain and geotechnical environment. The study makes recommendations for the use of alternative foundation designs that are still economical for construction and are better when considering the life cycle cost of these structures. The use of bamboo as a reinforcement in concrete for the foundation design is also analysed and compared against the traditional reinforced concrete and mass concrete designs. The results demonstrate that when bamboo is used as a reinforcement with concrete it has an increased flexural strength, but still do not exceed the flexural strength of traditional reinforced concrete, that utilizes steel reinforcement.

Keywords: *bamboo reinforcement, bamboo tensile strength, temporary housing, alternative reinforcement.*

A STUDY ON THE POSSIBLE IMPLEMENTATION OF COMMUNICATION MANAGEMENT METHOD TECHNIQUE FOR FOREIGN SKILLED WORKERS EXECUTING PROJECTS IN THE CONSTRUCTION SECTOR OF TRINIDAD AND TOBAGO

Jeremy A. Baptiste[1*] and Kailas S. Banerjee[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: jeremy.baptiste@my.uwi.edu *(Corresponding author)
[2]Email: kailis.banerjee@sta.uwi.edu

Abstract: When foreign contractors are engaged in overseas construction projects, previous studies have indicated these projects as 'high risk' and "cost over-run projects'. This is mainly, due to communication challenges between foreign and local workers, different types of communications method used and on-site interpreters' efforts to reduce existing language barriers. Communication barrier is present in these SIDs countries, where skilled foreign workers are being regularly engaged in local construction industries. Over past years, many such construction projects, using foreign workers, have been executed in the Republic of Trinidad and Tobago (T&T). This study has selected two important and large construction projects within the public community sector in T&T, where a good number of foreign workers are engaged during the execution of these projects. This work tried to determine the possible existence of construction delay in these ongoing construction sites in T&T due to language barrier. It also determined the factors controlling these barriers, and finally provided key communication attributes and recommendations necessary to reduce this barrier delay in construction.

Methods of communication usage on-site, language barrier's delay patterns, interpretation of instructions and written documents, visual aide communication, tones and other method of communication used to resolve delays were evaluated and reviewed. 148 respondents were interviewed with questionnaires; the participators include 66 senior and 82 junior management staff members. Questionnaires capture each management team views on language as a construction barrier delay and other relevant issues on-site.

The assumption was that the CMM technique would be used for improving communication during projects, processes and systems. CMM was shown to be beneficial to the public community development construction's sector in this study and findings from the present study definitely improve this delay problem and help the local construction industry, if they are properly implemented.

Keywords: *Communications Management Method, Language Barrier Delay, Construction Industries, Trinidad & Tobago.*

RELATIONSHIP BETWEEN COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY OF SELF CONSOLIDATING HIGH PERFORMANCE CONCRETES (SCHPCS) INCORPORATING GSA A SSCM

Buari T. A[1, 2, 3*] Olutoge F. A[2, 3] Ayininuola G. M.[3]
[1]Department of Building Technology, The Federal Polytechnic Ede, Nigeria
[2]Faculty of Engineering, The University of the West Indies, Trinidad
[3]Department of Civil Engineering, University of Ibadan, Nigeria
[1]Email: buari4ever@federalpolyede.edu.ng *(Corresponding author)
[2]Email: Festus.olutoge@sta.uwi.edu
[3]Email: gm.ayininuola@ui.edu.ng

Abstract*:* This experimental work evaluates the relationship between compressive strength and modulus of Elasticity of self-consolidating High performance concrete (SCHPC) containing high volume of Groundnut Shell Ash (GSA) up to 40% substitution as SCM. A total of 210 specimens of the GSA blended SCHPCs comprising 105 cubes (100 x100 mm) and 105 cylinders (150x300 mm) were cured in water for 7,14,28 ,56, 92,120 and 180 days hydration periods and the compressive strength and Modulus of elasticity determined. The linear relationships were studied with regression analysis. The findings revealed that all the mixes met the Modulus of Elasticity values requirement of 18,000N/mm^2 to 42,000N/mm^2 and the compressive results show that three substitution levels of 0%, 10% and 20% attained the proposed design strength (40-130 Mpa) and also satisfied the requirement for self-consolidating and high strength concretes. In conclusion, 0%-20% GSA substitutions (SCHPCA0-SCHPCA20) indicated a strong linear relationship with regressions values obtained varies between 0.842 and 0.954 for the two variables. Addition of GSA as SCM has improved the mechanical properties of SCHPC and creates a strong relationship between the compressive strength and Modulus of Elasticity.

Keywords*: Compressive strength, GSA, Modulus of elasticity, Regression analysis and SCHPC*

INVESTIGATION OF THE WATERCOURSES AND MEASURES TO ALLEVIATE FLOODING IN THE PENAL/ DEBE REGION

Nadine Sangster[1*], Jorrel Bisnath[2], Aatma Maharajh[3], Allen Sammy[4]
[1,2,3]Design and Manufacturing Engineering, The University of Trinidad and Tobago, Trinidad
[4]Penal/Debe Regional Corporation, Trinidad
[1]Email: nadine.sangster@utt.edu.tt *(Corresponding author)
[2]Email: jorrel.bisnath@utt.edu.tt
[3]Email: aatma.maharajh@utt.edu.tt

Abstract*:* Flooding is a major concern for Small Island Developing States, particularly in the Caribbean region due to the tropical climate. The islands of Trinidad and Tobago, frequently experience severe weather conditions and of recent experience perennial flooding. Within the last three years, within Trinidad, the Penal / Debe region (PDR) has been affected by severe flooding, particularly in the year 2017 after Tropical Storm Bret, affecting the South Oropouche River Basin and so this region was chosen for this work. For this study, ten areas within the region were selected and a mix method comprising of both qualitative and quantitative research methods were utilized to gather data. It was found that businesses have incurred losses that amount up to TT$750,000.00 while domestic residents have lost over TT$60,000.00 worth of property during the incidents of flooding. The attributing factors for the flooding were determined to be the increased rainfall during the wet season coupled with the high tides and the sea level rise and watercourses within the area being clogged due to improper dredging and maintenance. The recommendations for alleviation of the flooding included a plan which looked at an education and awareness programme, dredging of the watercourses, the implementation of new water catchments, re-vegetation of damaged areas, the implementation of technology to improve monitoring and response and legislation to encourage best practices. Costings were performed for the various recommendations to allow for the region to make appropriate decisions regarding implementation.

Keywords: *Flooding, Penal/Debe, Watercourses.*

FINANACE AND GOVERNANCE MODELS FOR URBAN TRANSPORT IN DEVELOPING COUNTRIES

Lalitha Bala Cetty[1]*
[1]The University of the West Indies, Trinidad
[1]Email: lalithabalacetty@gmail.com *(Corresponding Author)

Abstract: This document reviews the "state of the art" in finance and governance models for urban transport in the Developing Countries, where urbanisation is taking place at the faster rate. Research shows that both developed and developing countries have been struggling to improve urban access. Both have to come up with novel solutions for mobilizing financing and arranging the funding for infrastructure to meet the growth in demand and to close the existing gaps (Shahid 2016). The exact replication of structures in other urban regions is neither possible not advisable, but knowledge of alternative structures and approaches can help improve a region's own governance structure (Kroen 2009).
(Ken 2017) in his paper emphasised that further work is necessary inclusive of assessing the distributional effects of cross-subsidy in integrated multi-modal systems, assessing the welfare distribution effects of subsidized metro investments.
Hence, focusing on the distributional effects of transport pricing policies such as road pricing, integrated fare schemes, and infrastructure capital subsidies aimed at improving the general efficiency of the system is likely to be more helpful to the poor than the design of primarily redistribution-oriented fare systems.
(Wojciech Keblowski 2019) in his article justifies that fare –free public transport has benefits in implementing and currently it is existing in 100 cities around the world.
The gap analysis indicates the requirement for an innovative way to redistribution –oriented fare system that will assist in developing a new financial model for the urban transport. This is essential as affordability for transport for poor is critical for developing countries future development due to urbanisation.

Keywords: *Urbanisation, Developed and Developing Country, Urban Transport*

Theme C

Smart and Intelligent Systems

GOODNESS OF FIT OF PROBABILISTIC MODELS FOR ELECTRIC VEHICLE CHARGING BEHAVIOUR

Letetia M. Addison[1], Sanjay Bahadoorsingh[2*] and Govinda A. Hosein[3]
[1]Faculty of Science and Technology, The University of the West Indies, Trinidad
[2,3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email:letetia.addison@sta.uwi.edu
[2]Email: sanjay.bahadoorsingh@sta.uwi.edu * (Corresponding author)
[3]Email: govinda.hosein@gmail.com

Abstract: Electric vehicles (EVs) have a number of environmental benefits in an era where fossil fuels have dominated. As such, the upgrade of electricity distribution grids to suit the needs of the modern world where the use of EVs can be accommodated is essential. Management of EV penetration is necessary, since uncoordinated charging can produce load imbalances and sharp variations in current, voltages and power. In order to assess the needs of such a system, estimates of random variables reflecting charging behaviour are necessary, particularly in cases where real data is insufficient. An attempt is made to assess some probabilistic models based on weekday load curves derived from the charging process. Level 1 EV charging profiles for uncoordinated charging schemes over one year for a data set consisting of 348 vehicles corresponding to 200 households are analysed and compared. Charging characteristics are reviewed and probability models are validated by goodness of fit statistics. Probability distribution functions (PDFs) which provide the best fit for these weekday load profiles are identified among the Johnson SB, Generalised Gamma and Dagum functions. This can provide an insight into estimation of PDFs based on EV charging behaviours, in order to build and assess models associated with transportation mobility data in other regions.

Keywords: *Electric Vehicles, Probability distribution function, Goodness of fit test, Uncoordinated charging*

SMART FARMING: ORGANIC COMMUNICATION CHANNELS (OCCS)

Aaron Roopnarine[1*] and Sean Rocke[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: aaron.roopnarine@sta.uwi.edu *(Corresponding author)
[2]Email: sean.rocke@sta.uwi.edu

Abstract*:* Organic Communication Channels (OCCs) are any hydrocarbon-based media which can be used to communicate data. This has great potential when applied to cyber-physical systems such as with smart farming. This paper establishes the relevance (though a literature survey and consideration of possible use cases for this technology), feasibility (through channel characterisation experiments) and proposes the infrastructure for OCC systems. The results show feasible communication of voice, video and text is possible with the proposed infrastructure for OCC communication. Finally, the approach of the proposal is evaluated through considerations for future work.

Keywords: *smart farming, internet of farming (IoF), human body communication (HBC), organic communication channels (OCC), path loss, propagation modelling.*

LOW COST SEISMIC DATA ACQUISITION SYSTEM BASED ON OPEN SOURCE HARDWARE AND SOFTWARE TOOLS

Arvid Ramdeane[1*], Lloyd Lynch[2]
[1,2]Seismic Research Centre, The University of the West Indies, Trinidad
[1]Email: arvid.ramdeane@my.uwi.edu *(Corresponding Author)
[2]Email: llynch@uwiseismic.com

Abstract*:* The University of the West Indies Seismic Research Centre, Trinidad and Tobago, operates a network of over 50 stations for earthquake and volcanic monitoring in the eastern Caribbean islands. These stations form a seismic network consisting of various types of instrumentation, and communication systems. Over a period of 11 years, the Centre has embarked on an initiative of upgrading and expanding the current network with combinations of broadband and/or strong motion sensors, high dynamic range digitizers and networking equipment to link each station to centralized observatories via high speed digital data transmission medium. To realize such an upgrade and expansion, the Centre has developed a seismic data acquisition system prototype built using open-source hardware and software tools. The prototype is intended to be low-cost using off the shelf hardware components and open-source seismic related software where it handles data acquisition and data processing in two separate modules. The prototype uses a three-channel accelerometer sensor and can process data into standard MiniSEED format for easy data archiving and seismic data analysis. A global position module provides network time protocol time synchronization within 1 millisecond for accurate timestamping of data. Data can be stored locally on the prototype through flash storage in twenty-minute data files or securely transferred to a central location via internet with the use of virtual private network capabilities. The prototype is modular in design allowing for components to be replaced easily and the system software can be updated remotely thus reducing maintenance cost.

Keywords: *MiniSEED, MEMS (Micro Electro Mechanical Systems), NTP (Network Time Protocol), Open-Source Hardware and Software Tools, Digitizer*

CUDA-ACCELERATED FEATURE SELECTION

Sterling Ramroach[1*], Jonathan Herbert[2] and Ajay Joshi[3]
[1,3]Department of Electrical and Computer Engineering,
[2]Department of Computing and Information Technology,
The University of the West Indies at Saint Augustine.
[1]Email: sterling.ramroach@sta.uwi.edu *(Corresponding author)
[2]Email: jonathan.herbert@my.uwi.edu
[3]Email: ajay.joshi@sta.uwi.edu

Abstract*:* Identifying important features from high dimensional data is usually done using one-dimensional filtering techniques. These techniques discard noisy attributes and those that are constant throughout the data. This is a time-consuming task that has scope for acceleration via high performance computing techniques involving the graphics processing unit (GPU). The proposed algorithm involves acceleration via the Compute Unified Device Architecture (CUDA) framework developed by Nvidia. This framework facilitates the seamless scaling of computation on any CUDA-enabled GPUs. Thus, the Pearson Correlation Coefficient can be applied in parallel on each feature with respect to the response variable. The ranks obtained for each feature can be used to determine the most relevant features to select. Using data from the UCI Machine Learning Repository, our results show an increase in efficiency for multi-dimensional analysis with a more reliable feature importance ranking. When tested on a high-dimensional dataset of 1000 samples and 10,000 features, we achieved a 1,230-time speedup using CUDA. This acceleration grows exponentially, as with any embarrassingly parallel task.

Keywords: *CUDA, Feature Selection, Pearson Correlation, High Performance Computing*.

DISPERSION OF A SOLUTE IN CASSON FLUID FLOW UNDER THE INFLUENCE OF EXTERNAL BODY ACCELERATION

Ajani Ausaru[1*] and Nagarani Ponakala[2]
[1,2]Department of Mathematics, The University of the West Indies, Mona, Jamaica
[1]Email: ajani.ausaru02@uwimona.edu.jm *(Corresponding author)
[2]Email: nagarani.ponakala@uwimona.edu.jm

Abstract: In this paper, the pulsatile flow of a solute in a straight circular tube with boundary absorption under the influence of external body acceleration is studied. The non-Newtonian nature of the fluid is taken into account by modelling as a Casson fluid. The equations governing the flow are solved using perturbation analysis. Due to the complexity of the resultant system of equations, the convection-diffusion equation is solved using a hybrid approach of analytical and numerical methods. In particular, the Crank-Nicolson finite difference numerical scheme is employed to derive numerical formulations for the exchange, convection, and dispersion coefficients respectively, as well as the mean concentration. The results are analysed with the aid of MATLAB software.

Keywords: *Convection-diffusion, Casson fluid, Body acceleration, Coefficients.*

DEEP LEARNING BASED SYSTEM FOR SMART SPECTRUM APPLICATIONS

Sanjeev Raghoonath[1*] and Sean A. Rocke[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: sanjeev.raghoonath@my.uwi.edu *(Corresponding author)
[2]Email: sean.rocke@sta.uwi.edu

Abstract: Channel quality information can be used to obtain higher data rates whilst ensuring low error rates, which are major requirements for 5th Generation Internet of Things (5G-IoT) services. 5G-IoT is the basis for many envisioned smart systems. Orthogonal Frequency Division Multiplexing with Index Modulation (OFDM-IM) has emerged as a candidate technique for 5G-IoT. This paper investigates the use of deep learning techniques for AMC in OFDM-IM scenarios. The deep neural network (DNN) model was trained initially, using data sets modified accordingly, and tested in a simulated environment to determine what information can be obtained from OFDM-IM scenarios. The channel quality information obtained can be used to perform the required adjustments to the channel. Finally, the application of this information can be evaluated in considerations in future work.

Keywords: *Automatic Modulation Classification (AMC), Deep Neural Networks, Internet of Things (IoT), OFDM-IM, 5G*

A MACHINE LEARNING MODEL FOR AN EARTHQUAKE FORECASTING USING PARALLEL PROCESSING

Manoj Kollam[1*], Dr. Ajay Joshi[2]

[1,2]Faculty of Engineering, Department of Electrical and Computer Engineering,
The University of the West Indies, Trinidad
[1]Email: mkollam@gmail.com *(Corresponding Author)
[2]Email: Ajay.Joshi@sta.uwi.edu

Abstract: Earthquake is a devastating natural hazard which has a capability to wipe out thousands of lives and cause economic loss to the geographical location. Seismic stations continuously gather data without the necessity of the occurrence of an event. The gathered data is processed by the model to forecast the occurrence of earthquakes. This paper presents a model to forecast earthquakes using Parallel processing. Machine Learning is rapidly taking over a variety of aspects in our daily lives. Even though Machine Learning methods can be used for analyzing data, in the scenario of event forecasts like earthquakes, performance of Machine Learning is limited as the data grows day by day. Using ML alone is not a perfect solution for the model. To increase the model performance and accuracy, a new ML model is designed using parallel processing. The drawbacks of ML using central processing unit (CPU) can be overcome by Graphic Processing unit (GPU) implementation, since the parallelism is naturally provided using framework for developing GPU utilizing computational algorithms, known as the Compute Unified Device Architecture (CUDA). The implementation of hybrid state vector machine (H-SVM) algorithm using parallel processing through CUDA is used to forecast earthquakes. Our experiments show that the GPU based implementation achieved typical speedup values in the range of 3-70 times compared to conventional central processing unit (CPU). Results of different experiments are discussed along with their consequences.

Keywords: *GPU, CUDA, Parallel Processing, Machine Learning, H-SVM*

DEVELOPING PARALLEL COMPUTING ALGORITHMS USING GPU'S TO DETERMINE OIL AND GAS RESERVES PRESENTED IN THE UPSTREAM (EXPLORATION) SECTOR

Stefan T. Boodoo[1*] and Ajay Joshi[2*]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: stefan.boodoo1@my.uwi.edu *(Corresponding author)
[2]Email: ajay.joshi@sta.uwi.edu

Abstract*:* Oil and Gas companies keep exploring every new possible method to increase the likelihood of finding a commercial hydrocarbon bearing prospect. Well logging generates gigabytes of data from various probes and sensors. After processing, a prospective reservoir will indicate areas of oil, gas, water and reservoir rock. Incorporating High Performance Computing (HPC) methodologies will allow for thousands of potential wells to be indicative of its hydrocarbon bearing potential. This study will present the use of the Graphics Processing Unit (GPU) computing as another method of analyzing probable reserves. Raw well log data from the Kansas Geological Society (1999-2018) forms the basis of the data analysis. Parallel algorithms are developed and make use of Nvidia's Compute Unified Device Architecture (CUDA). The results gathered highlight a 5 times speedup using a Nvidia GeForce GT 330M GPU as compared to an Intel Core i7 740QM Central Processing Unit (CPU). The processed results display depth wise areas of shale and rock formations as well as water, oil and/or gas reserves.

Keywords: *GPU, Parallel Processing, CUDA, HPC, Well Logging.*

SEMI-AUTOMATED CRICKET BROADCAST HIGHLIGHT GENERATION

Sahil A. K. Ramlogan[1*], Akash Pooransingh[2] and Daniel J. Ringis[3]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[3]Faculty of Electronic & Electrical Engineering, Trinity College Dublin, Ireland
[1]Email: sahil.ak.ramlogan@gmail.com*(Corresponding author)
[2]Email: akash.pooransingh@sta.uwi.edu
[3]Email: ringisd@tcd.ie

Abstract*:* This paper provides an improvement to automated cricket highlight identification from full broadcasts. Further refinement is provided through semi- automated user verification. This visual result is synchronized with an automated text extraction process. The visual result was successfully extracted at a rate of 97.5% using the ORB function. With user validation a false detection rate of 0% was realized. The metadata from the commentary was then successfully extracted and combined with the visual results to allow for easy searching of the highlight video using any search field.

Keywords: *ORB, BRS, Automated Highlight Generation, Cricket Broadcasts*

RFID TAGS USED IN PREVENTATIVE MAINTENANCE PROGRAM FOR MOTORS AND GENERATORS

Tracy Aleong[1*]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: tracy.aleong@sta.uwi.edu *(Corresponding author)

Abstract: In modern plant operations, a well-planned preventative maintenance program is vital to reliable and long-life operation of motors and generators. Without this in place, the chance of unscheduled production stoppage or unplanned shutdowns become unpredictable. The downtime can result in profit loses and reduced production. Many companies lack interest in having such a program in place due to the high cost and intricacy associated with employing major sensing techniques for monitoring live equipment status. This report describes a pilot project to design a low-cost RFID-based system paired with the Internet of Things communications to create a preventative maintenance program that can provide real-time updates for all installed motors and generators at a particular site. The basic system will incorporate ultra-high frequency RFID sensor tags for monitoring vibration and temperature, fixed RFID readers with antennas, and a based unit (built around a personal computer) with access to the internet. The RFID-based monitoring system is just as effective as other online sensing systems used, easy to install, lower cost to implement, and is simple to use. The RFID tags will allow the connection of the physical assets to the digital world having a direct effect to a company's business drivers such as cost savings, greater operational efficiency, and increased productivity. Installing the basic system on a trial basis is recommended and if the trial proves successful, the RFID based system could provide a long-term solution to the current problems of complex and expensive data collection.

Keywords: RFID, Internet of Things, sensors, maintenance, productivity.

MACHINE LEARNING TECHNIQUES FOR THE DETECTION OF UNFAIR PRICING IN SUPERMARKETS ACROSS TRINIDAD AND TOBAGO

Ms. Arti K. Ramdhanie[1*]
[1]Faculty of Science and Technology, The University of the West Indies, Trinidad
[1]Email: arti.ramdhanie@sta.uwi.edu *(Corresponding author)

Abstract*:* The tracking of prices in monitored supermarkets across Trinidad and Tobago is done by the Ministry of Trade and Industry. This initiative involves data collection every month for 118 grocery items ("standard basket"). The task of identifying which supermarkets are non-conforming in their pricing schemes is linked to the "total basket price" (total cost of the 118 items). An outlier is defined as any datapoint that varies significantly from all other observations in a dataset. In this paper, it is any supermarket that exceeds this total basket price by 5%. The aim of this research was twofold, with the first goal being to employ feature selection methods to reduce the number of items being collected. The second goal was to create a logistic regression learning model that can identify whether supermarkets are non-conforming, given their pricing information. The dataset contained 692 datapoints and out of these, only eight (8) were classified as outliers. This is an imbalanced dataset. Resampling by SMOTE (Synthetic Minority Oversampling Technique) was used to synthetically generate data for the training set. Seven (7) feature selection methods were also investigated and their results discussed and analysed. In doing this, a more balanced dataset was achieved which was tested and validated on the unseen data (testing set). The metrics indicated that a subset of these features can be collected whilst still maintaining the supermarket outliers.

Keywords: *outlier detection, feature selection, logistic regression, machine learning, SMOTE*

A SIMULATION FRAMEWORK FOR CONTROLLED CRITICAL INFRASTRUCTURES SUBJECT TO NATURAL DISASTERS

Amir Mohammed[1*], Craig J. Ramlal[2], Arvind Singh[3], Sean Rocke[4], Daniel Goitia[5]

Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: amirmohammed45@gmail.com *(Corresponding author)
[2]Email: Craig.Ramlal@sta.uwi.edu
[3]Email: Arvind.Singh@sta.uwi.edu
[4]Email: Sean.Rocke@sta.uwi.edu
[5]Email: Daniel.Goitia@sta.uwi.edu

Abstract: Natural disasters are inherently unpredictable and can cause major damage to critical infrastructures in cities and loss of life. In this study, a simulation and control framework is developed for evaluating response decisions for natural disaster scenarios with the objective of minimizing the life loss count. The package was developed in MATLAB Simulink using the infrastructure interdependencies simulator (I2Ssim) with a test system of six small residences, one large residence, two health centres, one large hospital, three water pumps with varying capacities and an energy production cell. The research focused on the development of Heuristic controllers which were used to evaluate the best possible outcome, given a situation in which a critical infrastructure was affected by a disaster scenario. Response decisions were generated for 625 unique scenarios, this information once grouped, can be used to inform response policies after natural disasters.

Keywords: *Critical Infrastructure Simulation, I2SIM, Public Utilities, Heuristic Control*

A REVIEW OF BIAS IN DECISION-MAKING MODELS

Peter Poon Chong[1*] and Terrence R.M. Lalla[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: peter.poonchong@sta.uwi.edu * (Corresponding author)
[2]Email: terrence.lalla@sta.uwi.edu

Abstract*:* Decision-making has a significant role in advanced services. For example, the manufacturing, finance, law, and management industries require solutions from a complex assortment of data. The popularity of combining decision-making with artificial intelligence (AI) for intelligent systems causes concern, as it can be a predisposition to a fair solution. A true solution avoids impartiality and maintains repeated results from a natural phenomenon without favoritism or discrimination. This paper appraises the development of the decision-making environment with particular attention to the path and variables used in a model. The literature reviewed was associated with the design of a decision-making criterion rationalizing the application of variables. The influence on variables was observed with respect to the available resources, environment, and people. This list was further extended to consider the constraints of the resource, customer, network, and regulation fed to the structure. The study of variables showed the opportunity for a conscious bias from unethical actions during the development of a decision-making environment. It was found that bias is best resolved with continuous model monitoring and fair adjustments. Ignoring these implications increases the chance of a bias decision-making model. It also influences the decision result and may be avoided with an ethical and fair quality review.

Keywords: *Decision-Making, Variables, Attributes, Intelligent Systems, Status Quo Bias*

CONSUMERS' ADOPTION OF AUTOMATED, SELF-DRIVING, ELECTRIC, AND SHARED VEHICLES

Asad Khattak[1*], Numan Ahmad[2], Behram Wali[3], and Ramin Arvin[4]
[1,2] Dep. of Civil & Environmental Engineering, The University of Tennessee, Knoxville, U.S,
[3,4] Senseable City Lab, Massachusetts Institute of Technology, Cambridge, U.S.
[1]Email: akhattak@utk.edu*(Corresponding author)
[2]Email: nahmad1@vols.utk.edu;
[3]Email: bwali@mit.edu;
[4]Email: rarvin@vols.utk.edu

Abstract: Remarkable developments in software, sensors, artificial intelligence, battery technology and social networks have been influencing consumer preferences specifically towards emerging mobility concepts and technologies. In the future, integration of automation, connectivity, electrification, and sharing (ACES) has the potential to bring more tangible benefits while improving overall transportation system performance. The question is how consumers will adopt these new concepts and technologies. This study uses extensive California Vehicle Survey (CVS) data collected in 2017 and maintained by the California Energy Commission. The residential portion of CVS data includes consumers' stated preferences for automation, self-driving, and electric vehicles and revealed preferences for car-sharing. Using the stated and revealed preference information (N=3,535), this study first develops an affinity matrix encapsulating households' simultaneous affinity towards synergetic technologies, i.e., ACES. While transforming 16 different outcomes of affinity on a four-level scale (e.g., will purchase vehicle with none, any one, two, and three/four technologies), we explore how consumers' concerns, priorities, and current use of available technologies/services correlate with their affinity towards ACES. Both fixed and random parameter ordered probit models are estimated to account for potential unobserved heterogeneity. Modelling results indicate evidence of unobserved heterogeneity in variables that include transit use and paid parking. The random parameters ordered probit model outperforms its counterpart in terms of goodness of fit, i.e., McFadden R^2 value, Akaike Information Criteria, and Bayesian Information Criteria. The modelling results indicate that transit use, current ownership of electric vehicle/s, participation in ride-share programs, and consideration of fuel costs as top preference are associated with increased chances of purchasing vehicles with new automated and electric technologies. Moreover, higher vehicle price and low reliability were key deterrents. Several interesting results are discussed in the paper.

Keywords: *California vehicle survey, Automated-Connected-Electric-Shared Vehicles, probit models, Consumer Choice.*

CASE STUDIES IN ENGINEERING AND TECHNOLOGY INNOVATION IN THE CARIBBEAN: A FOCUS ON EDUCOLCOM AND BEVCOM

Jason R. Rameshwar[1*] and Graham S. King[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: jrameshwar@gmail.com *(Corresponding author)
[2]Email: graham.king@sta.uwi.edu

Abstract: Caribbean SMEs (EduColCom and BevCom) identified Industry 4.0 (I4.0) enabling technologies integrating areas of their value networks. This enabled them to be innovative, competitive and sustainable within the global marketplace. This paper illustrated Proof of Concept examples of I4.0 technologies and overcoming implementation challenges by horizontally integrating with a vendor.
Structured interviews with C-level executives determined each SME's I4.0 developmental readiness and the methods used to select and adopt new technologies. Their strategies were based on the existing stability of each system and reinforced the need of C-level support for transformation. Their evolution roadmaps can be duplicated by other SMEs to achieve similar improvements.

Keywords: *Industry 4.0; SIDS SME; Evolution Roadmap; Innovation; Competitiveness*

DESCRIPTION OF A SIMULATED ENVIRONMENT DEVELOPED FOR VALIDATING CFS AUTONOMY

Gerardo Fernandez-Lopez[1], Ruel Ellis[2] and Gerard Pounder[3*]
[1]Faculty of Engineering, Simón Bolivar University, Venezuela
[2,3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: gerardo.fernandez.lopez@gmail.com
[2]Email: ruel.ellis@sta.uwi.edu
[3]Email: pounderji@yahoo.co.uk *(Corresponding author)

Abstract: Purpose – To describe a simulated environment developed for validating Cognitive Function Synthesis, or CFS, Autonomy. Design/methodology/approach – We developed a simulated environment in V-REP to validate CFS autonomy. A Pioneer robot was configured as a Behaviour-Based robot using the Braitenberg algorithm. A state diagram was developed that maps the robot's movement about the test area based solely on pre-configured reflexes. Findings – Vision sensors, or simulated cameras, were found to be better suited to configure robot behaviour than light sensor cues. Originality/value – This is the first simulated environment produced for investigating CFS Autonomy.

Keywords: *Cognitive Function Synthesis, Artificial General Intelligence, Associative Memories, Autonomous Navigation, Biomimetic Navigation*

VALIDATION OF A SIMULATED ENVIRONMENT DEVELOPED FOR VALIDATING CFS AUTONOMY

Ruel Ellis[1], Gerardo Fernandez-Lopez[2] and Gerard Pounder[3*]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[2]Faculty of Engineering, Simón Bolivar University, Venezuela
[3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: ruel.ellis@sta.uwi.edu
[2]Email: gerardo.fernandez.lopez@gmail.com
[3]Email: pounderji@yahoo.co.uk *(Corresponding author)

Abstract: Purpose – To validate the simulated environment developed for Cognitive Function Synthesis, or CFS, Autonomy experiments. Design/methodology/approach – Validation of the simulated environment designed in V-REP to investigate CFS autonomy was undertaken by comparing performance of the simulated Pioneer robot platform, navigating with preconfigured reflexes alone, with performance under the Braitenberg Obstacle Avoidance algorithm. Performance metrics used were: Average Cycle Time per simulation run; Average Wall Contact per cycle; and Average Shock Treatment Activation per simulation run. Findings – Robot performance under Braitenberg Obstacle avoidance was superior to performance without it. Ultrasound sensor configuration was found to be a significant factor affecting performance. The environment was deemed suitable for validating CFS Autonomy. Originality/value – Results not only validate the simulated environment, but also serve as control experiment for CFS validation.

Keywords: *Cognitive Function Synthesis, Artificial General Intelligence, Associative Memories, Autonomous Navigation, Biomimetic Navigation*

METHODS OF SOLVING MULTI-AREA ECONOMIC DISPATCH PROBLEMS- A SURVEY AND PROPOSED CANDIDATE SDP APPROACH

Kolapo S. Alli[1*] and Haniph A. Latchman [2]
[1,2]Faculty of Engineering, The University of the West Indies, Jamaica
[1]Email: kolapo.alli@uwimona.edu.jm *(Corresponding author)
[2]Email: haniph.latman@uwimona.edu.jm

Abstract*:* Computational intelligence methods may be effectively used to control power system settings automatically to achieve optimal operating power systems objective functions and ensure optimal load flows while fulfilled system constraints. Economic dispatch of power systems involving large interconnecting areas or zones require optimum and efficient allocation of the power to ensure efficient transferred output power to the systems in the various zones. One approach in achieving optimum dispatch of the power generated is to model the system as a Multi Area Emission Economic Dispatch (MAEED) optimization problem. One such formulation could be the minimization the running cost and emission objective functions at the same time subject to generator power limits, power balance and tie-line capacity constraints. This paper provides comparative survey of some of the existing research on both single area and multi area economic dispatch problems respectively and discusses the associated methods used in solving these different problems. Based on this study, we propose a candidate approach to address multi area economic dispatch problems using a semidefinite programming (SDP) method and we outline the associated computational and performance advantages.

Keywords: *MAEED Problem, tie-line constraint, SDP*

AERIAL DRONE TO HARVEST MANGOES

Jorrel Bisnath[1*], Demseys Thielman[2], David Edwards[3], Aneil Ramkhalawan[4]
[1,2,3,4]Design and Manufacturing Systems, The University of Trinidad and Tobago, Trinidad and Tobago
[1]Email: jorrel.bisnath@utt.edu.tt *(Corresponding author)
[2]Email: demseys_thielman@yahoo.com
[3]Email: david.edwards@utt.edu.tt
[4]Email: aneil.ramkhalawan@utt.edu.tt

Abstract: Over 1.8 million tonnes of mangoes were traded commercially in 2017. The current harvesting procedure predominantly involves either the elevation of workers to access the fruit or the use of long hand-held devices to reach into the tree canopy. These methods expose workers to injury either through falls or repetitive strain. This report is geared towards the design, build, and test of a remotely operated aerial drone, capable of harvesting mangoes. Here, a hexa-copter with a cutting implement attached, severs a mango stalk, while being remotely operated by an individual. The intended purpose is to assist in the mango farming industry by mitigating the risk of injury to which workers are exposed.

Keywords: *mango harvesting technology, innovation, design, aerial drone technology.*

FEASIBILITY OF POWERING MANZANILLA VIA A WIND FARM

Mickhal Polisher[1], Edward Cumberbatch[2*], Aneil Ramkhalawan [3], Jorrel Bisnath[4], Aatma Maharajh[5]

[1,2,3,4,5] Design & Manufacturing Systems, The University of Trinidad and Tobago, Trinidad
[1]Email: m.polisher@outlook.com
[2]Email: edward.cumberbatch@utt.edu.tt *(Corresponding author)
[3]Email: aneil.ramkhalawan@utt.edu.tt
[4]Email jorrel.bisnath@utt.edu.tt
[5]Email: aatma.maharajh@utt.edu.tt

Abstract: Remote communities on the outskirts of Trinidad and Tobago have the perennial challenge of a reliable supply of electricity. Frequent outages can have a negative effect on the quality of life for persons in such areas. Manzanilla is one such community. It however lies on the east coast of Trinidad. The east coast is commonly thought to have a significant wind resource compared with other areas of Trinidad. This study looked at the feasibility of providing wind energy to a community in the Manzanilla area. Average power consumption was determined by a survey for a total of almost 300 households, businesses and combined establishments in the area. The wind resource was examined to determine if it could meet the electricity demand which has been growing steadily from 2001 to the present. The wind resource was found to be adequate when compared with similar areas considering the generation of wind energy.

Keywords: *Remote communities, electricity demand, wind resource*

PROPOSAL TO POWER A TSTT CELL SITE IN BRASSO SECO, TRINIDAD USING RENEWABLE ENERGY

Andre Thomas[1], Edward Cumberbatch[2*], Prakash Persad [3], Aatma Maharajh[4], Aneil Ramkhalawan[5] and Jorrel Bisnath[6]

[1,2,3,4,5,6] Design & Manufacturing Systems, The University of Trinidad and Tobago, Trinidad

[1]Email: and_re4157@yahoo.com

[2]Email: edward.cumberbatch@utt.edu.tt *(Corresponding author)

3Email: prakash.persad@utt.edu.tt

[4]Email: aatma.maharajh@utt.edu.tt

[5]Email aneil.ramkhalawan@utt.edu.tt

[6]Email: jorrel.bisnath@utt.edu.tt

Abstract: Cell sites in remote areas such as Brasso Seco are subject to frequent power outages particularly during the rainy season when landslides are not uncommon. Cellular service providers need their cell sites to have continuous power to maintain or gain customer satisfaction in a competitive market. Backup power from diesel generators is a challenge in terms of the supply of fuel in such remote areas. Greenhouse gas emission reduction is also an important consideration in the present climate change crisis. This study examined the electrical energy demand, the cell site infrastructure and the renewable energy resource potential for photovoltaic and wind energy. A 2 KW stand-alone wind energy system was proposed for the site.

Keywords: *Cell sites, renewable energy, photovoltaic energy, wind energy*

AUTONOMOUS DETECTION OF VEHICULAR WHEEL ALIGNMENT PARAMETERS

Aaron Ameerali[1*], Nadine Sangster[2] and Gerard Ragbir[3]
[1,2,3]Design & Manufacturing Engineering, The University of the Trinidad & Tobago, Trinidad
[1]aaron.ameerali@utt.edu.tt *(Corresponding author)
[2]nadine.sangster@utt.edu.tt
[3]gerard.ragbir@outlook.com

Abstract: Vehicular technology has improved tremendously in the last few decades. Drivers and passengers are now being made more aware of their surroundings as well as the state of their cars, thus becoming increasingly capable of making better driving decisions. These 'smart-vehicles' are directed by microcontrollers and microprocessors where a network of sensors and actuators provide contextual feedback for the user. Some of these features include parking and reverse assistance, collision avoidance and cruise control.

Vehicle alignment was identified as one system where drivers, however experienced they are, may at times be unaware of the degree of misalignment their vehicle. Misalignment causes hazardous driving conditions such as uneven friction at the contact between the road and tyre, increased tyre tread wear leading to reduced traction with the road's surface and strain on multiple components within the braking system and suspension.

This paper provides a tested framework for a sensing system to alert the driver as to when the vehicle is misaligned. The system utilized wireless communications for data transmission and the sensor used was a combination 9 degrees of freedom type, which comprised a MEM's based gyroscope, accelerometer and magnetometer.

The system was implemented and proved successful as an early warning method for the extent of misalignment. This lead to decreased expenditure in the areas of maintenance and fuel consumption, contributed to an increase in reliability and improved the longevity of the vehicle.

Keywords: *Vehicle alignment, sensing system*

Theme D

Applied Spatial Information Systems

DEFINING COMMUNITY BASED GOVERNANCE FOR INFORMAL HOUSING & SETTLEMENTS IN TRINIDAD AND TOBAGO

Wayne Chaman Huggins[1*] (PhD Student)
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: wchuggins@yahoo.com *(Corresponding author)

Abstract*:* Encouraging and supporting Community Based Governance for Informal Housing and Settlements to achieve a sustainable built environment is essential. However, this will be the greatest challenge facing countries as they become more urbanized. Governance has become difficult to define and measure, much less described as a theory that can be modelled and applied to policy and in making decisions. The difficulty in definition was traced both to the evolving roles of the planner; and ontological and epistemological paradigms that have shaped research.

This research defined Community Based Governance as a theory. This was explored using a Grounded Mixed Methods to integrate quantitative and qualitative data. Using intersectionality and structuration, the outcomes were examined.

Initial results from Trinidad suggest that the reformulated theory of Community Based Governance has demonstrated failures and unsustainability of the public sector's squatter regularisation programme where Community Based Governance though essential, is undermined. However, this contradicts the success that the programme claims.

Keywords: *Community Based Governance, Grounded Mixed–Methods. Housing and Settlements, Intersectionality, Structuration.*

OPPORTUNITIES FOR TRANSFORMING INFORMAL SETTLEMENTS IN CARIBBEAN SMALL ISLAND DEVELOPING STATES

Michelle Mycoo[1*]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: michelle.mycoo@sta.uwi.edu *(Corresponding author)

Abstract: Informal settlements are quite complex because they consist of economically disadvantaged, often landless households located on steep hillsides, floodplains and swamps, which contribute to their exclusion from accessing infrastructure. These challenges need not be constraints; rather they offer opportunities for transformation. Such communities are generally characterised by inadequate access to safe water; inadequate access to sanitation and other infrastructure; poor structural quality of housing; overcrowding and insecure residential status. This paper uses primary and secondary data to determine the drivers which impact on the burgeoning of informal settlements in the Caribbean and analyses their implications for achieving the United Nations Sustainable Development Goal 11 which focuses on achieving safer, sustainable and resilient human settlements. The main findings of the paper are that housing shortages, delays in obtaining planning approvals, inflated land values and poverty contribute to the growth of informal settlements. However, such settlements occupy vulnerable sites where infrastructure is sometimes lacking and they help trigger environmental hazards which may be further exacerbated by climate change. Based on the key findings of the empirical evidence, the paper raises what is the critical role of engineering and engineering education in improving access by informal settlements to basic services that are fundamental in achieving sustainable, resilient human settlements and human well-being? These questions are answered within the Caribbean Small Island Developing States context and draws from a cross-section of case studies within the region.

Keywords: informal settlements; sustainable development; resiliency; engineering education

COUPLING CELLULAR AUTOMATA WITH MEDALUS ASSESSMENT FOR THE DESERTIFICATION ISSUE

Alassane Koné[1*], Allyx Fontaine[2] and Samira El Yacoubi[3]
[1,2]UMR Espace-Dev, Université de Guyane, France
[3]UMR Espace-Dev, IMAGES, Université de Perpignan, France
[1]Email: alassane.kone@etu.univ-guyane.fr *(Corresponding author)
[2]Email: allyx.fontaine@univ-guyane.fr
[3]Email: yacoubi@univ-perp.fr

Abstract*:* Desertification is one of the major problems affecting our environment in the 21st century. Indeed, it threatens more than 1.5 million people worldwide and affects a quarter of the land in less than 100 countries, it spreads over half a billion hectares per year and reduces the surface water and groundwater. Thus, according to a report by the FAO[1] (1993), the direct and visible impacts of desertification are the damage on crops, on livestock, on the electricity productivity, etc. Indirect impacts are lack of food production, poverty, social upheaval, rural exodus to cities. Areas subject to desertification are arid, semi-arid and sub-humid dry. In this paper, our work consists in modeling the degradation process of land whose advanced level leads to the desertification. The first step consists in assessing the degradation of land. The methodology of assessment used is based on the MEDALUS model developed by the MEDALUS[2] project of the commission of the European Union. This model assesses desertification by its sensitivity index which is the geometric mean of four quality factor indexes of soil, vegetation, climate and management (land use). The particularity of this assessment method is that it allows to consider the major part of the parameters influencing the land degradation process. The second step is to model the land degradation process using cellular automata (CA) approach. For that purpose, the study area will be divided into a regular grid of cells. Initially, each cell has a state (desertification sensitivity index) whose evolution at each discrete time step depends on the state of its neighbours through a built transition function. The third part is devoted to the simulation of our model.

Keywords: *Cellular Automata, MEDALUS model, Desertification sensitivity index.*

A GEOSPATIALLY DISTRIBUTED E-REFUGEE CAMP TECHNOLOGICAL FRAMEWORK FOR CARIBBEAN SMALL ISLAND STATES

Keisha Gaspard-Chickoree[1]*
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: keisha.chickoree@open.uwi.edu *(Corresponding author)

Abstract: As a result of the ongoing humanitarian crisis in Venezuela, the country has seen a mass exodus of persons into nearby Caribbean Small Island Developing States, SIDS, such as Trinidad and Tobago and Curacao. These island states do not have the infrastructure or local policies to implement a traditional refugee camp on their shores. Findings have shown the many disadvantages to existing or past traditional refugee camp settlements. However, as forced migrants continue to pour into these Caribbean states, a technological framework is necessary to capture, manage and connect forced migrants to food and shelter using Geographical Information System, GIS, enabled web technology. Thus, the Geospatially Distributed e-Refugee Camp framework aims to define a burden-sharing model between non-profitable organizations and the government utilizing a free and open source software approach to foster open data and citizen participation. The framework is developed using well-defined and tested software development methodologies – Lean Startup Methodology and Rapid Application Development. It analyzes existing technologies used by the UNHCR to represent migration and related GIS data on the web. An e-refugee camp framework is a digitized spatial representation, using a service oriented architecture, of forced migrants housed across the island, the volunteers, safe zones and other relevant stakeholders within the system. This camp, though electronic and distributed, adheres to the standards set by the UNHCR and Sphere for refugee camp settlements. The framework will allow SIDS to roll out a software solution rapidly to meet the urgency of the refugee problem.

Keywords: *Caribbean small island developing states, electronic refugee camp, forced migrants, GeoForms registration, Geospatially Distributed e-Refugee Camp, GIS web technology, migrants' movement, refugees, refugee camps, SIDS, UNHCR,*

ANALYSING SPATIOTEMPORAL URBAN DYNAMICS USING GEOINFORMATICS TECHNIQUES

Candice Dookree[1*] and Dr Raid Al-Tahir[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: caddice_dookree@hotmail.com *(Corresponding author)
[2]Email: raid.altahir@sta.uwi.edu

Abstract: The Caribbean possesses several growing cities, many of which are expanding rapidly with varying growth rates and patterns. These areas face rapid urbanization challenges and lack reliable data for developing urban specific policies. If ignored, the urban growth phenomenon will continue to intimidate the sustainable development of small island developing states (SIDS).
In this context, geoinformatics can be applied for mapping and analysing urban growth over long-periods at various spatial scales in a timely and cost-effective manner. Specifically, remote sensing techniques are used for collecting relevant spatial and temporal information while spatial analysis techniques are used for the quantifying and modelling the urban dynamics.
This study presents a framework for assessing and quantifying the spatiotemporal patterns of urban growth in a Caribbean city using geoinformatics methods and techniques. In this framework, classified images will be the main source for urban data for a chosen study area. The proposed methodology starts with a computer classification of multi-temporal satellite images to produce land use/land cover (LULC) maps. A change detection technique will then be used to determine the changes in LULC followed by quantitative analyses to determine the spatial extent and rate of urban growth. The outcome of the proposed framework will demonstrate the usefulness of spatial techniques and remote sensing for urban growth detection. Additionally, it will provide a data-driven assessment of the urban development process that would better support urban planning to address the impacts of urban growth.

Keywords: *Urban Growth, Geoinformatics, Remote Sensing, LULC, Change Detection*

EARTHWORK VOLUMETRICS WITH UNMANNED AERIAL VEHICLES: A COMPARATIVE STUDY

Raid Al-Tahir[1]* and Travis Barran[2]

[1,2] Department of Geomatics Engineering and Land Management,
The University of the West Indies, Trinidad and Tobago

[1]Email: raid.altahir@sta.uwi.edu *(Corresponding author)

Abstract: The recent evolution of Unmanned Aerial Vehicles (UAVs) as measuring instruments has become attractive for many surveying applications in civil engineering including the volumetric computations of earthworks in the construction of a highway. The application of softcopy photogrammetry to UAV acquired imagery has the potential to reduce data acquisition costs, time and with suitable accuracy for earthworks mapping and volumetrics. Their performance, however, is not well understood for these applications. This investigation tests the ability of the UAVs and photogrammetric software to generate volumes for the layers of material used in road construction, as well as to analyse their accuracies and limitations. Specifically, this study assesses the feasibility of UAV-based surveying in generating volumes for general earthworks in highway/road construction. Additionally, the study compares the performance of UAV-based surveying to that of Total Station surveying. Performance is evaluated along the required time for image acquisition and generating the final products, the required personnel and overall cost of survey. A segment of the Churchill Roosevelt Extension to Manzanilla was used in the assessment.

Keywords: *Photogrammetry, Unmanned Aerial Vehicles, Earthwork Computation, Highway Construction.*

URBAN SUSTAINABILITY INDICATORS FOR CARIBBEAN SMALL ISLAND DEVELOPING STATES

Tracey C.A. Beard[1*]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: tracey.beard@my.uwi.edu *(Corresponding author)

Abstract: This research seeks to develop an urban sustainability framework specific to Caribbean Small Island Developing States (SIDS). This is relevant given the reality that Caribbean SIDS are becoming increasingly urbanised. The three most urbanised countries within the Caribbean region; namely, the Bahamas, Trinidad and Tobago and Suriname are more than 70 percent urbanised. If the built environment within urban areas is developed in an unsustainable manner this can result in a number of negative outcomes. For example, a major challenge faced in Caribbean SIDS is that of disaster risk and management due to the location of human settlements and critical infrastructure in low lying coastal lands.

If more sustainable outcomes are to be attained in the face of increased urbanisation, there is a need for a change in the way spatial planning is practiced. Indicators can provide planners with an empirical basis for the examination and review of the relevant plans and policies which guide the way in which planning is practiced. There exist a number of urban indicator frameworks, which suggest useful indicators including the World Bank Urban Sustainability Framework (USF) and the Inter-American Development Bank Emerging and Sustainable Cities Initiative (ESCI). These two frameworks are critically examined and with the use of Trinidad as a case study island, the ways in which indicators can be useful in efforts toward increased urban sustainability within SIDS is discussed.

Keywords: *Caribbean, Small Island Developing States, Urban sustainability, Indicators.*

EXPLORATION OF ISSUES IN 3D CADASTRES FOR TRINIDAD AND TOBAGO

Charisse Griffith-Charles[1*]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Charisse.Griffith-Charles@sta.uwi.edu *(Corresponding author)

Abstract: 3D cadastres have reached an advanced stage in theory, if not in practice, in developed countries. There is also a need for 3D cadastres in developing countries as space is at a premium and equitable access to land is a human rights requirement.
This paper explores the current state of the theories on 3D cadastres and the challenges facing its practical implementation, including land administration processes, the Land Administration Domain Model infrastructure, visualisation methods and conversion from current datasets. The need and the opportunities presented by 3D cadastres in light of the particular issues faced by Caribbean SIDs, such as tenure informality, state capacity and resource gaps, and climate change impacts are examined.
Concrete recommendations are concluded for specifications such as the vertical datum and cadastral precisions, as well as legal requirements to establish the location of the boundary in respect to the physical structure.

Keywords: *3D Cadastre, LADM*

AN ANALYTICAL APPROACH TO GIS ANALYSIS AND MAP MAKING USING OPEN SOURCE SOFTWARE

Tarick Hosein[1], Bheshem Ramlal[2*], Lisa Kirton-Reed[3] and Adrian Trotman[4],
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[3,4]Caribbean Institute for Meteorology and Hydrology, Barbados
[1]Email: tarick.hosein@sta.uwi.edu
[2]Email: bheshem.ramlal@sta.uwi.edu *(Corresponding Author)
[3]Email: lkreed@cimh.edu.bb
[4]Email: atrotman@cimh.edu.bb

Abstract*:* Over the last two decades, advancements in analytical cartography have reduced the need for professional geomatics experts when creating maps. GIS software have greatly simplified the map creation process, allowing non-experts to make maps using many built-in tools. However, this has resulted in a lack of quality control and assessment when data is manipulated and processed towards developing maps. This also raises questions with regards to reliability, validity and objectivity of data, results and maps. In contrast, this paper presents a methodology for automating both the GIS analysis and Map Making processes using analytical cartography in a non-standard GIS environment. The work was done primarily in the R environment, open source software and programming, to replicate processes that were normally done using expensive proprietary software and many person hours. Applied in a case study to improve the workflow efficiency in precipitation index modelling, the developed system was found to improve on overall time by tenfold, the formats and number of products generated were more than doubled, the replicability of map layouts was greatly improved, and the published formats increased.

Keywords: *Cartography, GIS, Automation, R*

RED LIGHT RUNNING TOOLKIT FOR THE CARIBBEAN

Lacey Williams[1]

[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: lacey.williams@sta.uwi.edu *

Abstract*:* Red-Light-Running (RLR) has been a problem for many decades, ever since the installation of the first modern traffic signal in Ohio in 1923. Globally, several initiatives have been explored to address the perennial problem, however, statistics suggest that year-on-year, approximately 25% of intersection related crash deaths are associated with RLR. This number has been consistent among jurisdictions. RLR is a complex and difficult matter to address. The difficulty arises due to a plethora of factors that can be deemed causative that vary by jurisdiction. Predictive models have been developed in the past, however, when attempts were made to apply them in other geographical locations, there predictive effect was not found to be as accurate. There are a number of reasons for this not least of which relate to human factors. This research therefore seeks to explore, primarily, the engineering variables that contribute to RLR in Trinidad and Tobago, and to develop appropriate countermeasures to address these.

Keywords: *Red-Light-Running, RLR, Traffic Signals, Human Factors*

Theme E

Innovative Mechanical and Manufacturing Systems

LOAD CAPACITY OF RECESS FOIL JOURNAL BEARING

S. Arokya Agustin[1], C. Shravankumar[2] and T. V. V. L. N. Rao[3*]
[1,2,3]Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur - 603203, India
[1]Email: arokyaas@srmist.edu.in
[2]Email: shravanc@srmist.edu.in
[3]Email: tvvlnrao@gmail.com *(Corresponding author)

Abstract: Foil journal bearing load carrying capacity is investigated with a recess configuration on top foil. Analysis based on short bearing approximation of foil journal bearing is presented. The analytical model accounts for the recess extent and depth on the top foil. Compressible modified Reynolds equation using short bearing approximation is analysed based on bump foil compliance coefficient and recess configuration. Results of load carrying capacity of foil journal bearing are compared with and without recess.

Keywords: *Recess, Texture, Foil bearing*

DESIGN COMPLEXITY AS A DRIVER FOR ADDITIVE MANUFACTURING PROCESS IMPROVEMENT

Nishkal George[1*] and Boppana V. Chowdary[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: nishkalgeorge@gmail.com *(Corresponding author)
[2]Email: Boppana.Chowdary@sta.uwi.edu

Abstract: Design complexity in additive manufacturing (AM) is a current issue in the research community, fueled by the well-known phrase "complexity for free". This statement has promoted the assumption that complex geometries may be achieved without any increase in the cost of production. However, recent research has indicated that increasing shape complexity produces an increase in production costs for the material extrusion process. This challenges the mainstream assumption that AM technologies provide 'complexity for free'. The AM community requires further investigation of design complexity and its impact on sustainable production when used as a Design for Manufacturing (DfM) tool. This paper proposes a data-driven method which uses design complexity as an AM performance indicator for the material extrusion process. The manufacturing responses included build time (BT), dimensional accuracy (DA) and complexity index (CI). Design space exploration of an automotive air filter model was achieved by varying five critical design features which impact complexity. The study utilized a Face Centered Central Composite Design (FCCCD) of three levels for the design features, comprising 32 experimental models. The optimal model was manufactured based on multi-objective optimization using the MINITAB© response optimizer. This method exploits the design features to achieve target performance and manufacturability. The viability of design complexity as an AM performance indicator was discussed leading to three major improvements to the Product Design and Development (PDD) process for AM. The proposed improvements have the potential to reduce process times and minimize resources, providing a sustainable AM approach for developing regions.

Keywords: *Additive Manufacturing, Design Complexity, Multi-objective optimization,Product Design and Development, Design for Manufacturing*

INVESTIGATING THE EFFECTS OF PROCESS PARAMETERS ON THE FLEXURAL STRENGTH OF 3D PRINTED PLASTICS

Nikolai Beharry[1*], Boppana V. Chowdary[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: nikolai.beharry@my.uwi.edu*(Corresponding author)
[2]Email: boppana.chowdary@sta.uwi.edu

Abstract*:* In this paper, the flexural strength of 90% Recycled Polyethylene Terephthalate (RPET), Polyethylene Terephthalate Glycol (PETG) and Polycarbonate (PC), are investigated with varying layer thickness, infill percentage and raster angle. Across each material, higher infill percentage resulted in higher flexural strength when loaded, whereas raster angle was the least significant. Using a Genetic Algorithm, the maximum flexural strength of each material was determined to be 48.57 MPa for RPET, 44.22 MPa for PETG and 101.54 MPa for the PC samples. Using these results, practical applications in local industries were investigated. The relatively high flexural strength of the RPET indicates great progress in material science towards creating a strong and sustainable 3D Printing filament. However, a cost-benefit analysis performed on the existing market value indicated that in its current state, the price per strength of RPET is heavily outmatched by PETG as a cheaper option and PC as a stronger option. If the process of creating filament from recycled plastics is refined, RPET filament will become cheaper and more desirable for manufacturing. This can lead to diversifying the local economy as a competitive and eco-friendly option to satisfy consumer needs.

Keywords: *3D Printing, Flexural Strength, Genetic Algorithm, Recycled Thermoplastic*

EXPERIMENTAL AND NUMERICAL VIBRATION ANALYSIS OF PRINTED CIRCUIT BOARDS

Richard Bachoo[1*], Shurland Balliram[2], Jacqueline Bridge[3]
[1,2,3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Richard.Bachoo@sta.uwi.edu *(Corresponding author)
[2]Email: Shurland.Balliram@my.uwi.edu
[3]Email: Jacqueline.Bridge@ sta.uwi.edu

Abstract: Printed circuit boards (PCBs) are important modules which are incorporated in a wide range of industrial equipment and machinery for the purpose of control or signal manipulation applications. PCBs situated in dynamic environments may be prone to failure from excessive amounts of cyclical stresses arising from harmonic or random vibration sources. The ability to numerically model and predict the dynamic behaviour of PCBs and associated components is therefore a valuable tool for analysts concerned with PCB reliability. In this paper, experimental vibration analysis and the finite element method (FEM) are used to investigate the changes in resonant behaviour of a PCB as the mass, location and stiffness of electronic components vary. Circuit boards that are either sparsely or densely populated with ubiquitous soldered electronic components such as resistors, transistors, capacitors and integrated circuits are considered. The analysis indicates that for boards with a small number of components the natural frequency decreases compared to that of the bare PCB whilst a board with a larger number of soldered components has a corresponding increase. It is also shown that the overall effect of the solder is to reduce the natural frequency of the PCB and to a lesser extent the damping ratio. The study identifies the potential of tailoring the vibration response of a PCB by the appropriate selection and location of its connected components.

Keywords: *Electrodynamic shaker, Experimental modal analysis, Finite element method, Harmonic vibration, Printed circuit board, PCB.*

COMPUTATION OF ONE DIMENSIONAL ONE PHASE STEFAN PROBLEMS

V.G. Naidu [1]*, P. Kanakadurga Devi[2]
[1]* Adama Science and Technology University, Ethiopia.
[2]Department of Mathematics, MLR Institute of Technology, Hyderabad, India
[1]Email: naidoovedam@gmail.com *(Corresponding author)
[2]Email: durga.thulasi@gmail.com

Abstract*:* To design an efficient device or to calculate the performance of existing device requires an accurate analysis of parameters involved in the system. In this work, an efficient front tracking finite difference method is developed to solve one dimensional single phase moving boundary problem with Neumann condition. The basic difficulty apart from the need to find the moving boundary presented, that there is no domain for the first phase at initial time. This difficulty is handled by the age old principle of basic mathematics. Naturally, giving symbolic names to the unknowns by modelling the problem, governing equations are developed with the conditions of the Stefan type problem, solved it and compared the obtained solutions with existing results wherever possible.

Keywords: *Moving boundary problems, Interface, Green's theorem, One phase*

SIMULATION OF FDM MANUFACTURED PART FOR PREDICTION OF NATURAL FREQUENCY

Fahraz Ali[1*] and Boppana V. Chowdary[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: fahraz.ali@gmail.com *(Corresponding author)
[2]Email: Boppana.Chowdary@sta.uwi.edu

Abstract: Developments in additive manufacturing (AM) suggest the need to explore the influence of process parameters on dynamic mechanical characteristics in order to expand its application areas. This research study focuses on the development of a finite element model to simulate the resonant frequencies of the Fused Deposition Modelling (FDM) processed part. Key process parameters including raster angle, air gap, build orientation and number of contours have been selected for investigation through geometrical representation and finite element analysis (FEA). Correlation of FEA simulation with physical testing was performed on a simple part made of polycarbonate (PC) material. A comparison between simulated and actual results demonstrated good agreement by keeping within 5% accuracy.

Keywords: *Fused deposition modelling, natural frequency, finite element analysis.*

THE ROLL-UP DIGITAL STEELPAN

Umesh Persad[1*], Keivi Howard[2] and Jorrel Bisnath[3]
[1,2,3]Design and Manufacturing Systems, San Fernando Campus
The University of Trinidad and Tobago, Trinidad and Tobago
[1]Email: umesh.persad@utt.edu.tt *(Corresponding author)
[2]Email: keivihoward@gmail.com
[2]Email: jorrel.bisnath@utt.edu.tt

Abstract*:* The steelpan (steel drum) is the national instrument of Trinidad and Tobago. Over the years, there have been various innovations in the design of the steelpan, including new electronic versions. This paper presents an addition to the family of digital steelpan instruments in the form of a low-cost roll-up digital steelpan (similar to a roll-up piano or roll-up drum kit). The idea as conceptualized is to have a flexible surface with solid steelpan notes following the traditional circle of fifths pattern. The playing surface could then easily roll up for transport and storage. The design of the roll-up digital steelpan will be presented together with results on initial testing with musicians. Plans for further development of the product will also be discussed.

Keywords: *steelpan, innovation, interaction design, product development*

WAVE ANALYSIS OF A L-BEAM STRUCTURE WITH A BLOCKING MASS

Johnny Tiu[1*] and Richard Bachoo[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: johnny.tiu@sta.uwi.edu *(Corresponding author)
[2]Email: richard.bachoo@sta.uwi.edu

Abstract: The wave vibration approach regards the vibrations present within a structure as waves, whereby each wave flows along a structural member and upon meeting a discontinuity; portions of the incident wave are reflected and transmitted across the discontinuity. The reflected, transmitted and propagating wave transformations are represented mathematically by matrices, which are used to develop a set of wave relation equations at each discontinuity that can be used to describe the frequency response of the system holistically. This method creates a systematic approach of analysing structures by utilizing common cases as building blocks for a specific structure. The L-joint, described as two beams meeting at right angles; is a ubiquitous case for spatial portal and structural frames, which may become geometrically complex. Such structures are well suited to a wave vibration approach due to the large number of geometric changes and the prevalence as well as recurrence of specific cases. In this paper, the L-joint expanded to include a blocking mass, typically employed in structural systems and allows for the isolation and reflection of vibration away from contiguous structural elements. Included are; variance of transmission and reflection matrix components as the size of the blocking mass increases, numerical examples and comparison to a Finite Element Model developed in ANSYS.

Keywords: *Blocking mass, L-joint, Wave vibration approach, Timoshenko beam.*

APPLYING FUZZY QFD MCDM TO EVALUATE MUSICAL INSTRUMENTS

Peter Poon Chong[1*] and Terrence R.M. Lalla[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: peter.poonchong@sta.uwi.edu * (Corresponding author)
[2]Email: terrence.lalla@sta.uwi.edu

Abstract*:* This paper exhibits a method to improve the quality of musical instruments with the application of two Multi-Criteria Decision Making models, Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) and Analytic Hierarchy Process (AHP) in a quality function deployment (QFD) environment. A fuzzy analysis approach was also included to accommodate qualitative data in music. The QFD was constructed with literature based on optimizing the manufacture of musical instruments. At this phase of the research, the paper focused on the physical parameters and perceived qualities of musical instruments. The proposed modified QFD was developed to identify the product features chosen by the market and aid the manufacture of musical instruments. A standard QFD recognized and scored factors to develop and manufacture musical instruments. It accommodated some core engineering variables for the musical instruments but overlooked some feature stakeholder needs. For example, the musician may not have 100% gratification while playing the instrument as the manufacturer fails to capture acoustic features to psychologically satisfy the musician's audience. Using fuzzy logic, QFD and MCDM increased the model performance by expanding the data set. It offered the manufacturer of musical instruments a mode to capture and analyse behavioural linguistic data covering more customer requirements. Hence, the approach increased the range to correlate the physical features and psychological behaviours of musical instruments. It allowed non-technical persons to provide an improved form of reliable information. This modified QFD can also be applied to develop other products involving linguistic data.

Keywords: *QFD, Fuzzy Logic, MCDM, TOPSIS, AHP, Linguistic Data, Musical Instrument Design*

PERFORMANCE OF COATED CUTTING TOOLS IN MACHINING: A REVIEW

Rukmini Srikant Revuru[1]*, Vamsi Krishna Pasam[2] and Nageswara Rao Posinasetti[1]

[1,3] Department of Technology, University of Northern Iowa, Cedar Falls, IA, USA.
[2] Department of Mechanical Engineering, National Institute of Technology, Warangal, Telangana, India.
[1]Email: rukmini.revuru@uni.edu *(Corresponding author)
[2]Email: vamsikrishna@nitw.ac.in
[3]Email: posinasetti.rao@uni.edu

Abstract*:* Rapid advances in materials science have prompted the development of materials and alloys of enhanced properties like high strength, hardness, etc. Though these alloys are beneficial in their applications, their machining is difficult. For instance, Inconel 718, a nickel-based alloy, is used in several aerospace applications. This alloy can retain its strength at high temperatures up to 750℃. However, machining Inconel is a problem due to its poor machinability. Similarly, titanium alloys are not very hard but react with tools at high temperatures and lead to their premature failure. Carbide inserts are commonly used as cutting tools in the industry. Carbide tools are manufactured using powder metallurgy technique and possess high strength and hardness, even at elevated temperatures. However, these tools are not effective in machining of "difficult-to-machine" materials and have very short life. In light of this, coated tools have evolved. The cutting tools are coated using very hard, non-reacting material and sometimes a solid lubricant. The coatings are made usually by using PVD or CVD techniques. Often, intermediate layers are provided to improve adhesion between the substrate and the actual coating. Coated tools have better resistance to temperatures and hence, better tool life compared to the regular cutting tools. This paper deals with the evolution of the technology of coated tools. Different types of coatings, their advantages/limitations and efficacy of coated tools in machining are reviewed and discussed.

Keywords: Coatings, *cutting tools, properties, tool wear*

AN APPLICATION OF COMPUTER AIDED DESIGN AND COMPUTATIONAL FLUID DYNAMICS TOOLS FOR THE REDESIGN OF AN INTAKE MANIFOLD: A CASE STUDY INVOLVING A NATURALLY ASIRATED SPARK IGNITION ENGINE OUTFITTED WITH A TURBOCHARGER

Kyle Sealey[1*], Boppana Chowdary[2] and Fahraz Ali [3]
[1, 2, 3] Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: kylesealey@rocketmail.com* (Corresponding author)
[2]Email: Boppana.Chowdary@sta.uwi.edu
[3]Email: fahraz.ali@gmail.com

Abstract: An intake manifold is the component of an engine that transports the air or air-fuel mixture to the cylinders for combustion. Due to the dynamic nature of a multi-cylinder four-stroke internal combustion engine, details of the flow within the intake manifold are somewhat complex, which poses a challenge with respect to its design. For this study, the redesign was achieved through the use of Computational Fluid Dynamics (CFD) in conjunction with both steady-state and transient analyses.
steady-state analysis was implemented to investigate the pressure loss experienced across the original manifold when subjected to the elevated mass air flow rate generated by the turbocharger. A Computer Aided Design (CAD) model was constructed and validated against experimental data while a suitable runner length was chosen based on the Chrysler Ram Theory. Experiments were conducted with various combinations of the design parameters plenum volume (V), plenum inlet diameter (D) and runner inlet cross-sectional area (CA). By simulating a mass airflow rate of 0.4kg/s, these combinations were used to investigate their effects on the response variable manifold outlet pressure (MOP). For this particular design, CA was found to have the largest effect on MOP, yielding a reduction of approximately 0.007 x10^6 Pa.
Transient analyses were conducted to reduce runner velocity variation (RV) as well as to improve mass flow rate (MFR) by manipulating the runner air entry angle (AE) as well as the runner entry profile (RP) during transient operation. The result was a 50% reduction in RV with AE equal to 12 degrees, along with the complete elimination of runner backflow. This was accompanied by a 25%increase in MFR when a simple bell mouth runner entry profile of radius 2.5 mm was used.

Keywords: *Intake Manifold, Steady State analysis, Transient analysis, Intake Runner Backflow, Computational fluid dynamics*

BUCKLING CHARACTERISTICS OF SHALLOW THIN SPHERICAL CAPS

Devin Singh[1*] and Jacqueline Bridge[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: devin.singh@sta.uwi.edu *(Corresponding author)
[2]Email: Jacqueline.bridge@sta.uwi.edu

Abstract*:* This work investigates the experimental buckling of thin spherical caps (TSC) with free edges. Spherical caps are important structural members as they have a high strength to weight ratio and are aesthetically pleasing. As a structurally loaded member, the loading condition, as well as the edge boundary condition, is necessary for analytical calculations. Research and experimental work on TSCs were limited to few loading and boundary conditions. Previous work into buckling of TSCs focused point loads, ring loads and uniform external pressure. Boundary conditions previously investigated were clamped, pinned or elastically restrained. This experimental work focused on buckling TSCs between two rigid platens while keeping the boundary edge condition as free. The experimental configuration is a melding of all previous loading conditions into a new loading condition, starting from a point load, the platen flattens the TSC developing uniform external pressure and finally a ring load when the TSC buckles. The mechanical tests performed resulted in the identification of unique buckling modes of deformation in both aluminium and steel shallow spherical caps.

Keywords: *Spherical Cap, Buckling Modes, Free Edge, Axisymmetric Loading*

MODELING A MANUFACTURING ENTERPRISE- A SYSTEMS APPROACH

PSRK Nageswara Rao[1]*, P. Usha Sri[2], K. Vizayakumar[3]
[1]Department of Mechanical Engineering, SVIT, Secundrabad, India,
[2]Department of Mechanical Engineering, UCE, OU, Hyderabad, India.
[3]Department of Mechanical Engineering, BEC, Bapatla, India
[1]Email: panugantisrk@gmail.com* (Corresponding author)
[2]Email:emailushasri@yahoo.com
[3]E-mail: vizaya@gmail.com

Abstract: Understand the context and problems of a manufacturing enterprise (ME) and its internal dynamics, primarily through modelling by its processes, operations, and activities. This paper attempts to provide a deeper understanding of the structure and internal mechanisms of ME that shape the overall dynamic behaviour through system dynamics modelling. In this paper, we discuss the system dynamics model in detail and present the insights gained from running simulations. This model helps to explore various policy options relating to decisions and it can be applied to predict system behaviour and gain insights using sound engineering and scientific principles and techniques before implementing a new policy. The paper describes major influences in ME from a system perspective, problems inherent in production systems made clear because the modelling of causal loops introduce cross-departmental issues and promote process Integration. This model guides managers through a continuous improvement process relative to addressing physical, policy or paradigm constraints in their production system.

Keywords: *System Dynamics, Manufacturing Enterprise, Causal Loop Diagram, Policy*

A FEASIBILITY STUDY FOR IMPLEMENTATION OF A SMART PARKING SYSTEM IN PORT OF SPAIN TRINIDAD AND TOBAGO

Sarah Rooplal[1*], Boppana Chowdary[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: sroopla@gmail * (Corresponding author)
[2]Email: boppana.chowdary@sta.uwi.edu

Abstract: Parking challenges and problems are prominent worldwide and in Trinidad and Tobago. The capital city of Trinidad, Port of Spain, is a major area where these challenges are experienced as there are approximately 30% of the population who venture into the city on a daily basis during the week. Worldwide trends involve the utilization of Internet of Things (IoT) platforms to help alleviate parking challenges by implementation of a smart parking system (SPS). This study reviewed a feasibility of implementation of a smart parking system in Port of Spain.

In this study, a Discrete Event Simulation (DES) modelling approach was used to simulate real-life scenarios of the standard parking and a proposed SPS model for a facility chosen in Port of Spain. These simulations were done at zero costs and results were verified and validated. Verifications were done by comparing how the models worked, to the existing parking facility. Models were then validated using the Chi-squared statistic to determine if there were any statistical difference between developed models and actual statistic.

From validations performed, it was determined the wait time to find a park drastically reduced to zero minuities as a user only entered the parking facility once there was a vacant spot when using the proposed SPS. The proposed SPS will reduce driver frustration when finding a vacant parking spot, fuel usage and also reduce degradation to the environment.

Keywords: *Smart Parking System, Discrete Event Simulation, Internet of Things.*

PERIODIC SOLUTIONS OF A SHAPE MEMORY ALLOY OSCILLATOR BY AN ITERATIVE METHOD

Shivan Ramnarace[1*] and Jacqueline Bridge[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Shivan_ramnarace@yahoo.com *(Corresponding author)
[2]Email: jacqueline.bridge@sta.uwi.edu

Abstract: Linear vibration absorbers are limited in their performance such that they are usually only effective over very narrow excitation frequencies. As a solution to this, nonlinear vibration absorbers have been shown to be capable of reducing vibrations over broadband frequencies. The Shape Memory Alloy (SMA) oscillator considered here is inherent of nonlinearity from the geometric relationship due to the arrangement of its SMA wires as well as the effect of superelasticity. The aim of this paper is to examine the responses of this SMA oscillator as a precursor to determining it's absorbing effects when attached to a primary system undergoing unwanted vibrations. In particular, periodic solutions are sought by an iterative method and compared to numerical analysis.

Keywords: Vibration absorber, Nonlinear, Shape memory alloy, Oscillator, Broadband frequency

INVESTIGATION OF DYNAMIC AND CYCLIC LOADING OF SUPERELASTIC SHAPE MEMORY ALLOY WIRES

Shivan Ramnarace[1*] and Jacqueline Bridge[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Shivan_ramnarace@yahoo.com *(Corresponding author)
[2]Email: jacqueline.bridge@sta.uwi.edu

Abstract: Shape Memory Alloys (SMAs) possess a unique characteristic known as the superelastic effect when above a specific austenitic transformation temperature. This causes the material to have a nonlinear hysteresis behaviour due to a thermomechanical reaction with its environment when being loaded/ unloaded. For practical considerations, deviation in this behaviour is usually considered negligible as the material behaves very closely to that of static loading conditions. However, under dynamic conditions such as with SMA oscillators in vibration reduction devices, changes in behaviour become important as the thermomechanical reaction with its environment is significantly affected. The SMA material therefore needs to be tested considering not only the effect of its temperature when loaded but its strain-rate as well. In this paper, experimental findings are summarized for the usage of SMA wires under dynamic loading as it is of interest for usage in future work. In particular, the effect of cyclic tensile loading on the material's residual strain is investigated thus considering the stability of loading curves under dynamic loading conditions.

Keywords: Super elastic effect, Shape Memory Alloy,Dynamic loading,Cyclic loading, Strain-rate

ANALYSIS OF NUCLEAR BASED ELECTRIC POWER GENERATION SYSTEM – AN LCA APPROACH

N. Leela Prasad[1*], P. Usha Sri[2] and K. Vizayakumar[3]
[1]Vignan Institute of Technology and Science-Deshmukhi., T.S., India
[2]UCE - Osmania University, Hyderabad., T.S., India
[3]Bapatla Engineering College, Bapatla., A.P., India
[1]Email: nlp123@rediffmail.com *(Corresponding author)
[2]Email: emailushasri@yahoo.com
[3]Email: vizaya@gmail.com

Abstract: In a developing country like India with scarce hydrocarbon reserves and also due to variable nature of Renewables in terms of potential, penetration and technology, Coal must be relied upon as a source of energy in near future also, to meet the ever-growing demand for an instant form of energy *i.e.* Electricity. An alternative to not so clean source Coal appears to be Nuclear Power and this option can supplement and supplant our energy needs in spite of several concerns from various sources post-Fukushima Nuclear accident. This paper carries out a detailed LCA study of Nuclear based Electric Power Generation System with a wider scope that encompasses the waste disposal and plant decommissioning phases, is modelled and run on SimaPro 9.0.0.48 LCA software with ECOINVENT 3.0 as database. This study also covers the all-important Inventory Analysis for the inputs used, raw material extracted and residuals consequently released to the environment. The results are expressed in terms of pre-defined energy metrics such as ERR and EPBT. Further, the study covers the environmental impact assessment category such as GWP and finally the results are presented with a kWh of electricity produced by this option as a functional unit. These investigations help energy planners and policymakers to compare various power generating options and justify the alternatives to meet future demand for electricity in a cleaner and more sustainable manner by keeping the spirit of Paris Climate Agreement in mind.

Keywords: *Life Cycle Assessment (LCA), Energy Return Ratio (ERR), Energy Pay Back Time (EPBT), Global Warming Potential (GWP).*

A STUDY ON THE IMPROVEMENT OF A LOCAL BOTTLE MANUFACTURING OPERATION: DEPLOYMENT OF LEAN PRINCIPLES AND DISCRETE EVENT SIMULATION

Ezekiel Yorke[1*], Boppana V. Chowdary[2] and Jainarine Bansee[3]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: ezekiel_yorke@hotmail.com *(Corresponding author)
[2]Email: boppana.chowdary@sta.uwi.edu
[3]Email: jainarine_bansee@yahoo.com

Abstract*:* Local manufacturing small and medium enterprises (SME) have faced continuous challenges in competing with manufacturing firms of scale on the global market. Factors such as the presence of a traditional organisational structure and inefficient utilisation of resources have contributed to the challenges faced by local SMEs in keeping up with regional and international competitors within the manufacturing sector. To investigate the aforementioned challenges, a case study was conducted on a local bottle manufacturing SME which sought to improve their system performance across their Plastic Injection Molding (PIM) operation. Using strategies in the form of lean manufacturing as well as ARENA® simulation software, the challenges identified within their operation were observed and mitigated using key performance indicators. Lean strategies such as Heijunka, Kanban and Six Sigma were utilised as possible methods of reducing waste within the existing simulation model. When comparing the key performance indicators from the simulation, findings highlighted improvements in the Work in Process (WIP) and Waiting Time (WT) by 84.78% and 98.03% for the entire operation. A cost-benefit analysis was carried out to identify the most financially feasible strategy in purchasing the resources that were required for the strategy's integration into the actual system.

Keywords: *Discrete event simulation, Key performance indicators, Lean manufacturing, Plastic injection molding, Small and medium enterprise.*

COMPARISION OF FOUR FABRICS FOR FILTERING TURBID WATER IN A TWO STAGE CROSS-FLOW FILTER

Goldie Davis[1*], Edwin Ekwue[2] and Vincent Cooper[3]
[1,2,3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: goldie.davis@my.uwi.edu *(Corresponding author)
[2]Email: Edwin.Ekwue@sta.uwi.edu
[3]Email: vincent.cooper@sta.uwi.edu

Abstract: Surface water treatment plants in Trinidad are incapable of filtering highly turbid water. Water treatment operations are shut down whenever turbidity levels rise during or after rainfall. The aim of this research is to determine the physical properties of linen, burlap, crepe-backed satin and cotton fabrics and to compare their efficiencies as filter media for reducing turbidity in water. Scanning electron microscopy was used to generate images of each fabric. Fabric weave type was determined. Inter-yarn pore sizes, inter-fiber pore sizes, warp and weft spacings, warp and weft diameters and thicknesses were measured using ImageJ. Based on the properties examined, and execution of cross-flow filtration and perpendicular filtration tests, linen was the chosen fabric filter medium. Surface profilometry resulted in linen having the roughest surface of 685.5µm and the largest maximum profile height of 3632.4µm. Linen's inter-yarn and inter-fiber pore sizes were 41.98µm and 22.37µm respectively. This fabric had warp and weft spacings of 400µm and 700µm respectively and was 400.39µm thick. Measurements also revealed warp and weft diameters of 13.26µm and 14.96µm respectively. Linen had a high tensile strength of 402N. Linen, had a hopsack plain weave and was tightly woven; it was 95.16% porous with a sediment retention capacity of 71%. Linen is a fabric material that could prove to be a very good filter medium. Also, Acono River water turbidity levels measured ranged from 2.47NTU to 23.93NTU. Soil types contained in the turbid water were gravels, sand and silt varying from 25mm to 0.075mm in size.

Keywords: *Fabric, Filter, Linen, Turbidity, Water Treatment.*

EXPLORING QUALITY MANAGEMENT PRACTICES AT THE MINISTRY OF EDUCATION, PORT OF SPAIN OFFICE

Kit Fai Pun[1*] and Cherisse S. Lashley[2]
Department of Mechanical and Manufacturing Engineering, The University of the West Indies, St Augustine, Trinidad and Tobago, West Indies
[1]Email: KitFai.Pun@sta.uwi.edu *(Corresponding author)
[2]Email: scalashley@hotmail.com

Abstract: In Trinidad and Tobago (T&T), teachers describe the service offered by the Ministry of Education (MOE) in Trinidad and Tobago as poor because of the delays incurred during the processing of the majority of requests. This demonstrates low productivity since requests by teachers are not fulfilled in an acceptable time. This problem is a burden to teachers as little is done to address the issue and teachers are left to suffer the consequences of waiting long periods of time for requests to be processed or issues to be resolved which can turn into years of waiting. In order to investigate the low productivity issues and the challenges associated with quality management (QM) practices at the MOE Port of Spain (POS) Office, a recent study comprising site visits and interviews with stakeholders (MOE staff and teachers) was undertaken with the aid of online surveys. This paper presents the main findings of the study, aiming to examine the current QM processes, and identify the factors affecting the provision of quality services to teachers. The current quality culture and leadership styles of the MOE-POS Office are explored, along with the determination of various Quality dimensions, costs, core values and paradigms and principles. The paper concludes by underlining the adoption of Quality Function Deployment (QFD) and Hoshin planning in deriving an enabling path to attaining quality improvement, specifically for processing common requests or resolving issues at MOE-POS office.

Keywords: *Quality management, Deming's principles, Hoshin planning, Quality Function Deployment, Education*

MULTI-OPTIMIZATION OF EMPIRICAL MODELS FOR THE MATERIAL EXTRUSION PROCESS

Schuravi N. Mallian[1*], Boppana V. Chowdary[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: schuravi_z@hotmail.com *(Corresponding author)
[2]Email: Boppana.Chowdary@sta.uwi.edu

Abstract: Advances in materials and manufacturing technology and increased competition has led to companies needing to manufacture products more efficiently and rapidly to meet growing market demands. The AM process is ideally suited to the fabrication of complex geometries usually impossible with traditional methods furthermore it is capable of fabricating entire assemblies in step without the need for tooling or human involvement.

Due to the flexibility and advantages over conventional methods AM has garnered significant attention from the manufacturing sector in meeting market demands. Of the array of available AM processes, Material Extrusion (ME) utilizes a heated thermoplastic filament to construct parts or assemblies via a layer by layer deposition method. This process is not without its own flaws, suffering from accuracy, build time, strength etc., due to the conflicting nature of the process parameters of ME. Therefore, it is critical to understand the shortfalls of ME and classify the factors that directly influence the performance of a part.

This paper focuses on the enhancement of the performance measures of the part in terms of build time, material consumption and max torsional stress. This is accomplished by understanding the influence of the process parameters such as raster width, raster angle, part orientation and layer thickness on the performance measures via statistically valid models and optimization methods. This was accomplished using a Box-Behnken design for the experimental design followed by the multi-objective optimization of the empirical models from which the optimum process settings was determined.

This study has shown that complex non-linear relationship exists between the process parameters and performance measures. Results show that the Artificial Neural Network had a better fit when compared to the Response Surface Methodology model and it can be a promising alternative for the prediction and optimization of the ME process

Keywords: *Additive Manufacturing, Material Extrusion, Multi-objective optimization*

CIRCULAR ECONOMY ADOPTION WITHIN 3D PRINTING INDUSTRY: THE STATE OF THE ART, MAJOR ISSUES AND CHALLENGES

Boppana V. Chowdary[1], Angelina Rayside[2*] and Prasanta Dey[3]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[3]Aston Business School, Aston University, UK
[1]Email: boppna.chowdary@sta.uwi.edu
[2]Email: angelinarayside@hotmail.com *(Corresponding author)
[3]Email: p.k.dey@aston.ac.uk

Abstract: There is a growing realisation in the international community that economic development and environmental conservation must achieve a balance to enable future generations to survive and prosper as we exist on a planet of finite resources. Circular Economy (CE) has emerged as a paradigm shift to assist in attaining this balance. It has been argued that industry can achieve CE through five phases – take, make, distribute, use and recover i.e. converting their linear business processes (take, make and distribute) to circular. 3D printing/Additive Manufacturing (AM) industry is developing speedily and it could potentially involve trillions of dollars in business over the coming decades. 3D printing inadvertently achieves some of the most urgent environmental and resource goals facing the global industry. For example, the transportation and manufacturing carbon footprint of many products could be reduced as design, rather than products are shipped. Furthermore, 3D Printers will manufacture personalized products locally and only on demand. Moreover, with developments in bio-based 'smart' materials, the 3D printing process itself can lead to significant material savings. The promise of 3D printing with biomaterials is that it can create a fully sustainable and circular manufacturing process.
The literature indicates that the 3D printing industry can contribute various parts of the circular economy system: especially in maintenance, re-use, re-manufacturing and re-cycling of products and goods. Moreover, though there is evidence in other manufacturing processes, the literature on 3D printing industry adoption of CE is scanty. This study bridges the critical research and knowledge gap in the field. As the 3D printing industry has the promise to become the clear winner in realising a sustainable and CE, in this regard, the main objective of this paper is to identify the major issues and challenges of each phase of CE. The outcome of the study gives the way forward to the most urgent environmental and resource constraints facing the product suppliers scattered around the globe.

Keywords: *3D printing, Additive manufacturing, Circular economy, Re-cycling, Re-manufacturing*

NUMERICAL STUDY OF MHD CONVECTIVE NANOFLUID FLOWS WITHIN A CORRUGATED TRAPEZOIDAL ENCLOSURE

Victor M. Job[1], Sreedhara Rao Gunakala[2*], P.V.S.N. Murthy[3], R. Panneer Selvam[4]

[1,2]Department of Mathematics and Statistics, The University of the West Indies, Trinidad
[3]Department of Civil Engineering, University of Arkansas, U.S.A.
[4]Department of Mathematics, Indian Institute of Technology Kharagpur, India
[1]Email: victor.job@sta.uwi.edu
[2]Email: sreedhara.rao@sta.uwi.edu*(Corresponding author)
[3]Email: pvsnm@maths.iitkgp.ac.in
[4]Email: rps@uark.edu

Abstract*:* We consider the unsteady magnetohydrodynamic (MHD) natural convection flows of alumina (Al_2O_3)-water and single-walled carbon nanotube (SWCNT)-water nanofluids within a symmetrical corrugated trapezoidal enclosure with the effects of viscous and Joule dissipations. In this study, the corrugated bottom wall is isothermally heated, whereas the top wall is thermally insulated. The temperature of the side walls is fixed at the initial nanofluid temperature within the enclosure. We solve the governing equations for velocity and temperature, along with the corresponding initial and boundary conditions, using the polynomial pressure projection stabilized (PPPS) finite element method. The effects of sidewall inclination angle φ and Eckert number Ec on nanofluid flow and convective heat transfer within the corrugated enclosure are examined. The results obtained from this study are important in various fields of engineering and technology, such as the design and manufacture of efficient heat exchangers and the cooling of microelectromechanical systems (MEMS) using nanofluids.

Keywords: *Corrugated trapezoidal enclosure, finite element method, MHD, nanofluids, natural convection.*

THE DESIGN OF AN ASSET INTEGRITY PROGRAM TO ADDRESS PIPING CORROSION UNDER INSULATION

Charles N. Roopa[1], Kishore Jhagroo[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: charlesnroopa@gmail.com
[2]Email: Kishore.Jhagroo@sta.uwi.edu

Abstract: This project report aims to contribute to an identified need by a Petrochemical Facility located in Trinidad and Tobago seeking to manage Corrosion Under Insulation (CUI). The intent is to improve its static inspection program such that it will effectively address the issue of piping hydrocarbon leaks. With an average of two cases per year of leaks from hydrocarbon piping and with approximately 500 insulated lines identified, managing CUI can be daunting.
A Risk Based Approach has been used to prioritise the piping, which resulted in a list with 49 High Risk piping lines out of 500 insulated lines assessed. The best technology for Non-Destructive Examination was reviewed and it should be noted that at present all the various technologies are available locally.
Condition Monitoring for CUI is a new field and a handful of options are available, although with varying levels of cost and effectiveness. This project review identified the use of the COSASCO Corrosion Fuse Wire Sensor as the preferred technology.
The resultant program is one which specifies an inspection program for each of the three risk categories identified i.e. high, medium and low risk, and a separate program for the SBP (Small Bore Piping). This program will integrate the use of Condition Monitoring for CUI and proactively identify locations that are potential for piping leaks and address the coating failure or corrosion before it can become a leak.

Keywords: *Condition Monitoring, Corrosion Under Insulation, Non-Destructive Examination, Risk Based Approach, and Thermal Spray Aluminium.*

CONVECTIVE HEAT TRANSFER ON STENOSED BLOOD FLOW THROUGH PERMEABLE MICROCIRCULATION IN THE PRESENCE OF A MAGNETIC FIELD

Alana Sankar[1*], Sreedhara Rao Gunakala[2] and Donna Comissiong[3]
[1,2,3] Faculty of Science and Technology, The University of the West Indies, Trinidad
[1]Email: alana.sankar@sta.uwi.edu *(Corresponding author)
[2]Email: sreedhara.rao@sta.uwi.edu
[3]Email: donna.comissiong@sta.uwi.edu

Abstract: Blood flow through permeable microcirculation in the presence of a composite stenosis, an external magnetic field and convective heat transfer was examined. A two-layered model for the blood consisting of a fluid-particle suspension in the core region with a peripheral cell-free plasma layer was used. The proposed system of equations was solved and plots were generated. In the presence of permeable walls, an external magnetic field and convective heat transfer, the temperature of the blood, friction-factor Reynolds number and Nusselt number were investigated. The temperature of the blood increased when the Hartmann number increased, Darcy number increased, haematocrit level increased or the peripheral layer thinned. The friction-factor Reynolds number product increased as the haematocrit, Hartmann number, stenosis height or Darcy number increased. The Nusselt number decreased as the Hartmann number, haematocrit, stenosis height or Darcy number increased. These results were interpreted in terms of the physical situation. This study aids in understanding the effects of wall permeability, a magnetic field and the presence of heat transfer on different diseased arterial systems in the future.

Keywords: *Blood flow, Heat transfer, Magnetic field, Permeable microcirculation*.

.

CRACK PROPAGATION AND FRACTURE IN TWO TRINIDADIAN SOILS UNDER VARYING PEAT CONTENT DURING CONSTANT TENSILE TEST

Robert A. Birch[1*], Jacqueline Bridge[2] and Edwin Ekwue[3], Renee Regis[4], Shannon Steele[5] and Brad Harris[6],

[1,2,3] Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Robert.birch@sta.uwi.edu *(Corresponding author)
[2]Email: Jacqueline.Bridge@sta.uwi.edu[3]Email: Edwin.ekwue@sta.uwi.edu
[4] The Ministry of Agriculture, Trinidad and TobagoEmail: Renee.k.r@hotmail.com
[5]Caribbean Development Company (Carib)Likedin.com/in/Shannon-steele-475234bb

Abstract: There are many Caribbean farmers who perform tillage on sloping terrains. This activity presents a challenge to farmers as it initiates crack propagation and results in fracture and the crumbling of the soil, which may at times be a precursor to land slippage and soil erosion. An investigation into crack propagation and fracture of two Trinidadian soils, namely, Talparo clay and Piarco sandy loam was performed under constant tensile loading test (Creep). Constant load tests were performed on the two soils at a compaction level of 404 kPa under varying peat and water status content. Specialized experimental jigs and moulds were designed and fabricated for the constant tensile test coupled with image acquisition and processing techniques to measure and analyse crack propagation. Measurements on time to failure, resilience, creep compliance and crack growth rate were obtained. An ANOVA was performed ($p < 5\%$) on these results with soil type, % peat content, and water status being the main factors. Results showed that peat inhibits crack growth, especially with Talparo soil, further, time to failure for both soils increased with an increase in peat and water. However, water status had a more predominant effect on soil failure during creep. Also, the crack growth rate was highest for drier soils with no peat but it was similar for both soils irrespective of peat content when tested at the plastic limit. This information can be useful in improving agricultural soil management practices on areas where landslips are predominant.

Keywords: *Peat, Creep, Fracture, Crack propagation and Soil*

THE COMBINED EFFECT OF MAGNETIC FLUIDS WITH COUPLE STRESSES, VARIABLE VISCOSITY AND VELOCITY-SLIP ON THE LUBRICATION OF FINITE JOURNAL BEARINGS

Tyrone D. Dass[1], Sreedhara Rao Gunakala[2*] and Donna M.G. Comissiong[3]
[1]Foundations and Prior Learning, University of Trinidad and Tobago,
[2,3]Department of Mathematics and Statistics, the University of the West Indies, St. Augustine, Trinidad and Tobago
[1]Email: tyrone.dass@utt.edu.tt
[2]Email: sreedhara.rao@sta.uwi.edu* (Corresponding author)
[3]Email: donna.comissiong@sta.uwi.edu

Abstract: In this paper, we examine the combined effect of a non-Newtonian couple-stress lubricant, and a magnetic fluid, together with velocity-slip and piezo-viscosity, has on the lubrication characteristics of a finite journal bearing. Using the Stokes micro-continuum theorem and the Barus formula with an artificial (homogeneous) slip surface, we investigate the load-carrying ability, pressure distribution, and frictional coefficient of the bearing. Our results indicate that the piezo-viscosity parameter improves the maximum magnetic and hydrodynamic pressures of the journal bearing. The combined effect also significantly enhances the bearing characteristics.

Keywords: couple-stress lubricant, finite journal bearing, magnetic fluid, variable viscosity, velocity-slip.

THE POTENTIAL FOR LEAN AGRI-BUSINESS IN THE CARIBBEAN

Cilla Pemberton[1*], Dana Basdeo[2], Dieubon Simelus[3], Renique Murray[4] and Robert Birch[5]

[1,4,5] Faculty of Engineering, The University of the West Indies, Trinidad
[2]The Society of Caribbean Industrial Engineers
[3]Faculty of Food and Agriculture, The University of the West Indies
[1]Email: cilla.pemberton@sta.uwi.edu* (Corresponding author)
[2]Email: danabasdeo49@gmail.com
[3]Email: dieubeysims@gmail.com
[4]Email:renique.murray@sta.uwi.edu
[5]Email: robert.birch@sta.uwi.edu

Abstract: Agri-Business in the Caribbean has been fraught with challenges. The sector is vulnerable to physical and financial shocks due to disasters and price uncertainty, respectively. Stakeholders who depend on incomes from the industry are often lower-income individuals from rural districts that do not benefit from the same levels of infrastructure and access to resources as in the urban areas. This study investigates cases from three (3) Small Island Developing States (SIDS) from the Caribbean with a critical analysis of the potential for lean management. The Principles of Lean are aimed at delivering quality goods and services according to demand and eliminating wasteful activities. The methodology for the paper is qualitative and exploratory in nature. A literature review which highlights considerations for Lean Agri-Business and presents cases from Brazil and North America is followed by the presentation of the cases from Haiti, St. Kitts and Nevis and Trinidad and Tobago. The potential for the application of lean principles is then explored. It was concluded that while there are benefits to be gained from the implementation of lean within the sector, a holistic approach will have to be adopted and the major challenge to this would be the comprehensive education programme required since 'lean' goes against traditional instincts and humans would naturally display a preference for behaviours that are intrinsically anti-lean. As such, a system of circumventing these challenges in a sustainable manner could prove useful toward the survival of the sector and the increased profitability for even the most vulnerable stakeholders.

Keywords: *Small Island Developing States, Agri-business, Sustainable, lean*

MICROSTRUCTURAL CHARACTERISATION FOR POLYCRYSTALLINE NICKEL

Srihari Dodla[1*], Shashvat Agarwal[2], R Tejdeep Reddy[3] and Saurav Sahu Sahu[4]

Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur-603203, India

[1]Email: srihariovgu@gmail.com*(Corresponding author)

[2]Email: agarwalshashvat@gmail.com

[3]Email: sauravsameersahu@gmail.com

[4]Email: tejdeep54321@gmail.com

Abstract*:* Polycrystalline Nickel has very good mechanical properties and excellent corrosion resistance. In this paper we try to find the suitability of Nickel 200 for structural applications. Compression test on the specimens is carried out in the longitudinal and transverse directions and the difference in the strength in both the directions is studied before and after the heat treatment process. By investigation of the microstructure, the correlation between the deformation behaviour and grain morphology is investigated. The compression test results before the heat treatment reveal that by increasing the strain beyond the elastic limit, the material is anisotropic (up to 4 %). Also the heat treatment analysis reveals that the sub-grains have occurred in the microstructure. Machining experiments have been performed on Nickel 200 to accomplish proper surface finish and dimensional accuracy. Machining results reveal that the process parameters will have strong influence on cutting forces and surface roughness.

Keywords: D*eformation behaviour, grain morphology, heat treatment, polycrystalline Nickel*

THE DEVELOPMENT AND APPLICATION OF ENERGY AND EXERGY THERMODYNAMIC PERFORMANCE PARAMETERS TO DETERMINE THE AMOUNT OF PERFORMANCE DEGRADATION OF THE MAJOR COMPONENTS OF A COMBINED CYCLE POWER PLANT

Sennen Matabadal[1] and Delon N. Thompson[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: sennen.matabadal@sta.uwi.edu
[2]Email: delonthompson55@gmail.com

Abstract: This project is based on the philosophy that Actual Performance Parameters should be less than Design Performance Parameters and therefore the difference between the design performance and actual performance is an indication of Performance Degradation. In this paper, the Thermodynamic Performance Degradation or the decline in design performance of the major components of a Combined Cycle Power Plant was determined using a computational method that was formulated based on Energy analysis using the steady flow energy equation arising out of the First Law of Thermodynamics. Another computational method was developed using Exergy analysis arising out of the Second Law of Thermodynamics from which it can be hypothesized that mechanical degradation is a consequence of irreversible thermodynamic processes which suggests that entropy generation offers a natural measure of degradation. Data required to calculate the Design Thermodynamic Performance Parameters based on the Energy and Exergy Analysis was obtained from the Plant's Design Heat and Mass Balance diagram since manufacturers do not provide design performance parameters. To calculate the Actual Thermodynamic Performance Parameters based on the Energy and Exergy analysis, Actual Operating Data was obtained from the Combined Cycle Plant under study over a three-month period.

The results obtained for the Actual Performance Parameters for both the Energy and Exergy analysis deviated from the design performance or were less than design, which shows degradation and is in accordance with the philosophy that actual operating performance parameters should be less than design performance parameters. The results were then used to determine the percentage degradation of each component, and the components with the greatest overall degradation were selected and possible root causes for the degradation and methods to restore their performance were discussed and proposed. The results of this work can be used to implement a Thermodynamic Performance-based Predictive Maintenance Programme for the major components of the Combined Cycle Plant.

Keywords: *Design and Actual Thermodynamic Performance Parameters, Performance Degradation, Combined Cycle Power Plant, First Law of Thermodynamics (Energy), Second Law of Thermodynamics (Exergy), Thermodynamic Performance–Based Predictive Maintenance Programme, Isentropic Efficiency, Polytropic Efficiency, Thermal Efficiency, Effectiveness*.

EVALUATION OF A CRICKET BOWLING MACHINE WITH AN ARM AND HAND TO DELIVER THE BALL

Ronnie Bickramdass[1*], Professor Prakash Persad[2], Dr Kelvin Loutan Jr.[3] and Aaron Ameerali[4]

[1,2,4]Design and Manufacturing, The University of Trinidad and Tobago, Trinidad
[3]Faculty of Engineering and Physical Sciences, University of Surrey, England
[1]Email: ronnie.bickramdass@utt.edu.tt *(Corresponding author)
[2]Email: Prakash.persad@utt.edu.tt
[3]Email: k.loutan@surrey.ac.uk
[4]Email: aaron.ameerali@utt.edu.tt

Abstract*:* The use of bowling machines to train batsmen whether it be indoors or outdoors have increased significantly. In the absence of bowlers, batsmen can bat for hours without any bowlers getting tired. The designs of these machines are often a derivative of ball projection machines used for other sports such as tennis. Reviewed literature highlights the deficit in visual information in the form of an arm and hand when using these machines. Hence a cricket bowling machine was developed with an arm and hand. The usability, functionality, repeatability and accuracy of the cricket bowling machine with an arm and hand was tested which had been previously designed and built by Dr Kelvin Loutan Jr (2016) at The University of Trinidad and Tobago. A trajectory model was developed for an indoor environment and experimentally validated with data collected from extensive testing of the bowling machine using Pitch Vision hardware and software. A design procedure had to be formulated to determine what test had to be done and the method of collecting data. The testing, collecting data and validation of the model was done with the cricket bowling machine at its current state with minor changes to the hand. The release angle at which the ball leaves the hand was found to have a significant impact on the length of the delivery. Finally, the bowling machine was able to bowl various lengths and varying speeds consistently. The variation in speed placed the machine in the category of medium-fast, that is, speeds between 120 km/h (75 mph) and 130 km/h (81mph).

Keywords: *Arm and hand, testing procedure, collecting data, repeatability and validation*

SMART IRRIGATION ESTIMATOR

Nadine Sangster[1*], Aneil Ramkhalawan[2], Aatma Maharajh[3], Jorrel Bisnath[4], Edward Cumberbatch[5], Ronnie Bickramdass[6], David Edwards[7] and Prakash Persad[8]

[1,2,3,4,5,6,7,8]Design and Manufacturing Systems, The University of Trinidad and Tobago, Trinidad and Tobago

[1]Email: nadine.sangster@utt.edu.tt *(Corresponding author)
[2]Email: edward.cumberbatch@utt.edu.tt[3]Email: aneil.ramkhalawan@utt.edu.tt
[4]Email: aatma.maharajh@utt.edu.tt [5]Email: jorrel.bisnath@utt.edu.tt
[6]Email: ronnie.bickramdass@utt.edu.tt[7]Email: david.edwards@utt.edu.tt
[8]Email: prakash.persad@utt.edu.tt

Abstract*:* Many of the agricultural plots within Trinidad and Tobago remain in a state of dormancy due to a critical lack of infrastructure needed for their development. This has contributed to the increasing food import bill which was some TT$5.6 billion over the last couple of years.

This overall project aims at assisting the farmers in setting up a proper infrastructure that will utilize natural resources. The lack of pipe water will be substituted by rainwater capture, storage and distribution via drip irrigation. The lack of power for water distribution by irrigation will be obtained by the use of solar power for the pumps. The project will be done in phases.

This phase looked at creating a smart estimator to determine the water requirement and the planting land area for the 2-acre plot when the number of plants, type of plants, and the month in which the farmer chooses to start planting are chosen. It will estimate the water storage volume required for the various crops chosen based on the rainfall patterns, crop cycle and the crop water requirement. These output estimates will be based on the land area input, estimated water storage size, estimated tool shed size and produce storage area, and the type or types of crops chosen to farm by the farmer for the plot. The input parameters in the estimator can then be varied by the farmer, to help find an estimated or optimum balance of the number and type of crops, the planting land area, and the water captured and stored, based on the rainfall patterns and the unused land area.

Keywords: *solar irrigation estimator, agriculture, innovation, design.*

EXPLORING AN OPTIMIZATION STRATEGY AT THE MAINTENANCE DEPARTMENT OF AN OIL COMPANY

Stefan Harrison[1*], Jainarine Bansee[2], Boppana Chowdary[3], Rajeev Seepersad, Dillon Frederick,

[1, 2, 3] Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: stefan.harrison@sta.uwi.edu *(Corresponding author)
[2]Email: jainarine.bansee@sta.uwi.edu[3]Email: boppana.chowdary@sta.uwi.edu
Email: rajeev.seepersad@gmail.com
Email: dillonfrederick7@hotmail.com

Abstract*:* This paper looks at applying predictive maintenance and automated data storage and retrieval to reduce waste within a Petroleum Company. In this company, all pump maintenance was performed internally. This study explores the potential effect that the proposed strategy would have on the operations of three departments relevant to pump maintenance. These departments were, the Pump Shop, Stores Department and Shipping and Receiving. Rockwell Automation's Arena® simulation software was used to model an existing and proposed maintenance system comprised of these three departments and track the performance measures of Flow Time, Waiting Time and Work-in-Process. An analysis of the result revealed a significant reduction in average Flow Time and Waiting Time by 76% and 96% respectively with no significant change to Work-in-Process.

Keywords: *Data Storage & Retrieval, Predictive Maintenance, Discrete Even Simulation.*

CAPSTONE DESIGN PROJECTS – THEORY MEETS PRACTICE

Raghu Echempati[1*] and Several Senior Undergraduate Capstone Course Students

[1]College of Engineering, Kettering University, Flint, Michigan USA
Email: rechempa@kettering.edu

Abstract*:* This paper describes one example of an *adjustable gooseneck trailer hitch assembly* that was assigned as a *senior capstone design project course* at Kettering University, Flint, Michigan, USA to carry out their work from *concept to testing phases* of a real prototype – in short, following "Theory meets practice" concept. Typically, at most other engineering colleges, students complete their capstone projects in one year, while at Kettering University, the students complete their capstone courses in one academic term that lasts only about 11 weeks. Using math and advanced Computer Aided Engineering (CAE) tools for analysis is expected. Three different groups of students enrolled in three separate courses over 3 academic terms developed two different trailer hitch devices. The first gooseneck hitch system briefly described here was the effort of a group of four students of the *capstone course*. They designed a manually adjustable device. However, due to time constraints, their fabricated device ended up being a rigid frame. These students carried out all the different tasks of the project more or less equitably. The second trailer hitch system described in this paper was the effort of a single student of the *capstone course* who designed and fabricated a *compliant (adjustable) hitch system*. However, due to time constraints, detailed finite element analysis (FEA) or testing of the device could not be done. A third group of two students enrolled in *Applied Finite Element Analysis* course in another academic term chose the compliant hitch design carried by the single student for their final class project, and attempted analysis by MatLab and FEA. Preliminary results obtained for both of these gooseneck trailer hitch systems are presented and discussed briefly in the paper. Majority of the capstone course projects carried out at Kettering University represent uniqueness in terms of completing them in one academic term.

Keywords: *Capstone courses, gooseneck trailer hitch, Innovative & low-cost mechanical design & production, Assessment & design communication, Finite element analysis, Ethics & societal issues*

ANALYSIS OF THE CAUSE AND EFFECTS OF PART DEFECTS IN ABS SAMPLES MADE USING ADDITIVE MANUFACTURING

Arshad Mohammed[1*], Boppana V. Chowdary[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: arshad.mohammed2@my.uwi.edu *(Corresponding author)
[2]Email: boppana.chowdary@sta.uwi.edu

Abstract*:* This study highlights the cause and effects of part defects in ABS-Based samples using an additive manufacturing process. The parameters that were investigated include build orientation, infill pattern, number of contours, airgap, road width and annealing as a post-processing parameter. Samples were made, and their compressive strength was tested. Additionally, the tested samples were investigated using optical microscopy and the classification of their defects was done. This study is unique in investigating the effect of stress relief annealing along with build process parameters. Furthermore, the various defects associated with compressive failure in additively manufactured artefacts were categorized and a cause and effect diagram was derived which would enable designers to predict the areas of failure of a part.

Keywords: *Additive Manufacturing, ABS Material, Compressive Strength, 3D Printing Defects*

A TIME STUDY OF THE PASTELLE MAKING PROCESS: AN INVESTIGATION AIMED AT REDUCING LABOUR AND TIME

Jeselle Gajadhar[1], Aneil Ramkhalawan[2*] and Jorrel Bisnath[3]
[1,2,3]Design and Manufacturing Systems, The University of Trinidad and Tobago, Trinidad and Tobago
[1]Email: jesellegajadhar@gmail.com
[2]Email: aneil.ramkhalawan@utt.edu.tt *(Corresponding author)
[3]Email: jorrel.bisnath@utt.edu.tt

Abstract: Pastelles are a seasonal staple enjoyed primarily at Christmas time by Trinidadians. At present, pastelle production is limited to home cooks for personal consumption and/or low volume sales (output of 6 to 20 dozen based on demand) as well as established catering companies whose output goes up to the hundreds of dozens.

Regardless of the production scale, pastelle making has been a manual process involving long hours and laborious repetitive tasks to achieve the output. The ultimate goal is to design, build and test a prototype to assist pastelle producers with their output.

For this project, a time study of the processes involved was conducted by timing a few different pastelle makers to identify the average time taken for the various processes involved. From this study, the mechanized pastelle press was created based on a need to increase the production time of pastelles and decrease the energy input on pastelle makers.

Keywords: *pastelle, innovation, design, time study.*

THE 5TH INDUSTRIAL REVOLUTION 2020 AND BEYOND OUR WILDEST IMAGINATION

Winston H.E. Suite,
Faculty of Engineering, The University of the West Indies, Trinidad
Email: winstonsuite@yahoo.com

Abstract: The paper is the third in a series that seeks to analyze the impact of technological change on economic, political and social development from the pre-Industrial era. In this instance the paper seeks to project, using the prior analysis, into the next period, the 5th Industrial Revolution from 2020 and beyond.

The paper selects the principal threats of the early twenty first century as one of the bases of the analysis. On the other hand, it selects the principal technological drivers which will provide opportunities for development of human civilization for possibly the next four decades. These two facts and the calculus derived from a study of the period from the first industrial age (1750) are the central vehicles that will be used in this paper. The paper culls from a wide study of the relevant literature across professions, economic sectors and various historical periods. It will include as well the views of several outstanding future and technology watchers.

The paper is not based on clairvoyance but history, science and the study of the growth and development of human societies fortified by the scholarship of outstanding thinkers from several differing fields of research.

The paper invites the reader on a journey into the future that is not yet written.

Keywords: *Industrial Revolution, Technology, Human Society Development, Fifth Phase*

Theme F

Entrepreneurial Approaches in Engineering Education

RETURNS TO FIELD OF STUDY: A GENDER PERSPECTIVE

Roshnie A. Doon[1*]
[1]Faculty of Social Sciences, The Sir Arthur Lewis Institute of Social and Economic Studies (SALISES),
The University of the West Indies, Trinidad
[1]Email: roshnie.doon@my.uwi.edu *(Corresponding author)

Abstract: This study examines the impact that workers' field of study in Trinidad and Tobago is likely to have on his earning capacity. Using individual persons' data from the Continuous Sample Survey of the Population (CSSP), for the period 1991-2015, the returns of private and public sector workers are estimated in two cohorts, i.e., 1991-2003 and 2004-2015 by employing the Quantile Regression technique. This study finds that men employed in low- and middle-income jobs for most fields (arts, humanities, science, engineering and architecture, social science, business, law, and mathematics and computer science and law enforcement) all suffered a wage decline in 2004-2015. This may be due to changes in the skill set where there was much growth in the industry demand for highly-skilled and unskilled men. This implies that middle income jobs which hire semi-skilled men, may be possibly becoming more polarized during the 2009-2015 recession. Men employed in high income jobs, earn better wages in more fields, particularly STEM areas. The earnings of women employed in low, middle- and high-income jobs for most fields (arts, humanities and education, science, engineering and architecture, medicine and veterinary science, social science, business, law, mathematics and computer science, transport and services, and law enforcement), especially in the areas of STEM all improved in 2004-2015. This improvement maybe influenced by the rising participation of women in STEM fields, as well as greater integration of STEM competencies in STEM and Non-STEM occupations.

Keywords: Human capital, Mincerian Earnings Equation, Quantile Regression, STEM, Fourth Industrial Revolution.

SURVEY OF CURRENT TRENDS IN MANUFACTURING ENGINEERING POSTGRADUATE PROGRAMS

Trishel Gokool[1*] and Boppana V. Chowdary[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: trishel.gokool@my.uwi.edu *(Corresponding author)
[2]Email: boppana.chowdary@sta.uwi.edu

Abstract*:* The promotion of innovation and current trends in the manufacturing engineering curriculum is essential to support the adoption and creation of advanced manufacturing technologies. However, the content and teaching methods employed by the engineering fields have long faced issues with incorporating industry needs and new developments into their various curricula. Manufacturing engineering (MfgE) is no exception as there exists significant gaps between the MfgE curricula, latest advances in research and current industrial practices in the MfgE curricula of Trinidad and Tobago. The present paper investigates the trends in postgraduate programmes in the United Kingdom (UK) in the area of MfgE. It highlights the current curricula structure and content of universities in a developed region with a similar education system with the aim of identifying key areas of MfgE focus. The study reveals that UK universities balance soft skills with technical learning, as research skills, management, manufacturing systems, systems simulation and, design and innovation are the top course themes. Moreover, there exists significant collaborative efforts between UK universities, industry and the government which drives research and development of emerging technologies.

Keywords: *Curriculum, Education, Manufacturing Engineering, Trends, United Kingdom*

MANUFACTURING ENGINEERING EDUCATION IN TRINIDAD AND TOBAGO: REVIEW AND FUTURE RESEARCH AGENDA

Trishel Gokool[1*] and Boppana V. Chowdary[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: trishel.gokool@my.uwi.edu *(Corresponding author)
[2]Email: boppana.chowdary@sta.uwi.edu

Abstract*:* Manufacturing has long served as the main engine that drives a country's economic growth and development. Manufacturing engineering (MfgE) education should thus support and help drive advances in the manufacturing sector. In Trinidad and Tobago, there has been much talk about diversifying the economy by strengthening sectors such as manufacturing. However, the bolstering of MfgE education to drive this diversification has largely been ignored. This paper provides an overview of the present structure of manufacturing engineering education in Trinidad and Tobago with an aim of briefly benchmarking its current state. A new concept of science, technology, engineering, mathematics, manufacturing and entrepreneurship (STEMME) education is introduced to draw as much focus on manufacturing and entrepreneurial education as the traditional science, technology, engineering, mathematics (STEM) subjects. A research agenda is then outlined which proposes the future research direction of the authors towards the development of MfgE education to support the sustainable diversification of the economy, specifically the manufacturing sector.

Keywords: *Curriculum, Diversification, Manufacturing Engineering, STEMME, Trinidad and Tobago*

TRANSFORMING THE DELIVERY OF CURRICULUM IN THE CARIBBEAN SIDS THROUGH MOBILE LEARNING

Alice O. Thomas-Martin[1*] and Dr. Ruel L. A. Ellis[2]
[1,2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: athomasmartin@gmail.com *(Corresponding author)
[2]Email: ruel.ellis@sta.uwi.edu

Abstract*:* Mobile devices and mobile technologies are significantly impacting the field of education. The dynamics of mobile computing is transforming the landscape of traditional classrooms. Education is a major factor in developing and sustaining a country. In a fast paced environment, traditional classrooms can be a hindrance to higher education. Mobile learning has the capacity to provide effective pedagogical and suitable learning activities for students of higher education. This paper explores m-learning and the shift of focus that it brings to educators and students. It looks at the relevance and place of m-learning in higher education, the framework for design as well as the devices and technologies that are available for use. The pedagogical approaches, assessment techniques and training that are suitable for the mobile environment are explored. The use of mobile devices allows for a level of flexibility that allows students to access education anywhere, anytime. Mobile learning provides a way for educational institutions to deliver educational content to its students on any platform, anyplace and at the time of need. For the design and implementation for mobile learning, the design approach was the point of focus. The relevance of mobile learning to Small Island Developing States and the future was highlighted.

Keywords: *devices, education, learning, mobile, technology*

A GUIDE IN THE USE OF EXISTING MAINTENANCE AND RELIABILITY THEORIES TO ENHANCE EQUIPMENT RELIABILITY AND AVAILABILITY IN THE INDUSTRIES IN THE CARIBBEAN

Kishore Jhagroo[1*]
[1]Department of Mechanical and Manufacturing Engineering, The University of the West Indies, St. Augustine, Trinidad and Tobago, West Indies;
[1]Email: Kishore.Jhagroo@sta.uwi.edu *(Corresponding author)

Abstract: In order to improve the Equipment Reliability and Availability in the Industries in the Caribbean this paper discusses the use of existing Maintenance and Reliability theories in the areas of condition monitoring techniques, root cause analyses, quality systems, Computerized Maintenance Management Systems (CMMS), Planning and Scheduling, Reliability Centered Maintenance (RCM), Total Productive Maintenance (TPM), the Ishikawa Diagram in addition to introducing a guide to facilitate their application. It describes the management accounting system, driven by leading and lagging Key Performance Indicators (KPI's), which ensure sustainability in the implementation of the improvement recommendations in the maintenance and reliability systems in these industries. Emphasis is placed on the need for Engineers and other professionals in the industry to play key roles in deciding when and for how long equipment shall be run and subsequently taken out of service. This can only be achieved by "placing their shoulders to the wheel" and working with passion towards their focused goals. They need to celebrate and learn from their successes and be innovative and critical thinkers to efficiently and effectively surmount any barriers in their way.

Keywords: *Maintenance, Reliability, RCM, TPM, Root Cause Analysis, Quality, CMMS, Planning and Scheduling, KPI's, Management Accounting*

TRANSITION FROM MASTER CRAFTSMAN TO ENGINEERING DEGREE

Clément Imbert[1*] and Reynold John[2]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[2]MIC Institute of Technology, Trincity Business Park, Macoya, Trinidad
[1]Email:clementimbert40@gmail.com *(Corresponding author)
[2]Email: rjohn@mic.co.tt

Abstract: There is a great need for Master-Craftsmen who are highly valued in industry locally but are not afforded the same recognition as in Germany, so in order to encourage more applicants a bridging progression to a Bachelor's degree should be devised. There are several paths to the education of engineers. Traditionally students of engineering attend secondary school from which they matriculate to a tertiary institution. In many countries candidates may opt to do an Associate degree articulating to a Bachelor's degree. However, in some countries, it is possible to become an engineer without a traditional degree, usually in a more practically-oriented apprenticeship programme. In Britain for example, such candidates complete National Vocational Qualifications (NVQs) in engineering while working at a company. NVQs typically range from Level 1 to Level 8, Levels 6 and 7 being equivalent to Bachelor's and taught Master's degrees respectively. In Germany, there is also an alternative qualification to the Bachelor's degree, the more practically-oriented Meister (Master-Craftsman in English), both of which are equally recognized and respected professionally and are both pegged at Level 6 in the 8-Level German National Qualifications Framework (NQF). The MIC Institute of Technology has adopted a Master-Craftsman programme which is accredited by the German Chamber of Crafts and Trades. Candidates have to first complete the (trimester) Journeyman programme comprising three years, about 50% of which comprise industrial attachments/internships. Successful Journeyman graduates can progress to the Master-Craftsman qualification by completing an extra (trimester) year of study. This paper deals with the progression of Master-Craftsman graduates, through advanced placement, in a Bachelor of Technology programme. The Master-Craftsman curricula have to be mapped against a typical Bachelor of Technology programme to determine the gaps in mathematical, theoretical and other areas and mechanisms to fill any gaps.

Keywords: *Bachelor's Degree, Master Craftsman, Transition*

EXPERIENCES OF USING A SINGLE ASSESSMENT FOR BOTH PRACTICAL PROTOTYPING SKILLS AND INTRODUCTION TO ENERGY ENGINEERING

Jorrel Bisnath[1*], Aneil Ramkhalawan[2], Edward Cumberbatch[3], Prakash Persad[4], Aatma Maharajh[5], Natalie Persadie[6], Ronnie Bickramdass[7] and Dinesh Soodeen[8]

[1,2,3,4,5,6,7,8] Design & Manufacturing Systems, The University of Trinidad and Tobago, Trinidad
[1]Email: jorrel.bisnath@utt.edu.tt *(Corresponding author)
[2]Email: aneil.ramkhalawan@utt.edu.tt
[3]Email: edward.cumberbatch@utt.edu.tt
[4]Email: prakash.persad@utt.edu.tt
[5]Email: aatma.maharajh@utt.edu.tt
[6]Email: natalie.persadie@utt.edu.tt
[7]Email: ronnie.bickramdass@utt.edu.tt
[8]Email: dinesh.soodeen@utt.edu.tt

Abstract: Engineering students are often faced with many assessment points during a semester. One of the more common assessments in an engineering programme are group-based, design and build projects. These projects often require a disproportionate amount of time due to coordination between members and resources for acquiring materials. This study relates an attempt to reduce this burden by utilising a common project as an assessment point for two separate courses: Practical Prototyping Skills and Introduction to Energy Engineering. The challenges faced by instructors in creating a project that would adequately address their individual learning outcomes are presented, along with the students' perspective on this approach.

Keywords: *Engineering education, project-based assessment, student assessment.*

K. C. CONFECTIONERY: A NEW PRODUCT DEVELOPMENT AND INNOVATION CASE

Amrita Mahabir[1], Dinesh Soodeen[2*] and Natalie Persadie[3]
[1, 2, 3]Design and Manufacturing Engineering, The University of Trinidad and Tobago
[1]Email: amrita.mahabir000@we.utt.edu.tt
[2]Email: dinesh.soodeen@utt.edu.tt *(Corresponding author)
[3]Email: natalie.persadie@utt.edu.tt

Abstract: Teaching case studies are a great way to implement active learning tactics. Writers describe case studies as complex examples, giving insight into the context of a problem and illustrating the main point. It provides student-centred activities based on topics that demonstrate theoretical concepts in an applied setting. This teaching case study was formulated explicitly for the purpose of teaching the subject matters of New Product Development (NPD) and Innovation in the Design and Manufacturing Engineering programmes at the University of Trinidad and Tobago in its undergraduate programme. Most NPD and innovation theoretical concepts are explained using foreign businesses as examples rather than local ones. While it is critical to understand global trends and practices, it is equally important to be equipped with the knowledge of local cultural, economic and industrial positioning in today's market. The aim of this paper is to create the first local teaching case study to be published and used at the University of Trinidad and Tobago. This is accompanied by an instructor's manual, also known as a "teaching note". This particular case study examines the processes involved in NPD and innovation at K. C. Confectionery Limited, a Trinidad and Tobago based food and beverage manufacturing company.

Keywords: *Innovation, New Product Development Strategy, Teaching Case Study*

INTEGRATED APPROACH TO MASTERS PROGRAMME DELIVERY IN MANUFACTURING AND DESIGN ENGINEERING AT UTT

Natalie Persadie[1*], Nadine Sangster[2], Aaron Ameerali[3], Dinesh Soodeen[4], Aatma Maharajh[5], and Aneil Ramkhalawan[6]

[1, 2, 3, 4, 5, 6]Design and Manufacturing Engineering, The University of Trinidad and Tobago
[1]Email: natalie.persadie@utt.edu.tt *(Corresponding author)
[2]Email: nadine.sangster@utt.edu.tt
[3]Email: aaron.ameerali@utt.edu.tt
[4]Email: dinesh.soodeen@utt.edu.tt
[5]Email: aatma.maharajh@utt.edu.tt
[6]Email: aneil.ramkhalawan@utt.edu.tt

Abstract: Translating theory into practice at the university level is easier said than done. Students often tend to experience difficulty in the application of knowledge learnt, as they seem to be accustomed to learning theory by rote and simply repeating it for the purpose of assessments. A somewhat different approach has been taken by the Design and Manufacturing Engineering (DME) Unit at the University of Trinidad and Tobago. In its BASc and MSc offerings, the DME Unit has made the application of knowledge learnt in the various courses offered a key feature of its programmes. The focus of this paper will be on the MSc programmes offered by the Unit. The DME Unit currently offers two Masters programmes, one which focuses on management (Innovation, Manufacturing Management and Entrepreneurship – IMME) and another which focuses on design (Innovative Design and Entrepreneurship – IDE). These programmes are designed with a view to achieving several outcomes, among which include: fostering the entrepreneurial spirit of students with the intention that they will start businesses at the end of their course of study, thereby commercialising any product or service they develop during the programme; developing their management capabilities, which prepares them for higher level positions and responsibilities at their places of work; immersing students into real-time, problem-based scenarios at companies over the period of a semester to allow them to act as consultants in a work environment different to their own; and nurturing their engineering design capabilities for new product development, with the intention that any such design produced will eventually be commercialised. In light of these outcomes, both programmes share common features in the courses that are covered. Such courses focus on management, entrepreneurship, business development and industry immersion. This paper will highlight the successes of this approach in both programmes.

Keywords: *Design, Design and Manufacturing Engineering, Management, Masters Programmes, University of Trinidad and Tobago*

QUALITY ASSURANCE AND ACCREDITATION OF ENGINEERING PROGRAMMES AT THE FACULTY OF ENGINEERING AT THE UNIVERSITY OF THE WEST INDIES, ST. AUGUSTINE CAMPUS, TRINIDAD

Edwin I. Ekwue[1*]
[1]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: Edwin.Ekwue@sta.uwi.edu *(Corresponding author)

Abstract: The quality of engineering education is challenging and of paramount importance in today's globalised world. The Faculty of Engineering at the University of the West Indies (UWI) inherited a western education system and the accreditation systems in the five departments within the Faculty are based on the British Accreditation System. This paper provides a description of quality assurance and accreditation processes carried out at the Faculty of Engineering and sees this as a method for maintaining and improving the quality systems in the Faculty.

Keywords: *Accreditation, quality, engineering, Faculty, British*

STIMULATING REGIONAL ECONOMIC DEVELOPMENT: A CASE FOR INFORMAL SCIENCE EDUCATION

Ruel L.A. Ellis
Faculty of Engineering, The University of the West Indies, St. Augustine
Email: Ruel.Ellis@sta.uwi.edu

Abstract: Most OECD countries have passed through three phases in the last century; Industrialization, Post-Industrialization and now the new economy known as the Knowledge-based Economy. Economic success in the knowledge based economy has been identified as being hinged upon the development of human capital [5]. In the Global Competitiveness Indices, the Caribbean Region (including Latin America) continues to perform well below regions in other parts of the world on all 12 pillars [4]. Informal science learning experiences has been known to influence the development of science curiosity and motivation to learn science more broadly. Early informal science learning involvements have been highlighted in analyses as to the reason for students making science-related curriculum and career choices, which supports the knowledge economy and will therefore economic development [1].

Keywords: *CARICOM, NIHERST, Economic Development, Science Education*

EXTENDED ABSTRACTS

EXTRACTION OF SODIUM ALGINATE FROM WASTE SARGASSUM: AN OPTIMIZATION APPROACH USING RESPONSE SURFACE METHODOLOGY

Akeem Mohammed[1], Arianne Rivers[2] and Keeran Ward[3*]
[1,2,3]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: akeem.mohammed08@gmail.com [2]Email: arianne_rivers@yahoo.com
[3]Email: Keeran.Ward@sta.uwi.edu *(Corresponding author)

Abstract :*Sargassum* in the Caribbean region has affected the livelihood of several coastal communities due to the influx of large quantities of this pelagic brown seaweed in recent times. This influx has created a variety of problems as it harms tourism-based economies, affects aquaculture operations and disrupts traditional fisheries and fisher livelihoods (Smetacek & Zingone, 2013). It was estimated that 10000 wet tonnes of seaweed was being deposited daily onto the shores of the Caribbean (Beckles, 2015). Beckles (2015) described the Sargassum inundation as "an international crisis" and "the greatest single threat" to the Caribbean. Sodium alginate can be extracted from the cells walls of this seaweed but is known to give relatively low yields of borderline quality. Alginates are polysaccharides that are found in the cellular wall matrix of brown seaweeds and are composed of linear binary copolymers of (1→4)-linked β -D-mannuronic acid (M) and ∝-L-guluronic acid (G) monomers (Torres et al., 2007). Therefore, this study seeks to further optimize the alkali extraction process using Box-Behnken response surface design coupled with multistage extraction to obtain a higher yield and purity of alginate. Design of Experiments (DoE) can be used for experimental investigation allowing for process modelling and optimization with minimization of the total number of experimental trials by the simultaneous variation of all influencing factors (Marchetti et al., 2013). Response surface methodology (RSM) is a statistical tool which gives a model that describes the process by evaluation of the interactive effects of independent variables on process parameters (Box & Wilson, 1951). BBD is efficient and useful in avoiding experiments performed under extreme conditions where unsatisfactory results may occur (Ferreira et al., 2007). BBD has successfully been used in optimizing the extraction parameters of polysaccharides from different types of biomasses (Luo, 2012; Ren et al., 2017; Ye et al., 2016). Furthermore, insight into the physiochemical properties of the extracted *S.natans* alginate that has never been reported is found. The variables investigated were extraction temperature, alkali concentration, and excess volume of alkali to *Sargassum* and extraction time. Seaweed pretreatment and acid treatment were done according to Mohammed et al. (2018). Alkaline extraction was carried out over a temperature range 22-80ºC, a concentration range of 1-10 % w/v Na_2CO_3, an excess volume range of 5-15 mL (Na_2CO_3: seaweed) and at reaction times ranging from 0.5-6 hours. Box-Behnken experimental design with four independent variables at three levels (high, intermediate and low) was chosen to investigate the effect of the extraction treatments on the yield. The complete design comprised of 29 experimental runs including 24 factorial points and 5 replicates at the center point. Design Expert 10.0.3 (Stat-Ease Inc, Mineapolis, MN, USA) software package was used for the response surface analysis (RSM). Analysis of variance (ANOVA) in the Design Expert software was used to analyze the experimental data via multiple regression analysis.

The regression coefficients of the linear, quadratic and interactive terms of the model and their effects were generated. The significance was evaluated by the F-test at a significance level ($p \leq 0.05$). The adequacy of the developed model was tested using the coefficient of determination (R^2), adjusted coefficient of determination (R^2_{adj}) and predicted coefficient of determination (R^2_{pre}). After fitting the data to the model, 2D plots and response surface plots (3D contour plots) were plotted and analyzed. The obtained experimental data were successfully fitted to a second order polynomial equation. Optimum conditions were determined to be an extraction temperature of 80ºC, 3.75 % w/v Na_2CO_3, excess volume of alkali of

12.63 mL for 6 hours and confirmed through validation experiments. Multistage extraction at the optimum conditions gave a high yield (28%) and after bleaching, high purity alginate (92%) at an extraction efficiency of 86% was obtained. Bleaching of the alginate was found to have no significant effect on the yield and purity but improved the whiteness with lower rheological properties. The M/G ratio was found to be 0.45 for the bleached alginate and shows that the alginate has the ability to form strong gels owing to its enriched guluronic acid content. The properties of the alginate strongly suggest that it can be used in future studies for the fabrication of films and thus would help in developing the waste *Sargassum* into a valuable end product.

Keywords: *Pelagic Sargassum, Response surface methodology, Sodium alginate, Extraction, Optimization.*

References

[1] Beckles, H. 2015. Greetings from the vice-chancellor. In Sargassum Symposium. UWI.

[2] Box, G.E.P., Wilson, K.B. 1951. On the Experimental Attainment of Optimum Conditions. *Journal of the Royal Statistical Society. Series B (Methodological)*, **13**(1), 1-45.

[3] Ferreira, S.L.C., Bruns, R.E., Ferreira, H.S., Matos, G.D., David, J.M., Brandão, G.C., da Silva, E.G.P., Portugal, L.A., dos Reis, P.S., Souza, A.S., dos Santos, W.N.L. 2007. Box-Behnken design: An alternative for the optimization of analytical methods. *Analytica Chimica Acta*, **597**(2), 179-186.

[4] Luo, D. 2012. Optimization of total polysaccharide extraction from Dioscorea nipponica Makino using response surface methodology and uniform design. *Carbohydrate Polymers*, **90**(1), 284-288.

[5] Marchetti, P., Butté, A., Livingston, A.G. 2013. Quality by Design for peptide nanofiltration: Fundamental understanding and process selection. *Chemical Engineering Science*, **101**, 200-212.

[6] Mohammed, A., Bissoon, R., Bajnath, E., Mohammed, K., Lee, T., Bissram, M., John, N., Jalsa, N.K., Lee, K.-Y., Ward, K. 2018. Multistage extraction and purification of waste Sargassum natans to produce sodium alginate: An optimization approach. *Carbohydrate Polymers*, **198**, 109-118.

[7] Ren, B., Chen, C., Li, C., Fu, X., You, L., Liu, R.H. 2017. Optimization of microwave-assisted extraction of Sargassum thunbergii polysaccharides and its antioxidant and hypoglycemic activities. *Carbohydrate Polymers*, **173**, 192-201.

[8] Smetacek, V., Zingone, A. 2013. Green and golden seaweed tides on the rise. *Nature*, **504**, 84.

[9] Torres, M.R., Sousa, A.P.A., Silva Filho, E.A.T., Melo, D.F., Feitosa, J.P.A., de Paula, R.C.M., Lima, M.G.S. 2007. Extraction and physicochemical characterization of Sargassum vulgare alginate from Brazil. *Carbohydrate Research*, **342**(14), 2067-2074.

MODELING A TURBULENT BUBBLY FLOW IN A HORIZONTAL PIPELINE

Elena Meretskaya[1] and Dmitry Eskin[1, 2*]
[1]Skolkovo Institute of Science and Technology, Russia
[2]Faculty of Engineering, The University of the West Indies, Trinidad
[1]Email: elena.meretskaia@skoltech.ru
[2]Email: Dmitry.Eskin@sta.uwi.edu*(Corresponding author)

Extended Abstract: Modelling gas-liquid flows represents a significant interest for different industrial applications. Such examples as transport of boiling water, a live oil, different two and three-phase chemical reactors could be mentioned in this respect. Corresponding flows are frequently need to be accurately modelled for process design and optimization. Most of research papers on bubbly flows in pipes are focused on vertical flows because they are expected to be simpler for simulations. However, in practice, horizontal pipelines are used even more frequently than vertical ones.

A bubbly flow that we consider in the present work is characterized by gas bubbles dispersed in a continuous liquid phase, whereas a bubble maximum size is much smaller than a pipe diameter. An accurate simulation of a bubbly flow requires modelling bubble size distribution that within the Eulerian-Eulerian approach, regularly used for multiphase flow modelling on industrial scales, requires solving a Population Balance Equation (PBE).

ANSYS Fluent commercial CFD code has been employed for computations. Although, this code allows simulating the problem formulated, a high accuracy cannot be achieved because models of separate phenomena, incorporated into the code, do not account peculiarities of breakup of gas bubbles rising under gravity. A bubble breakup model, recently developed by Eskin and Vikhansky [1], accounts for a reduction in the critical Weber number for a bubble rising in a turbulent flow. This breakup model associates a decrease of this number with a reduction in the minimum capillary pressure on the top of a bubble deformed due to rising. This model was incorporated into ANSYS Fluent through a User Defined Function (UDF). To a great extent, simulations of bubble dispersion in a horizontal flow, demonstrated in the present work, have been conducted for an additional validation of the bubble breakup model developed.

It is important to emphasize that experiments in a horizontal pipe for validation of a bubble breakup model are preferable over those in a vertical pipe. In a vertical flow, both size and concentration distributions significantly depend on a balance between the lift force and the bubble dispersion force caused by turbulence. An accuracy of lift force calculations is not high and strongly depends on a turbulence model. This problem can lead to an inaccurate computation of the entire droplet dispersion process. In the process model of model validation, corresponding deviations between computed and measured data could be wrongly attributed to a breakup model to be validated. In the horizontal pipe case, the major forces acting on a bubble are the buoyancy force, the gravity force, and the dispersion force caused by turbulence. These three forces to a great extend determine droplet concentration distribution across a pipe. An effect of the lift force on the force balance and, therefore, on bubble concentration distribution across a horizontal pipe is nearly negligible. Thus, validation of a bubble breakup model in a horizontal pipe is advantageous compared to that in a vertical pipe.

Our goal was as closely as possible reproducing experimental data, obtained by Kocamustafaogullari and Wang [2]. These researchers studied air-water bubbly flow in a transparent pipeline of 9 m long with internal diameter D=50.3 mm by a double-sensor resistivity probe. Mean liquid superficial velocities varied in the range from U_{sl}= 3.74 to 5.71 m/s, and the mean gas volume fraction - from ϕ =0.043 to 0.225. Both bubble sizes and concentrations were measured over the pipe outlet cross-section. It is worth to mention the work of Ekambara et al. [3], who earlier simulated these experimental data by the CFX commercial CFD code that is also an ANSYS product. These authors obtained a satisfactory agreement with the

experimental data by varying coefficients in front of both the lift and the turbulence dispersion forces, whereas maintaining the standard bubble breakup and coalescence models unchanged. Note also that they employed a standard key-epsilon turbulence model, characterized by a relatively low accuracy for pipe flows. For our computations, we employed a number of sub-models, normally used by different researchers for simulations of various bubbly flows. We selected rather accurate realizable key-epsilon model of turbulence. For calculation of the bubble drag force, the correlation of Ishii-Zuber [4] was used.

The lift force, resulting from an interaction of a bubble with the shear field, was calculated by the well-known equation of Tomiyama et al. [5]. The turbulent dispersion force was computed by the Lopez de Bertodano equation of turbulent dispersion [6].

The Fluent-based flow model, developed in the present work, contains the two non-standard elements. The major one, the bubble breakup model accounting for bubble rising under gravity, was incorporated into Fluent through UDF. Also, for coalescence modelling, we employed a simple model assuming a constant coalescence probability. Possibly, due to a rather narrow bubble size distribution, observed in the experiments, this model demonstrated better performance than relatively complex models intentionally developed for bubble coalescence.

Overall, our bubbly flow model demonstrated much better performance than the model of Ekambara et al. [3], based on standard sub-models; though, we did not introduce any tuning parameters. In Figure 1 one can see the mean Sauter bubble diameter distribution over the vertical coordinate at the pipe outlet cross-section for a flow with the gas volume fraction equal to ϕ=0.043. The superficial liquid velocity was U_{sl}=5.71 m/s and the superficial gas velocity U_{sg}=0.25 m/s respectively. The pattern of the experimental data points indicates a limited measurement accuracy of bubble sizes. However, a relatively good agreement of the calculated data with the experimental results can be clearly seen. The deviations of the computed data from the experimental results do not, probably, exceed the measurement errors.

In Fig.2 we showed both the experimental and computed gas volume fraction distributions along the vertical coordinate at the pipe outlet cross-section for the same experiment. The agreement is nearly excellent that confirms a proper choice of the sub-models composing the bubbly flow model developed.

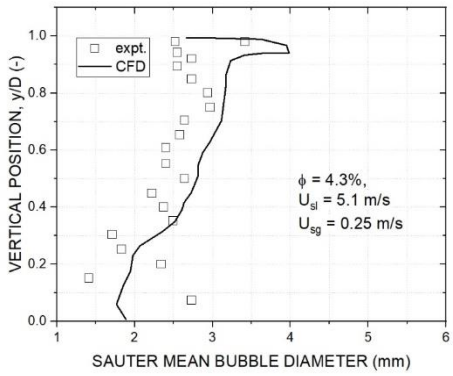


Figure 1: Sauter mean bubble diameter vs. vertical coordinate for the experimental and computed data

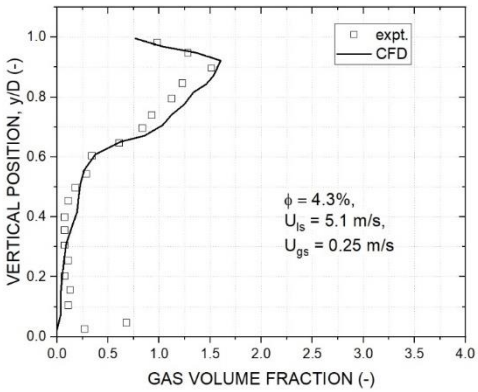


Figure 2. Gas volume fraction vs. vertical coordinate for the experimental and computed data

Thus, the computational code that we have developed on the basis of ANSYS Fluent software allows rather accurate computations of dispersed bubble flows. Calculations conducted for other flow conditions (different gas holdup and phase superficial velocities) also demonstrated high computational accuracy.

Keywords: *breakup, bubble, modelling, pipe, turbulence*

References

[1] Eskin, D., Vikhansky, A., 2019. Modeling Breakup of a Rising Bubble in a Turbulent Flow. In *10th International Conference on Multiphase Flow ICMF 2019*. Extended Abstract. Rio de Janeiro, Brazil.

[2] Kocamustafaogullari,G., Wang, Z., 1991. An experimental study on local interfacial parameters in a horizontal bubbly two-phase flow. *Int. J. Multiphase Flow* 5, 553—572.

[3] Ekambara, K., Sanders, R.S., Nandakumar, K., Masliyah, J.H, 2008. CFD simulation of bubbly two-phase flow in horizontal pipes. *Chemical Engineering Journal*, 144 (2), 277-288.

[4] Ishii, M., Zuber, N., 1979. Drag coefficient and relative velocity in bubbly, droplet or particulate flows. *AIChE J*. 25 (5), 843–855.

[5] Tomiyama, A., Tamai, H., Zun, I., Hosokawa, S., 2002. Transverse migration of single bubbles in simple shear flows. *Chemical Engineering Science* 57, 1849–185

[6] Lopez de Bertodano, M., Lahey Jr., R.T., Jones, O.C., 1994. Phase distribution in bubbly two-phase flow in vertical ducts. *Int. J. Multiphase Flow* 20, 805–818.

PROCESS OPTIMIZATION FOR THE PRODUCTION OF ACTIVATED CARBON USING WASTE COCONUT SHELL IN TRINIDAD & TOBAGO

Safiyyah Wahid[1*], Rean Maharaj[2], Donnie Boodlal[3], and Jeffrey Smith[4]
[1,2,3]Process Engineering Department, The University of Trinidad & Tobago
[4]Department of Chemical Engineering, University of the West Indies, St. Augustine, Trinidad
[1]Email: safiyyah.wahid@utt.edu.tt
[2]Email: rean.maharaj@utt.edu.tt
[3]Email: donnie.boodlal@utt.edu.tt
[4]Email: jeffrey.smith@sta.uwi.edu

Extended Abstract: One of the main negative impacts associated with the oil and gas industry in Trinidad & Tobago is the quality of the produced water generated as it usually contains the pollutant phenol in concentrations higher than the acceptable levels outlined by the United States Environmental Protection Agency and the Environmental Management Authority of Trinidad & Tobago. This presents environmental challenges regarding the re-use and disposal of the produced water. Globally, Activated Carbon Adsorption technology has been proven to be an effective method to significantly reduce the concentration of phenolic compounds [1,2] in produced water, however, its utilization in Trinidad & Tobago is limited as activated carbon has to be imported, is expensive and is hampered by the scarcity of USD foreign exchange within the local economy.

In an effort to develop an innovative and sustainable solution to these challenges, a preliminary investigation into the possibility of converting locally abundant waste coconut shells to a microporous type activated carbon was undertaken, and the findings were presented at the International Congress on Sustainability Science & Engineering '19 in Kuala Lumpur, Malaysia titled "The Kinetics & Thermodynamics of the Interaction between Phenol and Granular Activated Carbon prepared from Waste Coconut Shell" authored by the above mentioned.

Key steps in this investigation involved ascertaining conditions for the production of the activated carbon to remove at least 75% of the phenol from the produced water (activation time, temperature and CO_2 flow-rate), determining the adsorptive capacity of the product as well as the adsorption isotherm model which defined its behaviour, and evaluating the thermodynamics of adsorption. This information is critical to the design of a regenerative adsorption unit.

The activation conditions directly influence the type of porosity developed in the activated carbon. Previous studies showed that high activation temperatures (> 850°C) for short duration (< 30 mins) are favourable for the development of micropores [3-5].

An adsorption isotherm indicates how the quantities of the species are distributed between the liquid and solid phases when the adsorption process reaches equilibrium. It is used to establish the maximum capacity of the adsorbate on the adsorbent (mg/g).

Various isotherm models have been used successfully to describe adsorption in wastewater treatment applications and the interaction between phenol and activated carbon, however the Langmuir and Freundlich models have fitted phenol adsorption data the best according to previous studies [2,6-9].

(i) Langmuir Isotherm Model - Assumes that adsorption can only occur at a finite number of definite localized sites on homogeneous surfaces, the adsorption maximum corresponds to a single monolayer saturated with adsorbate molecules and the adsorption energy is constant [5,6,10].

The linear form of the Langmuir isotherm model is:

$$\frac{C_e}{q_e} = \frac{1}{q_m} C_e + \frac{1}{q_m K_L} \quad (1)$$

(ii) Freundlich Isotherm Model – Assumes that adsorption occurs in a heterogeneous surface through a multi-layer mechanism and the adsorbed amount increases with concentration. The linear form of this equation is:

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \quad (2)$$

"n" represents the energetic heterogeneity of the solid surface. "1/n" is a measure of the surface heterogeneity and ranges between 0 and 1. As its value approaches zero, the surface is more heterogeneous. When "n" values are higher than 1, this indicates favorable multilayer adsorption and adsorption is satisfactory when "n" ranges from 1 – 10 [6,8,10].

Results from this preliminary study showed that the maximum removal of phenol was approximately 67% at a minimum adsorbent dosage of 5.5 g, and this was achieved at activation conditions of 900°C for 10 mins at a CO_2 flow-rate of 120 mL/min.

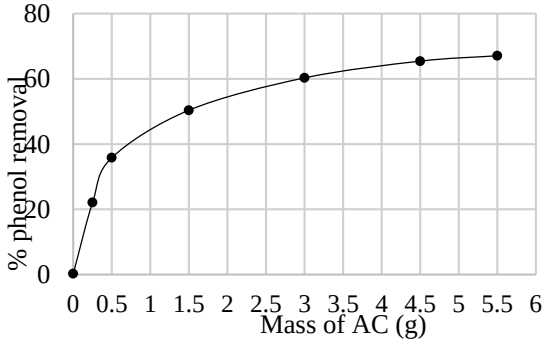


Figure 1: Relationship between mass of AC and the quantity of phenol removed; C_o = 2 mg/L, T = 25°C

It was found that the Freundlich isotherm model fitted the data the best at all temperatures studied. However, the adsorption capacity was low (0.24 mg phenol/g AC) as well as the equilibrium binding constant K_F (a maximum of 1.379), which indicated that the adsorption of phenol onto the activated carbon was poor. The results of this study indicate that the activated carbon can be successfully
prepared, and the utilization of this coconut shell activated carbon can alleviate Trinidad & Tobago's present disposal problems within the coconut industry.

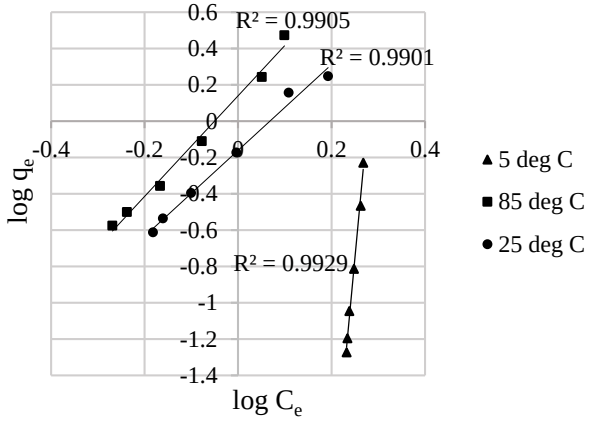


Figure 2: Fitting of the Freundlich isotherm model at various temperatures, C_o = 2 mg/L

It is the intent of this paper to optimize the activation conditions, specifically the activation temperature, time and CO_2 flow-rate in order to increase the adsorption capacity of the activated carbon. At 900°C and 10 mins activation time, the CO_2 flow-rate will be varied from 80 mL/min – 160 mL/min. Then each sample will be tested for phenol removal according to the "US EPA "Method 420.1: Phenolics" using a Hach DR5000 Spectrophotometer.
Adsorption isotherm modelling involving two and three parameter isotherm models at various temperatures would indicate how the product performs in terms of how favourable the adsorption is. The adsorption of phenol at temperatures of 5°C, 25°C and 85°C will be carried out by contacting 100 mL of a 2 mg/L (C_o) phenol solution with varied masses of adsorbent. The samples would then be placed in a water bath at the desired temperature for an equilibration time of 2 hours. Each sample would then be filtered, and the phenol concentration in each analyte (C_e) quantified as mentioned above.

Keywords: *activated carbon, coconut shell, phenol*

References

[1] Cordova Villegas, L. G., N. Mashhadi, M. Chen, D. Mukherjee, K. E. Taylor, and N. Biswas. 2016. "A Short Review of Techniques for Phenol Removal from Wastewater." Curr Pollution Rep 157-167.

[2] El-Naas, M. H., S. Al-Zuhair, and Manal Abu Alhaija. 2010. "Removal of phenol from refinery wastewater through adsorption on date-pit activated carbon." Chemical Engineering Journal 997-1005.

[3] McDougall, G. J. 1991. "The physical nature and manufacture of activated carbon." Journal of the South African Institute of Mining and Metallurgy 109-120

[4] Gonzalez, J. F., S. Roman, C. M. Gonzalez-Garcia, J. M. Valente Nabais, and A. L. Ortiz. 2009. "Porosity development in activated carbons prepared from walnut shells by carbon dioxide or steam activation." Industrial and Engineering Chemistry Research 7474-7481.

[5] Lorenc-Grabowska, E. 2016. "Effect of micropore size distribution on phenol adsorption on steam activated carbons." Adsorption 599-607.

[6] Fierro, V., V. Torne-Fernandez, D. Montane, and A. Celzard. 2008. "Adsorption of phenol onto activated carbons having different textural and surface properties." Microporous and Mesoporous Materials 111 276-284.

[7] Kennedy, L. J., J. J. Vijaya, K. Kayalvizhi, and G. Sekaran. 2007. "Adsorption of phenol from aqueous solutions using mesoporous carbon prepared by two-stage process." Chemical Engineering Journal 279-287.

[8] Aygun, A., S. Yenisoy-Karakas, and I. Duman. 2003. "Production of granular activated carbon from fruit stones and nutshells and evaluation of their physical, chemical and adsorption properties." Microporous and Mesoporous Materials 189-195.

[9] Salame, I. I., and T. J. Bandosz. 2003. "Role of surface chemistry in adsorption of phenol on activated carbons." Journal of Colloid and Interface Science 307-312.

[10] Hamdaoui, O., and E. Naffrechoux. 2007. "Modelling of adsorption isotherms of phenols and chlorophenols onto granular activated carbon Part I: Two-parameter models and equations allowing determination of thermodynamic parameters." Journal of Hazardous Materials 381-394.

THE SUSTAINABLE IMPACT OF AGGRESSIVE DRIVING IN COLLEGE-AGED DRIVERS

Turuna S. Seecharan
Department of Mechanical and Industrial Engineering, University of Minnesota Duluth, Duluth, MN, USA
Email: tseechar@d.umn.edu

Extended Abstract: The use of a personal vehicle has become a staple in modern society. Road transport is of crucial importance for individual mobility, commerce and for economic growth of all nations but has several major negative consequences. In particular, it is responsible for crash-related fatalities and injuries, and to harmful emissions and the use of non-renewable energy. Human behaviour is, directly or indirectly, an important determinant of these negative consequences. Aggressive driving, in addition to being the major cause of traffic accidents also negatively impact fuel consumption. Most drivers are aware of these negative impacts but still engage in aggressive driving habits. This study presents some preliminary findings from on-road driving data from a small sample of 18-24-year-old drivers with the goal of developing a fuel-efficient driving training program.

The benefits of motor vehicle transportation in the economic and social life of Minnesotans are irrefutable. However, disadvantages exist in terms of environmental impact, road traffic injuries, and fatalities [1]. Transportation is the largest source of Greenhouse Gas (GHG) emissions in Minnesota. In the transportation sector, emissions include on-road vehicles, airplanes and other aviation equipment, trains, leaky vehicle air conditioning units and natural gas transmission pipelines. Among these, more than 70% of emissions from the transportation sector come from light duty trucks, passenger vehicles and medium to heavy-duty trucks. Although federal regulations have resulted in newer vehicle models that are generally more fuel-efficient and therefore produce fewer GHG emissions than older, similar vehicles, Minnesotans are choosing to drive larger, less-efficient and more-polluting vehicles instead of smaller, more-efficient cars [2].

In addition to engineering or technological advancements, behavioural approaches such as choosing eco-friendly vehicles, proper vehicle maintenance or eco-drive techniques help reduce personal consumption [3]. Eco-drive training programs are typically geared toward older fleet drivers that often do not maintain long-term eco-friendly habits [4, 5, 6]. In Minnesota, 18-24-year-old drivers are the most represented in fatal crash statistics and form the demographic with the highest poverty rate [7]. This work hypothesizes that in order to encourage long-term behavioural changes in driving or commuting habits, young drivers should be the demographic of interest.

Although drivers are generally aware of the effects of vehicle type and road type on fuel economy, the U.S. Department of Transportation National Highway Traffic Safety Administration (NHTSA) claims that drivers do not have a clear understanding of how driving behaviour influences fuel economy [7]. Maintaining a constant, moderate speed and avoiding aggressive manoeuvres such as rapid acceleration and rapid deceleration improves fuel economy. Studies that offer eco-drive training for fleet drivers see a reduction in fuel economy using fuel-efficient driving habits; however, drivers often do not maintain long-term habits [9]. The research question is although drivers are generally aware of the negative impact of these aggressive manoeuvres it is unclear why they continue using these manoeuvres and what is required to encourage fuel-efficient driving behaviour.

Traditionally, road user behaviour research uses driving simulators, instrumented vehicles, self-reports, analyses of crash statistics and, increasingly, in-depth crash investigation. These methods have greatly contributed to the understanding of road user behaviour. However, they also have several limitations. Results from simple, static-based driving simulator studies cannot always be easily transferred to real traffic situation, since both the traffic environment and the vehicle characteristics are only approximations of

reality [1]. In instrumented vehicle studies, subjects drive in real traffic but in a special, highly equipped vehicle with an experimenter on-board. On-road driving studies where real-time data is collected while driving offers wider perspectives in understanding normal traffic behaviour. Although participants are aware of the presence of data logging equipment in their vehicle, the equipment is small and out of the viewing area of the driver, so drivers revert to their normal driving manoeuvres. Recent studies advocate using on-road data to understand driving in realistic conditions; however, no studies focus on understanding why drivers do not continuously adopt fuel-efficient methods like alternative fuel vehicles, eco-driving or alternative forms of commuting.
This research investigates the driving behaviour of 18 to 24 year olds, in Duluth MN, to ascertain how they drive and develop ways to encourage them to drive less aggressively.

Results

The driving behaviour of 8 study participants was collected, over 8 weeks, using GPS loggers installed in their car's computer accessing data such as speed, fuel consumption, hard acceleration and hard braking. Understanding this can help future research develop a driver training program to encourage eco-driving habits in young drivers. A total of 630 trips were recorded. Among these, 507 trips (80.4%) were less than 10 miles in length and 378 trips (60%) were less than 5 miles in length. For this work, analytics will focus on trips less than 10 miles in length. Figures 1 to 5 show the performance of all drivers in terms of fuel consumption, hard acceleration and hard braking. From Figure 1, the best fuel consumption was obtained from both the Nissan Juke and Subaru with the worse performing vehicle as the F150. This should make sense since the F150 is a pickup truck and naturally burns more fuel than a small car.

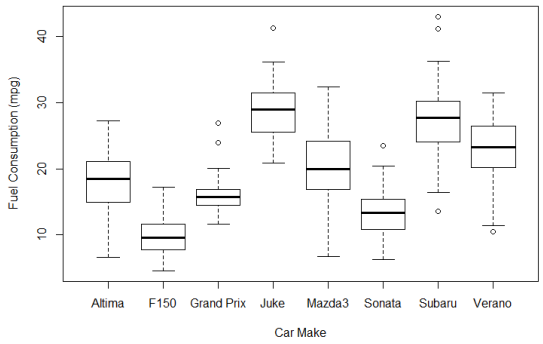


Figure 1: Fuel Consumption of all Vehicles

In eco-driving literature, hard acceleration and hard braking are of particular importance due to its negative correlation with fuel consumption. The summary data from the data loggers contained hard acceleration and hard braking indicators calculated by FleetCarma and will be used for this paper. Future research will dig further into these thresholds.
From Figures 2 and 3, the Juke generally had the highest percentage of hard acceleration and hard braking. In terms of hard acceleration, the Juke and Altima had similar hard acceleration percentages while the F150 and Grand Prix had significantly smaller percentages of hard acceleration events. With respect to hard braking, the Grand Prix, again, had one of the lowest hard braking percentages along with the Subaru. The Juke had the highest percentage hard braking events.

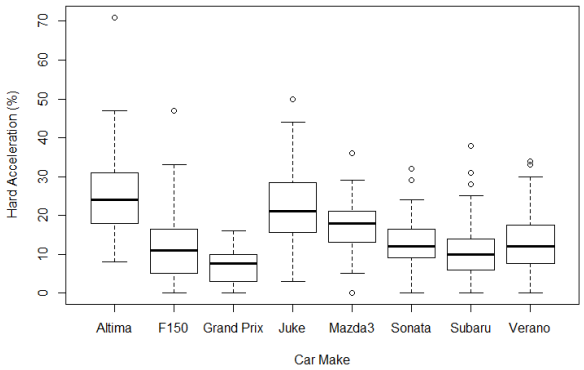


Figure 2: Percentage of Hard Acceleration for Each Vehicle

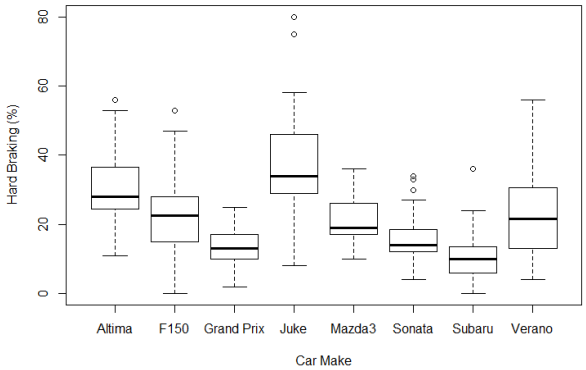


Figure 3: Percentage Hard Braking of Each Vehicle

On looking at all vehicles together for an aggregate analysis (Figures 4 and 5), the majority of percentage hard acceleration was less than 20% meaning that most trips contained hard acceleration events in the range of 0 to 20% of the trip. For hard braking, a right-skewed distribution is also observed with the majority of hard braking percentages between 0 and 30%.

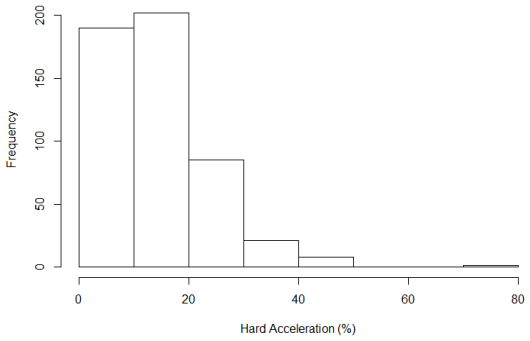


Figure 4: Distribution of Hard Acceleration for All Vehicles

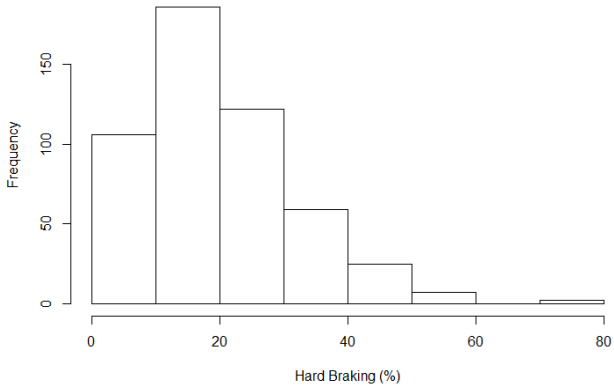


Figure 5: Distribution of Hard Braking for All Vehicles

Conclusion

These preliminary findings indicate that 18-24-year-old drivers focus their commuting within the Duluth city limits as observed by the trip distances. Approximately 80% of trips are 10 miles and under. Hard acceleration and hard braking events are observed in this sample of drivers. The goal of an eco-drive training programme would be to attempt to reduce these numbers. The next steps of this work will combine questionnaire results and on-road driving to correlate self-reported environmental concern with actual behaviour. Within the study period, drivers will get a summary of their report in a manner similar to that presented in this paper to show how they compare with other drivers. It is hoped that gamification will be used to encourage young drivers to adopt less aggressive driving habits through friendly competition and their individual impact toward the environment.

Keywords: *Aggressive Driving, Eco-Driving, Young Drivers, Driver Behaviour, Duluth*

References

[1] Y. Barnard, F. Utesch, N. van Nes, R. Eenink, M. Baumann. 2016. The study design of UDRIVE: the naturalistic driving study across Europe for cars, trucks and scooters. European Transportation Research Review, Vol. 8 (14).

[2] A. Claflin, F. Steinward. 2019. *Greenhouse gas emissions in Minnesota: 1990-2016*. Saint Paul: Minnesota Pollution Control Agency.

[3] U.S. Department of Energy. (2019, May 23). "Driving more efficiently". 2019 May 23. [Online]. Available: https://www.fueleconomy.gov/feg/driveHabits.jsp

[4] T. S. Seecharan, B. Donmez, H. W. Chen and A. K. S. Jardine, "Simulator-Based Eco-Drive Training for Fleet Drivers", *Proceedings of the 10th World Congress on Engineering Asset Management*, Koskinen K. et al. (eds), March 2016, pp. 545-552.

[5] A. E. af Wahlberg, "Long-term effects of training in economical driving", Int. J. of Industrial Ergonomics, vol. 37, no. 4, pp. 333-343, Apr. 2007.

[6] M. Zarkadoula, G. Zoidis and E. Tritopoulou, "Training urban bus drivers to promote smart driving: A note on a Greek eco-driving pilot program", Transportation Research Part D: Transport and Environment, vol. 12, no. 6, pp. 449-451, Aug. 2007.

[7] Data USA, "Duluth, MN". Accessed: May 7th 2019. [Online]. Available : https://datausa.io/profile/geo/duluth-mn

[8] U.S. Department of Transportation National Highway Traffic Safety Administration. 2009. Fuel Economy Driver Interfaces: Design Range and Driver Opinions. Virginia: DOT NHTSA.

[9] B. Beusen, S. Broekx, T. Denys, C. Beckx, B. Degraeuwe, et. Al. 2009. Using on-board logging devices to study the longer-term impact of an eco-driving course. *Transportation Research Part D: Transport and Environment* (pp. 514-520).

ACOUSTIC BLACK HOLE AS A STRUCTURAL DESIGN APPROACH TO VIBRATION AND NOISE CONTROL

M.G.Prasad[1], and Chenhui Zhao[2]
[1,2]Department of Mechanical Engineering, Stevens Institute of Technology, USA
[1,2]Email: czhao1@stevens.edu

Extended Abstract: Vibration and noise control of mechanical structures plays an important role in the design of many industrial systems. With the development of high-speed machinery, the control of unwanted vibration and noise becomes important for stability and reliability of a mechanical system as well as environmental noise impact. The two well-known methods for passive control of structural vibrations, which also results in a reduction of noise are constrained layer damping and tuned dynamic absorber. The first method is based on using a viscoelastic layer attached to the structure and the second method needs an attachment of additional weight to the target structure. Additionally, the active vibration control devices are also used for vibration damping. However, these active methods require consistent input energy and more complex electro-mechanical design. So for the reasons of limitation of size, budget or weight, sometimes it is not possible and also is not desirable to use these above methods. There has been an effort in the literature to look for an additional effective passive approach for the control of vibrations.

High noise levels can result in psychological and physiological discomfort. Vibrating structures is one of the primary sound sources. Engineers make their effort to develop various methods to control the sound radiation from vibration structures, thereby reducing the noise. Exhaust noise from automotive engines is another major source of noise pollution in the environment. Therefore, mufflers are widely used for reducing the noise emitted by the exhaust of an internal combustion engine. Simple Expansion Chamber (SEC) is a well-known design of a muffler. However, in the Transmission Loss (TL) curve of a simple expansion chamber muffler, at frequencies corresponding to half wavelength resonances, the TL goes to zero. So, the elimination of half wavelength resonances without adding further duct elements in the chamber is desirable. Double expansion chamber (DEC) muffler is another commonly used element in duct noise reduction. By increasing the diameter of one of the chambers, the half wavelength resonances can be eliminated, and the noise reduction can be improved. However, it increases the size of the muffler, which sometimes is impractical due to the space arrangement.

In recent times micro-devices such as portable electronics and wireless remote sensors have been developed and widely used. Most of these low-power electronics are powered by battery. However, even for the long-lasting batteries, they still need to be replaced because of limited life cycle. For some applications, such as sensors deployed in remote locations or inside the human body, it is challenging and costly, or even impractical. Energy harvesting is the process of capture and conversion of ambient energy in the environment into usable electrical energy to extend the life of batteries, which make the devices self-sustainable and environmental-friendly. Piezoelectric vibration energy harvesting (PVEH) is one of the typical energy harvesting methods. In the design of portable micro devices, the challenge is to reduce the weight and size of the host structure. So, approaches to increase the energy harvested from the vibrations of the host structures are desirable.

Recently an approach for passive vibration control, Acoustic Black Holes (ABH), was developed. An ABH is usually a power-law tapered profile built on beams and plates, where the vibration energy is concentrated due to the reduction of wave speed. Therefore, due to the concentration effect of ABH, by attaching a small amount of damping material at the ABH location, it can absorb vibration energy, resulting in reduced sound radiation. Also, the performance of energy harvesting is enhanced by attaching a piezoelectric material at

the ABH location. Because it is a tailing method, it decreases the weight of host structures and hence it is a good option for light weight structures. Therefore, the use of ABH in structural design is effective in controlling vibration and noise control. ABH has also shown a good promise in vibration energy harvesting. It is seen that the acoustic black holes have a great potential for quiet design of complex structures. In addition, the influences of the various geometrical parameters and the configuration of acoustic black holes has been studied. The studies indicate that with proper geometric design, ABH approach is an effective method for vibration and noise control. Also, Mironov and Polyakov developed a theoretical analysis of ABH termination in ducts and found that ABH termination has a high reflection coefficient at lower frequencies. Based on this theory, the simple expansion chamber and double expansion chamber designs were modified using an ABH profile. The TL curves evaluated for the modified SEC mufflers show that the half-wavelength resonances were eliminated. This results in considerable TL at the frequencies where TL was zero earlier without modification. Also, the modified SEC muffler is about one-half of the volume of the original design. The numerical results for modified DEC muffler show that higher TL is obtained without increasing the size of the chambers. This study provides the potential for application of ABH in muffler design.

In this paper, a review of basic theoretical, numerical and experimental studies on vibration damping, sound reduction and vibration energy harvesting in structural design with ABH were presented.

Keywords: *Acoustic Black Holes, Structural Design, Vibration and Noise Control, Vibration Energy Harvesting, Muffler Design.*

References

[1] C. Zhao and M.G. Prasad. 2019. Acoustic Black Holes in Structural Design for Vibration and Noise Control. *Acoustics 2019,* 1, 220-251.

[2] C. Zhao and M.G. Prasad. 2019 Studies on a Modified Simple Expansion Chamber Muffler using Acoustic Black Hole, *Noise-Con 2019,* San Diego, CA.

[3] C. Zhao and M.G. Prasad, 2016. Studies on sound radiation from Beam with Acoustic Black Hole", NoiseCon 2016, Providence, RI.

[4] H. Ji, W.Huang, J. Qiu, L.Cheng. 2017. Mechanics problems in application of acoustic black hole stru ctures. Advances in Mechanics, 47.

[5] E.P.Bowyer, D.J. O'Boy, V.V.Krylov, and F. Gautier. 2010. Experimental investigation of damping flexural vibrations using two-dimensional acoustic 'black holes'. *Proceedings of the International Conference on Noise and Vibration Engineering (ISMA 2010),* Leuven, Belgium, 20-22 September

[6] E.P. Bowyer, D.J. O'Boy, V.V. Krylov and F. Gautier. 2013. Experimental investigation of damping flexural vibrations in plates containing tapered indentations of power-law profile, *Applied Acoustics*, 74(4), 553-560.

[7] E.P. Bowyer and V.V. Krylov. 2014. Damping of flexural vibrations in turbofan blades using the acoustic black hole effect, *Applied Acoustics*, 76, 359–365.

[8] H.Ji, Y. Liang, J. Qiu, L. Cheng, and Y.Wu. 2019. Enhancement of vibration based energy harvesting using compound acoustic black holes. *Mechanical Systems and Signal Processing*. Vol 132, 441-456

[9] P.A. Feurtado, S.C. Conlon and F. Semperlotti. 2014. A normalized wave number variation parameter for acoustic black hole design, *Journal of the Acoustical Society of America*,136(2),148-152.

[10] L. Zhao, S.C. Conlon and F. Semperlotti. 2014. Broadband energy harvesting using acoustic black hole structural tailoring. *Smart Materials and Structures,* Vol. 23 065021.

COMBINED EFFECTS OF INCLINED MAGNETIC FIELD AND NAVIER SLIP ON FREE CONVECTIVE AND RADIATIVE FLOW OF CNT-WATER NANOFLUIDS: A LIE GROUP ANALYSIS

P. Sreenivasulu[1*], S.R. Gunakala[2], T. Poornima[3], N. Bhaskar Reddy[4], V.M. Job[5]

[1]Department of Mathematics, Sri Venkateswara Engineering College for Women, India
[2,5]Department of Mathematics and Statistics, The University of the West Indies, Trinidad
[3]Department of Mathematics, VIT University, India
[4]Department of Mathematics, SV University, India
[1]Email: psreddysvu11@gmail.com *(Corresponding author)
[2]Email: Sreedhara.Rao@sta.uwi.edu
[3]Email: poornima.t@vit.ac.in
[4]Email: nbrsvu@gmail.com
[5]Email: Victor.Job@sta.uwi.edu

Extended Abstract: In this paper, the steady two-dimensional boundary layer flow of a nanofluid past a vertical stretching sheet with inclined magnetic field was considered. The flow is considered along the $\overline{x}$-axis, which is taken along the vertical stretching surface in the upward direction, and the $\overline{y}$-axis is taken to be perpendicular to the sheet as shown in Fig. 1. The surface of the plane is maintained at a constant temperature T_w, which is higher than the constant temperature T_∞ of the ambient nanofluid. A water-based nanofluid containing two kinds of nanotubes was considered; namely, the single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs). The nanofluid flow is assumed to be incompressible and laminar.

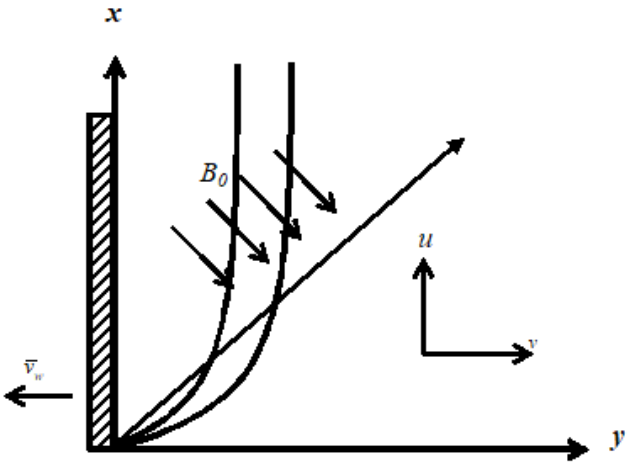


Figure 1: Physical model and coordinate system

Under the assumptions of the boundary layer, Boussinesq and Rosseland approximations, the governing equations of the problem can be written in dimensional form as follows:

$$\frac{\partial \overline{u}}{\partial \overline{x}} + \frac{\partial \overline{v}}{\partial \overline{y}} = 0 \qquad (1)$$

$$\overline{u}\frac{\partial \overline{u}}{\partial \overline{x}}+\overline{v}\frac{\partial \overline{u}}{\partial \overline{y}}=\frac{1}{\rho_{nf}}\left[\mu_{nf}\frac{\partial^2 \overline{u}}{\partial \overline{y}^2}+(\rho\beta)_{nf}g\left(\overline{T}-T_\infty\right)-\sigma B_0^2\overline{u}\sin^2\xi\right] \tag{2}$$

$$\overline{u}\frac{\partial \overline{T}}{\partial \overline{x}}+\overline{v}\frac{\partial \overline{T}}{\partial \overline{y}}=\alpha_{nf}\left(1+\frac{4}{3}R\right)\frac{\partial^2 \overline{T}}{\partial \overline{y}^2}+\frac{Q_0}{\left(\rho C_p\right)_{nf}}\left(\overline{T}-T_\infty\right) \tag{3}$$

where $\overline{u}$ and $\overline{v}$ are velocity components in the $\overline{x}$ and $\overline{y}$ directions, $\overline{T}$ is the local temperature of the nanofluid, g is the acceleration due to gravity, σ is the electrical conductivity, B_0 is the uniform magnetic field strength, ρ_{nf} is the effective density of the nanofluid, μ_{nf} is the effective dynamic viscosity of the nanofluid, ξ is the magnetic field inclination angle, $\alpha_{nf}=\kappa_{nf}/\left(\rho C_p\right)_{nf}$ is the thermal diffusivity of the nanofluid, σ^* is the Stefan-Boltzmann constant, k^* is the mean absorption coefficient, $R=16\sigma^*T_\infty^3/3k_fk^*$ is the radiation parameter and Q_0 is the volumetric rate of heat generation.
The boundary conditions of these equations are

$$\begin{gathered}\overline{u}=\overline{u}_w(\overline{x})+N\frac{\partial \overline{u}}{\partial \overline{y}},\ \overline{v}=\overline{v}_w,\ \overline{T}=T_w \text{ at } \overline{y}=0\\ \overline{u}\to 0,\ \overline{T}\to T_\infty \text{ as } \overline{y}\to\infty\end{gathered} \tag{4}$$

where $\overline{u}_w(\overline{x})=\dfrac{\nu_f Gr^{1/2}}{L^2}\overline{x}$ is the stretching velocity.

The thermophysical properties of CNT nanofluids are described using the following analytical models.

1. Viscosity:

$$\mu_{nf}=\frac{\mu_f}{(1-\phi)^{2.5}} \tag{5}$$

2. Density:

$$\rho_{nf}=(1-\phi)\rho_f+\phi\rho_{CNT} \tag{6}$$

3. Heat Capacity:

$$\left(\rho C_p\right)_{nf}=(1-\phi)\left(\rho C_p\right)_f+\phi\left(\rho C_p\right)_{CNT} \tag{7}$$

4. Thermal Expansion Coefficient:

$$(\rho\beta)_{nf}=(1-\phi)(\rho\beta)_f+\phi(\rho\beta)_{CNT} \tag{8}$$

5. Thermal Conductivity [1]:

$$\kappa_{nf}=\kappa_f\frac{1-\phi+2\phi\dfrac{\kappa_{CNT}}{\kappa_{CNT}-\kappa_f}\ln\dfrac{\kappa_{CNT}+\kappa_f}{2\kappa_f}}{1-\phi+2\phi\dfrac{\kappa_f}{\kappa_{CNT}-\kappa_f}\ln\dfrac{\kappa_{CNT}+\kappa_f}{2\kappa_f}} \tag{9}$$

In equations (5) to (9), ϕ is the solid volume fraction of nanotubes. The subscripts *nf*, *f* and *CNT* represent the thermophysical properties of the nanofluids, base fluid and solid nanoparticles respectively. The corresponding thermophysical properties for the CNT nanoparticles and base fluid (water) are given in Table 1.

Table 1. Thermal properties of base fluid and nanoparticles [2-4]

Physical properties	Base fluid	Nanoparticles	
	Water	SWCNT	MWCNT
ρ (kg/m^3)	997	2600	1600
C_p (J/kg K)	4179	425	796
k (W/m K)	0.613	6600	3000
β x 10^{-5}(K^{-1})	21	0.33	0.72

We introduce the following non-dimensional variables:

$$x = \frac{\overline{x}}{L}, y = Gr^{1/4}\frac{\overline{y}}{L}, u = Gr^{-1/2}\frac{L\rho_f}{\mu_f}\overline{u}, v = Gr^{-1/4}\frac{L\rho_f}{\mu_f}\overline{v}, T = \frac{\overline{T}-T_\infty}{T_w-T_\infty}. \tag{10}$$

and introduce the stream function ψ, which is defined by $u = \partial\psi/\partial y$ and $v = -\partial\psi/\partial x$.

Furthermore, we introduce the scaling Lie-group Γ of transformations defined by [5,6]:

$$\Gamma: \quad x^* = xe^{\varepsilon\alpha_1}, \qquad y^* = ye^{\varepsilon\alpha_2}, \quad \psi^* = \psi e^{\varepsilon\alpha_3}, \qquad T^* = Te^{\varepsilon j\alpha_4} \tag{11}$$

Since the governing equations are Γ-invariant, we have the following similarity transformations

$$\eta = y^*, \quad \psi^* = x^* f(\eta), \quad T^* = x^*\theta(\eta). \tag{12}$$

Using (12), we obtain the following non-dimensionalized ordinary differential equations

$$f''' + (1-\phi)^{2.5}\begin{Bmatrix}[1-\phi+\phi(\rho_{CNT}/\rho_f)][ff''-(f')^2] \\ +Gr\left[1-\phi+\phi(\rho\beta)_{CNT}/(\rho\beta)_f\right]\theta - Mf'\sin^2\xi\end{Bmatrix} = 0 \tag{13}$$

$$\frac{4R+3}{3Pr}\frac{\kappa_{nf}}{\kappa_f}\theta'' + \lambda\theta + \frac{(1-\phi)(\rho C_p)_f + \phi(\rho C_p)_{CNT}}{(\rho C_p)_f}[f\theta' - f'\theta] = 0 \tag{14}$$

with boundary conditions

$$f'(0) = 1 + \gamma f''(0), \; f(0) = S, \; \theta(0) = 1$$
$$f' \to 0, \; \theta \to 0 \text{ as } \eta \to \infty \tag{15}$$

where $S = -\frac{\rho_f L\overline{v}_w}{\mu_f Gr^{1/4}}$ is a suction/injection parameter, $Gr = \rho_f^2 g(\rho\beta)_f(T_w - T_\infty)L^3/\mu_f^2$ is the Grashof number, $Pr = \mu_f/(\rho_f\alpha_f)$is the Prandtl number, $M = \sigma B_0^2 L^2/(\mu_f Gr^{1/2})$ is the magnetic parameter and $\gamma = \frac{Gr^{1/4}N}{L}$ is the slip parameter. The skin friction coefficient C_f and the Nusselt number Nu_x are defined as

$$C_f = \frac{\mu_{nf}}{\rho_f u_w^2}\left(\frac{\partial\overline{u}}{\partial\overline{y}}\right)_{\overline{y}=0}, \quad Nu_x = \frac{\overline{x}\kappa_{nf}}{\kappa_f(T_w-T_\infty)}\left(-\frac{\partial\overline{T}}{\partial\overline{y}}\right)_{\overline{y}=0} \tag{16}$$

Using the equations (9), (12) and (15), the coefficient of skin friction and local Nusselt number are described as

$$Re_x^{1/2}C_f = \frac{1}{(1-\phi)^{2.5}}f''(0), \quad Re_x^{1/2}Nu_x = -\frac{\kappa_{nf}}{\kappa_f}\theta'(0) \tag{17}$$

where $Re_x = \rho_f\overline{u}_w(\overline{x})\overline{x}/\mu_f$ is the local Reynolds number.

The coupled nonlinear governing boundary layer equations (13) and (14) with boundary conditions (15) are solved numerically by utilizing the fourth-order Runge-Kutta technique along with the shooting method. Firstly, these higher-order non-linear equations are converted into simultaneous linear differential equations

of first order, and then transformed into an initial-value problem by applying the shooting method. The resulting initial-value problem is solved by employing the fourth-order Runge-Kutta technique. A

representative set of numerical results is presented graphically in Figs. 2 to 5. We found an incredible agreement with the current literature for some reduced cases; such as the work of Kalidas [7], Swahi Mukopadyay [8] and Reddy et al. [9].

Table 2: Comparison results for $f''(0)$ and $\theta'(0)$ some reduced cases.

Gr	$f''(0)$		$\theta'(0)$	
	Kalidas [7]	Present Result	Kalidas [7]	Present Result
0	–1.001423	–1.0014211	–2.321917	– 2. 3219232
1	–0.762983	–0.7629796	–2.384484	– 2. 3844349

Table 3: Values of Nusselt number for different values of Prandtl number in some reduced cases.

Pr	Swahi Mukopadyay [8]	NB Reddy et al.[9]	Present Study
1	0.9547	0.95485	0.954217
2	1.4714	1.47144	1.471489
3	1.8691	1.86906	1.869261
5	2.5001	2.50012	2.500285
10	3.6603	3.66037	3.660412

The influence of nanoparticle volume fraction on velocity and temperature are shown in Figs. 2 and 3 respectively. The velocity of the fluid increases for increasing values of nanoparticle volume fraction ϕ due to enhancements in the boundary layer thickness. Also it is evident that both the velocity and boundary layer thickness are greater in the case of MWCNT when compared to SWCNT. The temperature of the fluid increases for increasing values of nanoparticle volume fraction due to the increase in the thermal boundary layer thickness. For both SWCNT and MWCNT cases, the existence of carbon nanotubes increases the thermal conductivity, which leads to an increase of the thickness of the thermal boundary layer. Additionally, the temperature is higher for SWCNT in comparison to MWCNT.
The influence of various governing physical parameters on the surface skin friction and rate of heat transfer is shown in Figs. 4 and 5. Fig.4 shows that the surface skin friction rate decreases with an increase in volume fraction of carbon nanotubes. Also it is evident that the surface skin friction increases for higher values of inclined magnetic field angle, and the MWCNT have higher values than SWCNT. Fig. 5shows , that the rate of heat transfer decreases with an increase in volume fraction. Also it is evident that the rate of heat transfer decreases for increasing values of the radiation parameter, and SWCNT dominates the MWCNT.

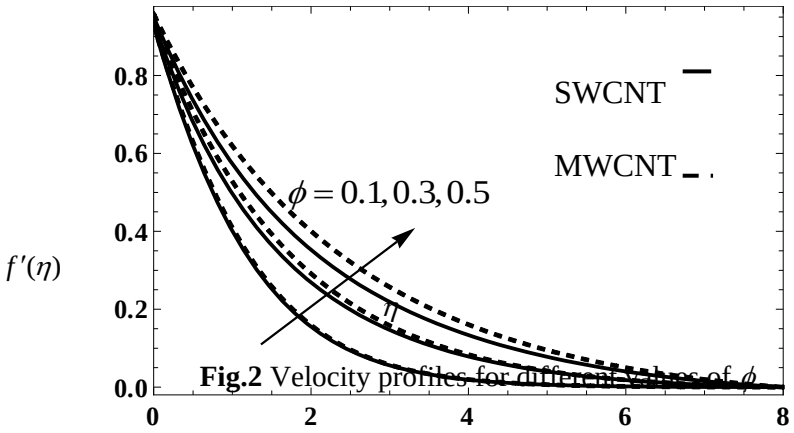


Fig.2 Velocity profiles for different values of ϕ

Figure 2 Velocity profiles for different values of ϕ

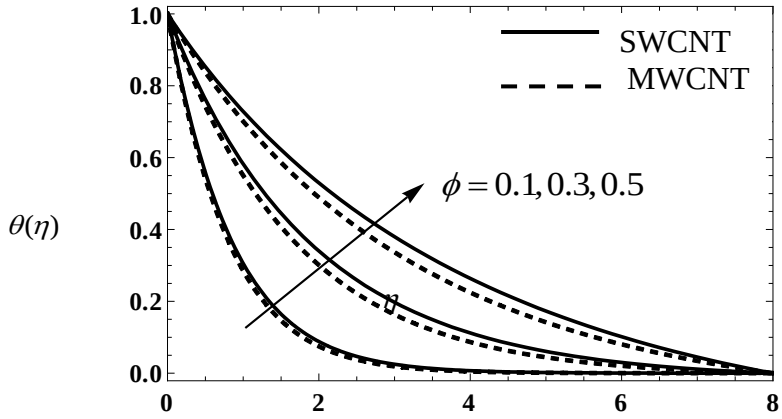


Figure 3 Temperature profiles for different values of ϕ

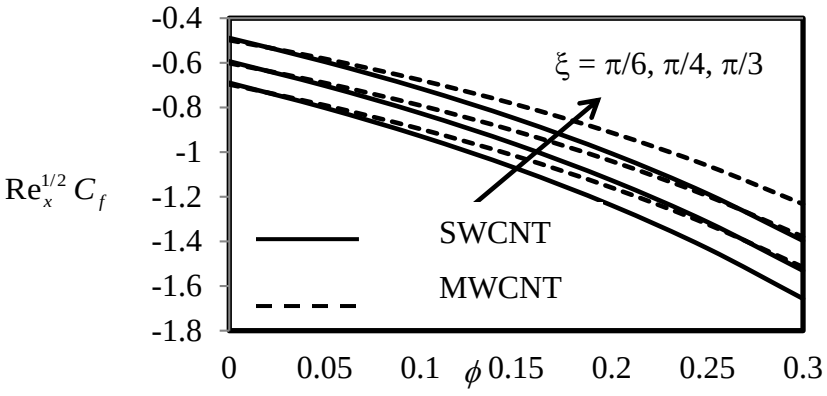


Figure 4 Surface skin friction verses volume fraction for different values of ξ

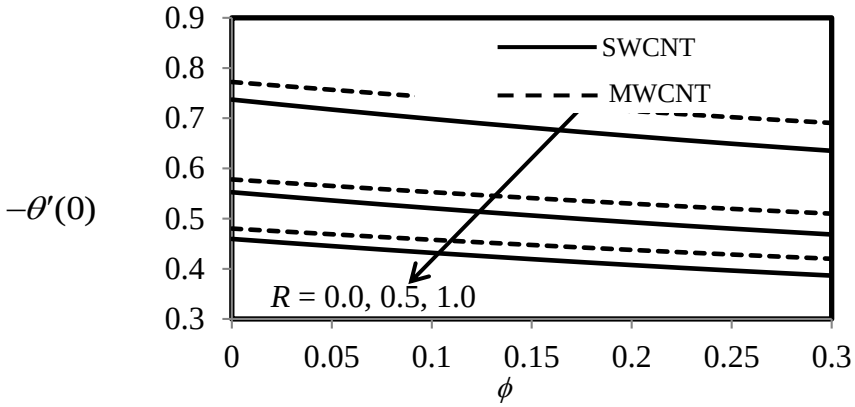


Fig. 5 Heat transfer rate verses volume fraction for different values of R

Keywords: *Carbon nanotubes, Heat Transfer, inclined magnetic field, Lie-group analysis, Navier slip.*

References

[1] Q.Z. Xue. Model for thermal conductivity of carbon nanotube-based composites. Physica B 368, (2005) 302–307.

[2] S. Nadeem, R.U. Haq, Z.H. Khan. Numerical study of MHD boundary layer flow of a Maxwell fluid past a stretching sheet in the presence of nanoparticles. Journal of the Taiwan Institute of Chemical Engineers 45 no. 1, (2014) 121-126.

[3] A. Waqar, I. Khan, I.R. Culham, R.U. Haq. Heat transfer analysis of MHD water functionalized carbon nanotube flow over a static/moving wedge. J. Nanomater 2015, (2015) 934367.

[4] R. Kandaswamy, I. Muhaimin, R. Mohammad. Single wall carbon nanotubes on MHD unsteady flow over a porous wedge with thermal radiation with variable stream conditions. Alexandria Engineering Journal 55, (2016) 275-285.

[5] T. Tapanidis, G. Tsagas, H.P. Mazumdar. Application of scaling group of transformations to visco-elastic second-grade fluid flow. Nonlinear Funct. Anal. Appl. 8 no. 3, (2003) 345-350.

[6] S. Mukhopadhyay, G.C. Layek, S.A. Samad. Study of MHD Boundary Layer Flow over a Heated Stretching Sheet with Variable Viscosity. International Journal of Heat and Mass Transfer 48 no. 21-22, (2005) 4460-4466.

[7] D. Kalidas. Slip flow and convective heat transfer of nanofluids over a permeable stretching surface. Computers and Fluids 64, (2012) 34-42.

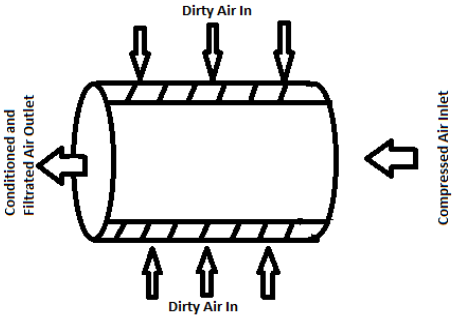
[8] S. Mukhopadhyay. Slip effects on MHD boundary layer flow over an exponential stretching sheet with suction/blowing and thermal radiation. Ain Shams Engineering Journal 4, (2013) 485–491.

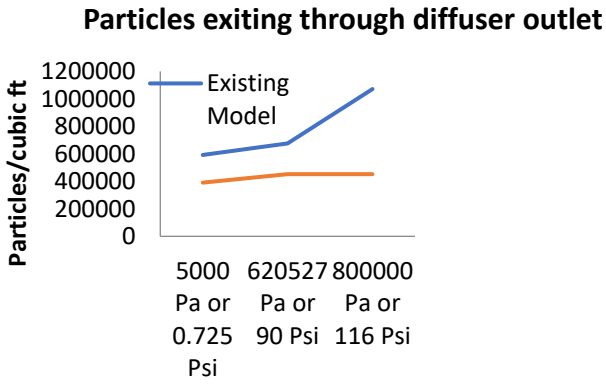
[9] N. B. Reddy, T. Poornima, and P. Sreenivasulu. Radiative heat transfer effect on MHD slip flow of Dissipating Nanofluid past an exponential stretching porous sheet. International Journal of Pure and Applied Mathematics 109 no. 9, (2016) 134–142.

OPTIMUM DESIGN FOR CARTRIDGE FILTER CLEANING SYSTEMS

Aneesha Gogineni[1] and T.S. Ravigururajan2*
[1]Faculty of Engineering, Saginaw Valley State University, Saginaw Valley, MI
[2] Department of Mechanical Engineering, Wichita State University, Wichita, KS 67260
[1]Email: agoginen@SVSU.edu
[2]Email: ts.ravi@wichita.edu *(Corresponding author)

Extended Abstract: Around 99% of the dirt particles can be filtered by Ultra-high efficient industrial air filters[1]. But, keeping the cost-effectiveness and environmental impact in focus, an optimum filtration limit is often used. In this study, two models were used i.e. 'Proposed Model' and 'Existing Model'. Everything except the compressed air inlet process is similar in these two models. Both of the models use 80% efficient air filtration unit where filtration holes are about 0.3µ to 10 µ diameter. Inside the diffuser, 250 cubic feet of air enter per minute. In this experiment the goal was to calculate the number of particles trapped, passing through the compressed air inlet and through the outlet to the target area.





The proposed model has a reduced number of particles trapped inside the diffuser compared to the existing model. Apart from the pressure values suggested by micro air filtration group[2], higher pressures are simulated to test the ability of filtration. It resulted in a decrease in particles collected at the diffuser outlet with increase in pressure. At low pressure more particles can be trapped in the diffuser. However, the existing model shows better results than the proposed model at low pressure. In the proposed model it is observed that some of the particles are collected at the compressor. In contrast there are no particles collected at the compressor for the existing model. Recommendations are proposed based on cost effectiveness and filtration capacity.

Keywords: *micro-filtration, HVAC, Environment, clean air.*

References

[1] Weeranoppanant, N., Amar, L., , Tong, E., Faria, M., Hill, M., and Leonard, E., Modelling of fouling in cross-flow microfiltration of suspensions, AIChE J, vol. 65, issue 1, 2018
[2] Tao, R., Yang, M., and Li, S., Filtration of micro-particles within multi-fiber arrays by adhesive DEM-CFD simulation. J. Zhejiang Univ. Sci. A 19, 34–44, 2018.

SINTERING OF MONOLAYERED STAINLESS STEEL (316L) PARTICLES FOR THERMAL MANAGEMENT APPLICATIONS USING PULSED CO_2 MICROSECOND LASER

Aparna Chandramouli[1], Mahmood Al Bashir[2], and Rajeev Nair[3*]
[1,2]Ph.D Candidate, Dept. of Mechanical Engineering
Wichita State University, Wichita, KS, USA
[3]Faculty, Dept. of ME, Wichita State University, Wichita, KS, USA
[1]Email: mxbashir1@shockers.wichita.edu
[2]Email: axchandramouli@shockers.wichita.edu
[3]Email: rajeev.nair@wichita.edu *(Corresponding author)

Extended Abstract:Three dimensional (3D) metallic porous structures are in great demand for various applications such as thermal management, filtration, lightweight structures, electrodes, and biomedical systems. Complex microporous structures are required for these desired functionalities. However, current manufacturing technologies, i.e., sintering, 3D printing, etc., have a few technical barriers that prevent them from being advantageous in developing 3D porous structures. Fabricating a sintered structure with a definite level of porosity is a challenge. The conventional sintering process, i.e. furnace sintering, can create porous single layer structures, however, this process is immensely time consuming. Also, it is difficult to control any predefined amount of porosity in the furnace sintered structure. In this study, we examine a new manufacturing process for developing microscale metallic porous structures using a pulsed microsecond carbon dioxide (CO_2) laser. The preliminary results show the successful fabrication of a sintered single layer metallic powder structure with controlled porosity, using a pulse period of 1000µs, pulse width of 205 µs with a defocused beam. To obtain validation of the sintering quality, laser sintered samples are compared with conventionally sintered samples. The main benefit of this new manufacturing process is that it provides a significant reduction in manufacturing time. The obtained results provide a crucial step toward developing a new class of manufacturing process for metallic porous structures. Sintering can be performed with various kinds of laser beams. This work involves the use of a pulsed microsecond CO_2 laser. Typically, commercial CO_2 laser setups have power ratings between 50 W and 200 W [1]. The parameters that are crucial to the laser sintering processes include laser power, wavelength, scan speed, pulse period and pulse width, among others. The material to be sintered, and the desired application determine the parameters and their corresponding importance to the laser sintering process. Some definitions of key laser parameters are given below:

Pulse Period: Time elapsed from the first laser pulse until the next.
Pulse Width: Time in a pulse period during which the laser emits power.
Scan Speed: Speed at which the laser beam travels on work surface
Scan Spacing: The distance between successive scan lines of the laser beam.

Other considerations that are important to the laser sintering process include material composition (of the material to be sintered), particle size, and material properties such as reflectivity, conductivity, etc., [2]. Research studies indicate that the material properties influence the input parameters for the laser sintering process [3]. For example, Salmoria et al found that metal powders have higher absorption of laser power when multiple reflections are allowed to occur [4].

Conventional sintering is primarily done by heating the particles in an electrical resistance furnace, fossil fuel, or induction furnace at a temperature of 0.6 -0.8T_m (melting temperature). The high costs involved in maintenance and fuel consumption, especially for extended periods of sintering, are the main drive to

discover and/or develop alternate sintering techniques. Laser sintering as a means to achieve 3D porous metallic structures present itself as an adequate solution, since the time required to sinter particles would be significantly less. Although the laser sintering setup is not inexpensive, the tradeoff of reduced time seems to be a worthy one.

The end goal of the research pertaining to this work is to develop three-dimensional metallic porous wick structures using copper. In order to obtain validation of the sintering technique, and to obtain a significant dataset, developing these wick structures in A4 stainless steel (316L) was chosen as an initial step. Stainless steel was chosen because of its easy availability, corrosion resistance, and appreciable mechanical properties. This work focuses on developing a single layer of sintered A4 stainless steel particles using the pulsed CO_2 microsecond laser setup.

A simplified model is used to estimate the energy required to sinter a spot size with diameter D, which will be used to decide the input laser parameters. The following assumptions are made for this model:

- The material properties of the A4 stainless steel micro-particles such as the specific heat density, latent heat of fusion, reflectivity, and density are assumed to be equivalent to that of the bulk material.
- The temperature at which A4 stainless steel particles will sinter is assumed to be about 10°C below the melting point of 1371-1399°C. Common sintering temperatures of A4 stainless steel can vary between 400°C-1350°C, depending on factors such as size of the particle, morphology, structure and sintering time [5]. In some cases, the maximum sintering temperature is 1400°C [6]. For this work, an upper limit for sintering temperature is initially assumed to be 1350°C, as per the literature.
- It is assumed that all lasing energy will be absorbed by the particles. Therefore, no losses in the transfer of energy will occur to the environment or any optical component.
- The spot size diameter is 10μm and the uniform layer thickness of particles is 200μm.

Table 1: Parameters for laser sintering Stainless Steel 316L

Pulse energy, E_n (J)	
Density of SS 316L, ρ (kg/m^3)	7980
Spot diameter, D (m)	1x10^{-5}
Layer thickness, h (m)	2x10^{-4}
Specific heat capacity of SS 316L, C_p (J/kg-K)	490
Final sintering temp., T_f (°C)	1350
Initial temp., T_i (°C)	25
Latent heat of fusion of SS 316L, l_f (J/kg)	290,000
Number of pulses, n	1
Reflectivity of SS 316L powder, R [7]	0.75

Using the following numerical model, the energy required to sinter a spot size diameter of 'D' and a layer thickness 'h' using 'n' amount of pulses can be calculated.

$$E_n = \frac{\rho \times \pi \times D^2 \times h \times \{C_p(T_f - T_i) + l_f\}}{4 \times n \times (1 - R)} \quad (1)$$

Average power is determined as follows:

$$P_{avn} = E_n \times f \quad (2)$$

where, 'f' = repetition rate of the laser (Hz)

In this preliminary study, the pulsed microsecond CO2 laser with controlled manufacturing parameters provided a new pathway to fabricate the desired metallic porous structures. The fabricated sample using the new laser sintering process is not expected to show any significant difference in features such as pore-scale geometry and porosity, from the one using the conventional sintering process. A specific amount of porosity can be attained by controlling the scan speed, overlapping and power of the laser. This study also shows that the laser sintering process substantially reduces the fabrication time by an order of magnitude. In some cases, a burnt surface of the A4 stainless steel particle was obtained, which can be attributed to the atmosphere created during the process. Better control and the provision of an inert atmosphere was found to address the problem. This study can be extended to understand how the overlapping of laser scan paths works in terms of particle softening and joining. This will help in creating improved wick structures with better porosity and reduced laser machining time.

Keywords: *laser sintering, single layer structure, stainless steel particle sintering, efficient thermal cooling*

References:

[1] P. Kruth, J., et al., *Lasers and Materials in Selective Laser Sintering*. Vol. 23. 2003.

[2] Laoui, T., et al. *Influence of powder parameters on selective laser sintering of tungsten-carbide cobalt*. in *Proceedings of the 7th European Conf. on Rapid Prototyping and Manufacturing*. 1998.

[3] K. Tolochko, N., et al., *Absorptance of powder materials suitable for laser sintering*. Vol. 6. 2000. 155-161.

[4] Salmoria, G.V., et al., *Rapid manufacturing of PA/HDPE blend specimens by selective laser sintering: Microstructural characterization.* Polymer Testing, 2007. **26**(3): p. 361-368.

[5] Panda, S., et al., *Sintering response of austenitic (316L) and ferritic (434L) stainless steel consolidated in conventional and microwave furnaces.* Scripta Materialia, 2006. **54**(12): p. 2179-2183.

[6] Youseffi, M. and K. Chong, *Enhanced sintering and mechanical properties of 316L stainless steel with silicon additions as sintering aid.* Powder metallurgy, 2003. **46**(1): p. 30-38.

[7] Marot, L., et al., *Rhodium coated mirrors deposited by magnetron sputtering for fusion applications.* Review of scientific instruments, 2007. **78**(10): p. 103507.

[8] Fischer, P., et al., *Pulsed laser sintering of metallic powders.* Thin Solid Films, 2004. **453**: p. 139-144.

[9] Roy, N.K., C.S. Foong, and M.A. Cullinan. *Design of a micro-scale selective laser sintering system*. in *2016 Annual International Solid Freeform Fabrication Symposium*. 2016.

[10] Roy, N. and M. Cullinan. *μ-SLS of Metals: Design of the powder spreader, powder bed actuators and optics for the system*. in *2015 Annual International Solid Freeform Fabrication Symposium*. 2015.

IMPROVEMENT OF SURFACE CHAREACTERISTICS OF LASER SINTERED STAINLESS STEEL 316L BY NICKEL PLATING

Pawan Tyagi[1*], Andrew C. Grizzle[1], Joshua Dillard[1], and Giancarlo Dorazio[1]
[1]Faculty of Engineering, University of the District of Columbia, United States
[1]Email: ptyagi@udc.edu *(Corresponding Author)
[2]Email: acgrizzle@gmail.com
[3]Email: Joshua.W.dillard@gmail.com
[4]Email: giancarlo.dorzio@udc.edu

Extended Abstract: This study presents the surface reflection and roughness evaluation of a 3D metal printed sample. The inherent characteristics of the surface were gradually changed using selected process parameters. In this work, an EOSINT M280 system fabricated nine Stainless Steel 316L samples via a metal laser sintering technique. The samples were then surface treated with electroplated nickel. A Taguchi Design of Experiment (TDOE) approach inferred the optimal parameter levels, which would improve the surface quality of the samples. The L9 experimental scheme of TDOE systematically analyzed four electroplating parameters, each with three levels. The observed surface roughness and reflectivity data per TDOE indicated that the optimal parameters for roughness reduction and increased reflectivity are: Temperature=70°C, Agitation=150 rpm, Cathode Current Denstiy=1 a/dm^2, and concentration of Nickel Sulfamate solution=33%. Finally, analysis of the data indicated agitation to be the most influential of the factors followed by solution temperature, concentration, and current density.

Keywords: *Surface roughness, Nickel electroplating, SS 316L, Taguchi design of experiment.*

Introduction

The fabrication of complex-shaped engineering components can be difficult or impossible to achieve with conventional manufacturing processes[1-2]. Cases like this require Additive Manufacturing (AM), which is a modern and advanced manufacturing technique. More particularly, Laser Sintering (LS) is a category of AM in which a high-intensity laser beam fuses metallic powder particles layer by layer into three-dimensional structures[3]. Subsequently, these fabricated parts find applications in diverse engineering applications such as aerospace, medical, and automobile industries. Stainless steel (SS) 316L is a highly used metal powder for the fabrication of components in the above-stated applications.
While there are many benefits to creating metal components via LS, the process usually leaves partially melted metal powder on the component. As a result, surface parameters such as roughness and reflectivity can be unacceptable, depending on the use case.

Thus, to enhance the surface properties of the AM metal components, processes such as electrochemical deposition and chem-polishing can be utilized. Electrochemical deposition of metals requires the reduction of metal ions from electrolytes in an aqueous solution. The focus of this study is to investigate electroplating by nickel and the subsequent surface property changes.

Methodology

To investigate the improvement of surface reflectivity and roughness on LS SS 316L components, a four-parameter model for nickel electroplating was utilized systematically according to the L9 experimental scheme of TDOE. In this model, the change in roughness and reflectivity measurements of each test piece is the dependent variables. Table 1 indicates the independent variables/parameters for this experiment, along with their levels.

Table 2: Experiment factors and levels.

Factors	Level 1	Level 2	Level 3
Temperature °C	30	50	70
Agitation (rpm)	0	150	300
Soln. Conc. (%)	33	66	100
Current Density (A/dm^2)	1	3	6

The electroplating process is sensitive to contamination. Hence the samples were chemically cleaned with acetone, isopropanol alcohol, and deionized water. Photoresist applied to the test samples facilitated in isolating a defined and consistent surface area for nickel plating. The electroplating tank was a Pyrex glass beaker with Nickel Sulfamate SN-10 as the electrolyte. A magnetic pellet created agitation within the solution to reduce the formation of hydrogen bubbles on the sample. An electric hot stirrer heated the electrolyte while a temperature sensor monitored bath temperature. For this experiment, the nickel and boric acid content of the solution (Nickel Sulfamate SN-10) is 10.2 oz/gal and 4.0 oz/gal, respectively, with a pH of 4.2-4.8. Table 1 indicates the other parameters and their levels.

Results

Roughness data was measured using a PCE RT 1200 roughness tester with a resolution of 0.005 μm on RA and RQ roughness parameters. Surface reflectance data was measured using Semiconsoft's MProbe 20 desktop spectrometer, which measured in the UVVis(200-1000 nm) wavelength range with precision and accuracy of 0.01% and 0.2%, respectively.

Our main goal of this study is to produce preliminary results of the optimal parameters used for nickel electroplating AM LS components. Four parameters with three levels were evaluated to find the combination that provided the best improvement in surface smoothness and reflectance.

Table 3: ANOVA

Factors	Sums of Sqrs (S)	Variance (V)	Pure Sum (S')	Percent P(%)
Temperature °C	18.805	9.402	18.805	24.734
Agitation (rpm)	29.607	14.803	29.607	38.941
Soln. Conc. (%)	17.222	8.611	17.222	22.651
Current Density (A/dm^2)	10.395	5.197	10.395	13.672

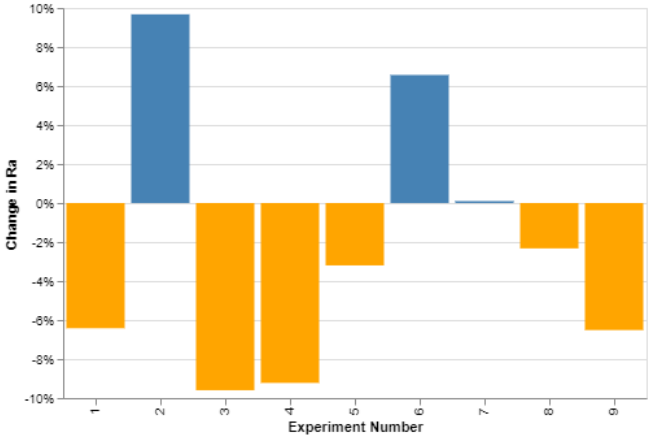


Figure 2: Bar plot showing the average surface roughness change

Discussion

The TDOE analysis indicated that the two most influential parameters are agitation and temperature, as can be seen in table 2. Additionally, Figure 1 shows that experiment number three produced the highest reduction in surface roughness, which corresponds to the following parameter values: Temperature level of 30°C, agitation is at a speed of 300 rpm, solution concentration is at 100%, and current density is 6 A/dm2. Analysis of the reflectance data is currently ongoing in preparation for the final paper.

References

[1] L.E. Murr , S.M. Gaytan , D.A. Ramirez , E. Martinez , J. Hernandez , K.N. Amato , et al., Metal fabrication by additive manufacturing using laser and electron beam melting technologies, J. Mater. Sci. Tech. 28 (1) (2012) 1–14.

[2] Gibson, Ian, Rosen, David, Stucker, Brent, Additive manufacturing technologies, 2nd Edition, Springer Publications, 2015. ISBN 978-1-4939-2112-6.

[3] O.N. Shellabear, DMLS—development history and state of the art, in: Proceedings of the fourth laser assisted net shape engineering, LANE 2004, vol. 1, September 2004, Erlangen, Germany, (2004) 393–404R.H. Lyon, R.G. DeJong, 1995. *Theory and Application of Statistical Energy Analysis.* Kluwer Academic Publishers.

EAGLEEYE: NEVER LOSE ANYTHING AT HOME AGAIN

Yemane Zewdu1, Henok Tasissa2, Brandon Botchway3, Kedamawi Mulualem4, Hiwot Gezahegn5, Tadele Lamma6, Alpha Amadou Diallo7, Thabet Kacem8 * and Nian Zhang9

School of Engineering and Applied Sciences, The University of the District of Columbia 1-7Email: [yemane.zewdu, henok.tasissa, brandon.botchway, kedamawi.mulualem hiwot.gezahegn, tadele.lamma, alphaa,adou.diallo]@udc.edu

8Email: Thabet.kacem@udc.edu *(Corresponding author)
9Email: nzhang@udc.edu

Extended Abstract: According to the Census Bureau [1], for the first time in US history, adults are projected to outnumber children by 2034. This makes aging and its related issues not only a big problem to address but also it makes the senior community a huge market as well. Through interviews that we conducted at Sunrise Assisted living facility [2], we found out that most common issues facing seniors in their daily life is losing items due to dementia. In this paper, we propose an application that helps the growing aging demographic locate misplaced items in their home easily by using a cloud-based computer vision technique. We designed a state-of-the-art system integrated with home surveillance cameras and different voice-based services such as Alexa [3] and Google Home Assistant [4]. The core module in our application is the object recognition algorithm that takes as input video feed from the home surveillance cameras and produces a log of the home items and their locations associated with their respective timestamps. Users looking for an item will enter their request into our mobile app and get a response of the last seen location and time of the item they are looking for from the log file saved on the cloud. Full integration with Alexa and Google Home Assistant will be the outcome of the second iteration of our solution. Possible stakeholders include Amazon, Google nest, other home cameras and security providers, nursing homes, and any senior who wants to live independently. However, it is not limited to senior as anybody can use it.

Keywords: *Computer Vision, Cloud Computing, Object Recognition, Voice-based Services*

References

[1] US Census Bureau, “Older People Projected to Outnumber Children for First Time in U.S. History”, Release CB18-41, March 2018.
[2] Sunrise Assisted Living Facility, 5111 Connecticut Ave NW, Washington, DC 20008, USA
[3] Amazon Alexa, https://developer.amazon.com/en-US/alexa [4] Google Home Assistant, https://assistant.google.com/

THE FUTURE OF LEARNING

Author: Janet Stewart[1]

[1]Certified Instructional Designer and CEO, WeLoveLearning, Canada
[1]Email: Janet@WeLoveLearning.ca

Extended Abstract : The learning landscape has shifted and as Trinidad and Tobago, along with other countries in the Caribbean, make the transition to the digital economy, so must the learning landscape of these countries.

In previous decades, when an organization needed to train its employees or customers, it meant booking a conference room and coordinating travel, accommodation and meals for many persons. Scheduling could be a difficult and time-consuming task. And invariably, some persons were not available to attend, leaving them with an important knowledge gap and no really good way to close it.

Fast forward to the *21st Century* and the year 2020. Learning has never been more accessible to more persons than it is now. The reach of eLearning today is greater than ever with the most rapid growth happening in emerging economies, trying to close the education gap. The combination of low on-going costs, high convenience, and accessibility are transforming eLearning into the predominant global educating force of the 21st century.

The *Modern Learner* expects to be able to access information when and where they need it. With widespread access to the Internet and the use of Smartphones, training and education is now available in anyone's hands, regardless of their geographic location or their socio-economic status. And to be successful, the Modern Workplace needs their employees to engage in life-long-learning – the fact that training can be made available through an Internet portal, makes the pursuit of continuous education more convenient and accessible than going to a traditional school/physical location.

This paper/presentation will introduce Conference attendees to the spectrum of eLearning choices and technologies that are being used to provide *digitally deployed learning* in the workplace.

When it comes to digital (on-line) learning there is no "one-size-fits-all" solution. Similar to the design of classroom training, we must always consider three important components when deciding on a direction to pursue:

- What is the learning objective(s)?
- Who is the target audience? (eg age, gender, prior knowledge, attitude/willingness, etc)
- How will the learners "consume" the training? (desktop, laptop, tablet, Smartphone)

Based on the answers to these questions, we make choices about how to best approach the training initiative. With respect to the desired learning objective(s), we also need to consider which "domain" of learning is involved:

- Cognitive;
- Physical; or
- Affective.

The answer to this question, further guides our choices. And finally, there is one more important set of questions that are inter-connected and impact our training solution:

- Time available plus the expected "shelf-life" of the training;
- Budget available
- Complexity (the more interactive the eLearning, the more labour hours required to "create/program it")

Figure 1: Ven Diagram, WeLoveLearning (Time-Budget-Complexity)

Much like the design of in-person training, there are a number of steps in the design process

1. Needs analysis – gathering information about the learner (prior knowledge, years of experience, demographics, etc) and understanding the performance gap as it relates to skills, knowledge and/or attitudes
2. Set learning objectives – as described previously, these cover the three domains of learning (cognitive, physical and affective) and will strongly inform the design and deployment decisions to be made
3. Content creation and curation – gather and sort the content with the help of Subject Matter Experts
4. Learning design – this is where the process diverges from the design of in-person training. At this point, it is up to the Instructional Designer to imagine how to bring the content to life in an *asynchronous* digital environment - when the Instructor and the Learner are not 'there' at the same time. While it is true that some on-line learning programs include a live-delivery component, more and more we are seeing models wherein the learner engages in the training program at a time that is convenient to them, rather than according to a pre-determined schedule.

It is critical during this phase, that the design be one that engages the learner and causes him/her to interact with the course. Interesting and meaningful ways to move through content are designed at this stage. The learning experience needs to be an interactive one – one that is rich in relevant imagery and exercises. The creation of appropriate stories and scenarios help to move learners through the content in meaningful ways and methodologies like *gamification*[1] tap into the psychology of learner curiosity and fun, to further engage.

It is important that learners see themselves in the training that they complete and although that is not a new part of course design, in an eLearning environment, this means that *character development* is an important additional step.

5. Asset creation - It is during this phase that the content starts to come to life. Any videos that have been identified as digital assets to be included in the courses, for example, are created at this time. Video styles may vary from animated to live-action (interview style) to screen-capture (for software focused processes), depending on the content to be covered. Depending on the assets to be created, this is also the time during which infographics and other specialized images are built. It is also during this step that the Instructional Designer will draft quizzing questions and design the scoring mechanisms to be built into the courses.
6. Programming - Although "programming" doesn't sound all that exciting, it really is – finally the course content comes to full life. All of the planning and storyboarding, all of the infographics and videos finally start to fall into place. Authors and Subject Matter Experts review the draft solution and provide feedback.
7. Implement - Once the feedback has been received, the updates made and the final draft SCORMED[2], we are ready for the learners!

Articulate is considered the "gold standard" in today's eLearning market when it comes to building "courses". For those that will be consumed on a desktop or laptop, *Articulate Storyline*[3] is the way to go, while those that are more likely to be consumed on a tablet or Smartphone should be built in *Articulate Rise*[4]. Both are considered to be *Rapid Development Tools* and have *Responsive Design* built into them. Responsive Design is a critical component in today's learning environment…solutions need to be able to 'play well' on all devices, regardless of size or manufacturer.

The following is a chart from an issue of *Training Magazine* that provides insights into the labour effort associated with creating eLearning. You can see that there are typically three levels – the sweet spot is Level 2 – it's where you find a nice balance between cost and complexity. But you can also see that for every finished hour of eLearning, approximately 184 hours goes into creating it.

Development Ratios - Summary

ILT, Level 1 eLearning (Basic), Level 2 eLearning (Interactive), Level 3 eLearning (Advanced)

	Rapid Development, Simple Projects	Average *Typical Project*	Advanced, Complex, More Media
Instructor-Led Training (ILT)	22:1	43:1	82:1
Level 1 eLearning (Basic) – Content Pages and Assessment	49:1	79:1	125:1
Level 2 eLearning (Interactive) – Level 1, plus 25%+ interactive exercises	127:1	184:1	267:1
Level 3 eLearning (Advanced) – Simulations, Games, Award Winning type	217:1	490:1	716:1

Figure 2: Development Ratios – Summary, Training Magazine

Given the increasingly short attention thresholds of the *Modern Learner*, we are seeing a shift away from courses that are an hour (or more) in length, and a shift towards a model wherein several mini-courses that are laser-focused on one or two topics and are no longer than 10-15 minutes each, are bundled together by related topics.

But eLearning is a spectrum of choices…so "courses" are not the only solution. How about turning a truck into a mobile classroom? That is absolutely possible!

Interactive *micro-learning* experiences designed for mobile devices often use 3rd-party Apps in the background. Affordable tools like Zappar that use *Augmented Reality* are changing the place of what a "classroom" looks like. Consider this micro-training recently created for GeoTechVision of Jamaica and embedded right onto their drone – this training can be accessed by a Smartphone in the middle of a field and accessed "just-in-time", exactly when the learner needs it.

Figure 3: Augmented Reality Training, WeLoveLearning

Shift from Instructional Designer to Learning Experience Designer

Creating interactive courses and learning experiences require the creation of a multitude of digital assets coupled with solid Instructional Design and creativity. It is no longer enough to understand the Experiential Design Model or KOLB's work around evaluation or *The Forgetting Curve*. The industry now requires the talents of *Learning Experience Designers* who have a solid background in learning and teaching methodologies as well as the visual creativity of a graphic artist and the digital skills of an IT person.

Good design DOES result in high learner-retention rates and changes behaviours. eLearning is an effective approach for the deployment of pre-requisite training activities, education for the masses, and post-training performance support for those in the workplace as well as product and services users/customers. As a Learning Professional, it opens up a whole new and exciting treasure chest of teaching tools!

References

[1] Papas, C 2019, Top 20 eLearning Statistics for 2019 You Need to Know. www.eLearningIndustry.com

[2] Dirksen, J 2020, The Science of Attention and Engagement. www.elearningguild.com

[3] eLearning Guild, Bozarth, J, Torrance, M & Dirksen, J 2019, The Current State of xAPI, Designing for AR/VR and the Expanding Role of the ID

[4] Stewart, J 2019, eLearning 101, viewed January 31, 2020, https://welovelearning.ca/elearning-101-success/

[5] Stewart, J 2019, We Love Learning Workbook, viewed January 31, 2020, https://welovelearning.ca/workbook

---

[1] *The Power of Gamification in Education* – Scott Hebert is an award-winning teacher in Fort Saskatchewan, Canada: https://www.youtube.com/watch?v=mOssYTimQwM

[2] SCORM is an international standard in the eLearning industry: https://scorm.com/scorm-explained/

[3] A sample of what a course, built in *Articulate Storyline* looks and feels like can be found here: https://welovelearning.ca/courses/introduction-to-mental-health/

[4] A sample of what a course, built in *Articulate Rise* looks and feels like can be found here: https://welovelearning.ca/caroni-catastrophe/

POSTERS

DESIGN OF A PROTECTIVE SYSTEM FOOR OWERRI 160 MVA, 132/33KV SUBSTATION

Osita Oputa and Arthur Ekwue | Department of Electrical/Electronic Engineering | University of Nigeria | Nigeria

Abstract

The Owerri 160MVA, 132/33kV distribution substation plays a very important role in the economics of the Imo state of Nigeria and its environs. Therefore, proper measures should be kept in place to protect the substation from abnormal fault conditions. An over-current protection as well as under/over voltage protection schemes for the substation have been provided by this work using results from load flow analysis and fault analysis on different locations of the substation done using the ETAP software. The switching sequence of the primary and secondary sides of the transformers in the substation were also provided.

Introduction

The Owerri 160MVA, 132/33kV substation feeds the loads around the Owerri, the Imo state capital of Nigeria and surrounding towns. It also acts as a switching station. Its importance to economic and social life of the people residing in these areas as well as the local EEDC (Enugu Electricity Distribution Company) cannot be over emphasized. A cross section of the substation and its protection is shown in Fig. 1. This substation is rated 160MVA and takes power at 132kV from Alaoji and Ahoada transmission lines. The substation has two 60MVA, 132/33kV and one 40MVA, 132/33kV power transformers and all three run in parallel. The substation feeds 6 (six) feeders namely: Owerri 1 and 2, Mbaise, Oguta, Orlu and Okigwe with maximum load demand of 30MVA, 30MVA, 26MVA, 22MVA, 26MVA, and 24MVA respectively.

Introduction

A cross section of the substation showing the three transformers running in parallel is shown below.

To keep this substation safe, it must be protected from high fault currents, under-voltages and high or over voltages. Under voltage increases the operating current (than at normal operating conditions) thereby causing over heating which tends to burn the insulation of the transformers; causes electrical stress on the transformer oil and reduces the dielectric strength of the transformer oil and insulator. On the other hand, over voltages (which are mainly caused by surges) can result in spark over and flash over between phase and ground at the weakest point in the network of the substation or transformer connection leading to breakdown of transformer oil insulation. Low voltages can be caused.

- closing and opening of circuit breaker (CB) due to fault, motor starting or load energizing.
- use of inappropriate cables (due to size, say) in distribution systems.
- Over voltages are usually caused by [5]:
- a special form of series resonance between the magnetizing reactance of the transformer and the system capacitance known as Ferro resonance.
- loss of the secondary neutral (by any means) and
- poor voltage regulation.

Substation Protection Design

The load flow analysis of the substation (i.e. the establishment of the initial operating condition) is done using the ETAP software. When the substation is running with all the feeders connected and at maximum load, the load flow of the substation is shown in Table 1.

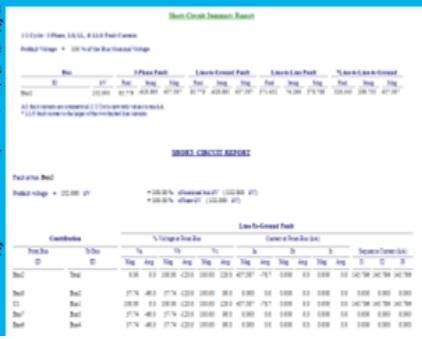
ID	MW Flow (MW)	MVar Flow (MVA)	Amp (A)	Ter. Vol.(kV)
T1	52.84	26.59	258.7	94.7
T2	52.84	26.56	258.7	94.7
T3	35.35	35.35	172.5	94.7

For different types of fault on the substation, the analysis is done using the bus nomenclature given on Table 2

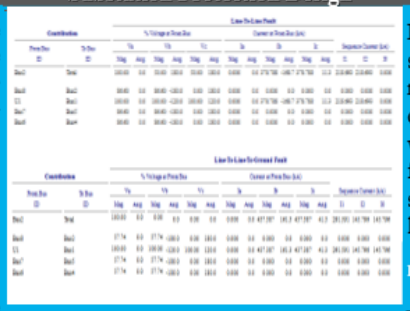
Bus Number	Description	Bus Number	Description
2	Primary of T1	8	Secondary of T1
5	Primary of T2	7	Secondary of T2
4	Primary of T3	6	Secondary of T3
IC	132 in-comer		

Since transformer T1 and T2 are identical and runs in parallel, the results of faults on them are the same. The results for some fault occurring at different areas of the substation are shown below.

Results for faults at the primary of TI & T2

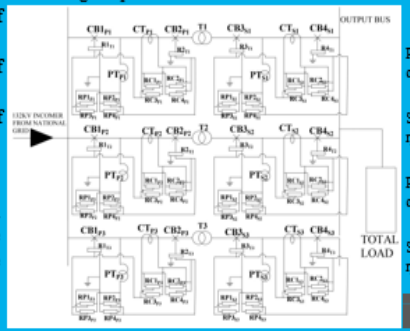


Substation Protection Design



Using these result (and more), a protective system is design as shown below to protect the substation from over current (over load) and Over/under voltage protections.

See in diagram provided



From the result of the simulation, the CTs and PTs, current and voltage relays, as well as the CBs

For T1 and T2, 60:1 and 1100:1CT and PT are used respectively for the primary side; while 275:1 and 100:1 PT and CT ratios are respectively used for the secondary sides. The current relays used for the primary side has a pickup value of 4.7A and a time delay of 0.2 second.. The low and high voltage relays has trips values at 108V and 132V and time delay of 0.2 second, the relays used have a burden of 3VA.

Substation Protection Design

For transformer T3, CT at the primary and secondary is 40:1 and 80:1 ratios respectively, relays used has a pick up value of 4.72A and a time delay of 0.2second..the voltage relay and PT are the same as used for T! and T2. with this design, the tripping sequence for faults occurring at different locations is given in the table below

Fault location	1st to Trip	2nd to Trip	3rd to Trip	Fault location	1st to Trip	2nd to Trip
Primary of T1	CB at primary of T1	CB at primary of T2	CB at primary of T3	Primary of T1	CB at primary of T1	CB at primary of T2
Secondary of T1	CB at secondary of T2	CB at secondary of T3	CB at secondary of T1	Secondary of T1	CB at secondary of T2	CB at secondary of T3
Primary of T2	CB at primary of T1	CB at primary of T2	CB at primary of T3	Primary of T2	CB at primary of T1	CB at primary of T2
Secondary of T2	CB at secondary of T2	CB at secondary of T3	CB at secondary of T1	Secondary of T2	CB at secondary of T2	CB at secondary of T3
Primary of T3	CB at primary of T1	CB at primary of T2	CB at primary of T3	Primary of T3	CB at primary of T1	CB at primary of T2
Secondary of T3	CB at secondary of T2	CB at secondary of T3	CB at secondary of T1	Secondary of T3	CB at secondary of T2	CB at secondary of T3

Conclusion

A comprehensive protection scheme for the Owerri 160MVA, 132/33kV substation has been realized; this protection scheme is based on the results obtained from the fault analysis and the rating of the substation with the present load (as at the time of carrying the study). For example, for a line to line fault occurring at the primary of transformer T2 between line 'b' and 'c' at rated pre-fault voltage, the resultant voltage and current on the primary T2 is , and ; the CB at the T1 will trip first, the CB at T2 will trip next and lastly that at T3 will trip last.

Compressive Strength Optimization Using IV-Optimal Design and Open-source 3D Printer

Arshad Mohammed | DEPARTMENT OF MECHANICAL ENGINEERING | UNIVERSITY OF THE WEST INDIES | TRINIDAD AND TOBAGO

Project Aim

This paper presents an approach to optimize the compressive strength of parts manufactured by using a material extrusion process.

Rationale

Compared to traditional manufacturing methods such as machining, 3D printed parts have several limitations such as low strength, poor dimensional accuracy and surface finish. If additive manufacturing is to wider acceptance in industry its drawbacks need to be overcome.

Introduction

By setting the appropriate build parameters it is possible to increase the performance of parts made with the ME process. The build parameters of ME are highly convoluted with interactions between parameters. Several studies have been done to increase the strength of AM parts while also considering the interactions. In some cases researchers have focused their efforts into investigating only one parameter at a time, one such case is where the effect of altering the infill pattern of the part on its strength was studied. This study will combine heat treatment as a post-processing parameter along with five build parameters of the ME process to improve the compressive strength of parts made by IV-optimal design approach and an open-source 3D Printer.

Methodology

Design Expert® was used to design an IV-optimal design of experiments (DOE) that was followed to build the specimens. This DOE method was chosen since it is recommended for experiments with both categorical and numeric factors that need to fit a higher-order model.

The sample used in this study comprised of cuboids with dimensions 30mm x 10mm x 10mm, the dimensions used were derived from past research. Layer thickness (LT), road width (RW), airgap (AG), number of contours (NC), build orientation (BO), infill type (IT) and annealing (AN) were selected as parameters for the investigation purpose. The table below summarizes the factors and their levels.

Factor	Levels		
	Level 1	Level 2	Level 3
LT	0.1	0.2	0.3
RW	0.3	0.35	0.4
AG	0	0.025	0.05
NC	0	3	6
BO	0	90	180
IT	L	HC	-
AN	No	Yes	-

Results

Testing was done on a Tinius Olsen H10KS, pictured below.

All samples were tested on the same day to reduce influence by changes in the environment. The results of the compression tests were input into JMP® software to train an Artificial Neural Network to predict the optimum settings for compressive strength. The results are listed in the table below.

Build Parameters	Optimum
LT	0.3
RW	0.3
AG	0
NC	6
IT	1 (HC)
BO	90
AN	1 (Yes)
Predicted Force	4438.2

Conclusion

Two validation specimens were then printed using the adjusted optimum build parameters. The samples failed at a maximum force of 3222N, 27.4% lower than predicted by the ANN model. This may be due to several factors. The validation specimens were printed and tested some weeks after the initial run of experiments and so the environmental conditions of the validation tests may have been different. Alternatively, while the ANN model did score a sufficiently high R-square value, the interaction among the build parameters and also the heat treatment may reduce its accuracy. The number of initial experiments can be increased along with more network training. Having a greater amount and a wider spread of input data may make a more robust ANN model.

Recommendations

A more rigorous DOE consisting of a greater number of experiments can be done to investigate any changes in the performance of the ANN model. Future research may also focus on optimizing other mechanical properties such as tensile and flexural strength.

ANALYSIS OF EDUCATIONAL POLICIES AND ECONOMIC IMPACTS IN SMALL ISLAND NATIONS

Trishel Gokool | DEPARTMENT OF MECHANICAL & MANUFACTURING ENGINEERING | UNIVERSITY OF THE WEST INDIES | TRINIDAD AND TOBAGO

Rationale

The global economic landscape is ever-changing as countries struggle to keep up with rapid technological advances to remain financially stable and globally relevant.

Traditional educational approaches are becoming less effective in light of this rapid technological growth and many higher education programmes struggle to keep their curriculum up to date.

However, small island nations like Trinidad and Tobago cannot follow the frameworks and strategies of larger countries as these do not account for the unique circumstances of small countries in terms of size, labour force, and access to technology and markets amongst others.

In order to develop educational policies and strategies for the diversification of the economy of a small island state like Trinidad and Tobago it is necessary to consult small island nations, namely Singapore, Malta, and Brunei Darussalam.

This research seeks to briefly report on the approaches adopted by these countries in terms of education for economic development.

This will be useful for the future development of Trinidad and Tobago's education policies, specifically in the area of manufacturing and its related technologies.

Research Questions

The main research questions to be investigated in this research are:

- What educational policies or strategies have the selected nations used?
- How has the manufacturing sector of these nations benefited from such polices or strategies?

Background

Figure 1 provides a brief background on each of the selected countries as well as Trinidad and Tobago to illustrate the similarities between them, namely small population and size, and similar history.

Figure 1: Background of investigated nations

Methodology

A brief search was performed in key databases, namely Emerald Insight, Link Springer, T and F Online and ScienceDirect. Keywords such as 'education', 'development', 'policy' and 'economic' were used as well as the names of the selected nations. The search results were sorted by relevance and screened based on the content of the title, keywords and abstract, as only articles that directly reported on the education strategies and results thereof of the selected nations were considered. These journal articles were then used to answer the research questions.

Findings

What educational policies or strategies have the selected nations used?

Singapore:

- Industry 21 initiative in 1998 which emphasized on turning Singapore into a knowledge-based economy with substantial investments into research and development and human capital development
- Technical programmes were redesigned to be more rounded by including innovation and entrepreneurship studies
- Strategies to attract foreign students and universities to create an education hub to further enhance its knowledge-based economy
- 'National Education' was ingrained into curricula which promoted the message of 'go global stay local'

Malta:

- Establishment of a Foundation for Educational Services and a Foundation for Tomorrow's Schools that can bypass restrictive bureaucracy and implement educational plans faster
- National Lifelong Learning Strategy 2020 which embraces open education and digital educational innovation to promote connected learning

Brunei Darussalam:

- Government included technical vocational education as part of its human capital approach to manpower development and economic diversification
- Established the Brunei Vision 2035 blueprint in 2009 to focus on diversification of the economy by becoming a knowledge-based society

How has the manufacturing sector of these nations benefited from such polices or strategies?

Singapore:

- Education strategies are closely tied in with the evolution of the modern Singapore state into a manufacturing and services hub

Malta:

- Economy experienced the second fastest rate of growth in the European Union, with the export of goods and services growing by 67% in the last decade → but no direct link to education found

Brunei Darussalam:

- Initially, the execution of diversification efforts were slow due to the continued reliance on the energy sector
- The growth of sectors like petrochemical manufacturing have increased leading to Brunei being named most improved economy in the world between 2016 and 2018 according to World Bank's 'Doing Business' report

Concluding Remarks

The small island nations investigated used educational tactics that mainly focused on creating knowledge based as opposed to resource-based economies. This included research and development activities and human capital investment especially in areas such as technical studies and entrepreneurship. These strategies served Singapore well, but Malta and Brunei have struggled with generating return on investment. A more in-depth study on the relationship between educational strategies and economic growth in terms of the manufacturing sector needs to be performed.