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Editorial

This Volume 40 Number 1 includes five (5) research/ technical articles and one special article contributing to our late colleague, Mr. Richard Charles of the Department of Civil and Environmental Engineering. The relevance and usefulness of respective articles are summarised below.

P. Jaggernauth, et al., "Energy Analyses and Operating Costs of Biodiesel Production", explore the potential use of coconut oil as the triglyceride feedstock for biodiesel production. In this paper, energy performance analyses of four (4) coconut oil biodiesels are presented, with respect to four energy performance metrics, namely net energy ratio (NER), net energy balance (NEB), net renewable energy value (NREV) and fossil energy ratio (FER). NER values ranged from 0.51 to 0.77, NEB from -12.00 MJ/L to -46.21 MJ/L, NREV from 9.00 to 21.31 MJ/L and FER from 1.52 to 2.88. Although the small-scale transesterification process would neither be energy-efficient nor sustainable, most of the physical properties are already within specification for use in the vehicular market of Trinidad and Tobago. Biodiesels would be a prospective component of environmentally friendly blends with petrodiesel.

In their article, "Design and Development of a Low Noise Lawnmower Blade: Application of CAD, CAE and RP Tools and Techniques", **T. Gokool and B.V. Chowdary** investigate the applications of virtual modeling tools and Rapid Prototyping (RP) principles in the design and development of a lawnmower blade. Computer Aided Design (CAD) and Computer Aided Engineering (CAE) tools and techniques were used to develop a prototype along with a Fused Deposition Modelling (FDM). The produced prototype could generate lower noise levels than the original blade, and the virtual modeling tools could predict the noise levels of the proposed blade design. Results show that the use of RP technology has its potential to reduce developmental cost and time.

L.O. Osoba, at al., "The Dry Sliding Wear Behaviour of Aluminum Composites: A Review", discuss the effects of dry sliding parameters (sliding speed, sliding distance and load) coupled with process parameters (stir cast and reinforcement parameters) on the dry sliding (adhesive) wear behaviour of aluminum composites produced by stir casting technique. Aluminum composites has been of wide applications in the automobile, aerospace, defense and other engineering sectors especially where dry sliding wear plays major role. Many processing techniques have been used over time depending on various predetermined criteria. Besides, many investigative works have been done on the impact of sliding speed, load and distance but only few of such studies linked stir casting and reinforcement parameters with the wear properties of aluminum composites.

In the third article, "Management of Knowledge and Ignorance in the Context of Organisational Learning: A Research Agenda", **K.F. Pun and M.Y.R. Yiu**, discuss the need for fostering knowledge management (KM) practices with ignorance management (IM) towards organisational learning (OL), with particular reference to the business environment in Trinidad and Tobago (T&T). It elaborates a research initiative, and outlines the purposes, hypotheses and areas for devising a KM/IM capability model. This paper serves as its purpose as a research agenda for a three-stage approach of the study. Built upon the present Stage 1 of literature review, the next two stages would be empirical data acquisition and model development and testing that would evaluate the applicability and efficacy of the model using the empirical data to be acquired in manufacturing enterprises in T&T.

CT. Benjamin, "The Entrepreneurial Motivations of Engineering Students: Case from the SIDS of the Caribbean", investigates into the entrepreneurial motivations based on more than 200 engineering students and recent graduates in Trinidad and Tobago (T&T), to gauge whether, among this group, some of these traditional factors are associated with higher order or 'pull' entrepreneurial motivations such as taking advantage of market opportunities, the need for control and independence, and desire for a challenge. It was found that the respondents primarily displayed higher order 'pull' motivators for entrepreneurship with eighty-four percent (84%) identifying welcoming a challenge, controlling their future or taking advantage of opportunities as potential motivators. The study revealed no statistically significant correlation between entrepreneurial motivation of the respondents and ethnicity, sex, parents' occupation, or training. This exploratory study, conducted in T&T, suggests that engineers may exhibit different entrepreneurial patterns to the rest of the population or to engineers in larger economies.

G.S. Shrivastava, "Raymond Francis Charles (1951-2017): A Remembrance and Historical Note of a Civil Engineer", speaks about both academic and profession life, and recognises the commitments and contributions, of late Mr. Raymond Francis Charles towards the development of civil engineering disciplines and professional in Trinidad and Tobago and a wider Caribbean region. Mr. Charles, being the past Head of the Department of Civil and Environmental Engineering and a Fellow of the Institution of Civil Engineers, United Kingdom, will live in the memory of his students and colleagues at The University of the West Indies.

On behalf of the Editorial Office, we gratefully acknowledge all authors who have made this special issue

possible with their research work. We greatly appreciate the voluntary contributions and unfailing support that our reviewers give to the Journal.

Our reviewer panel is composed of academia, scientists, and practising engineers and professionals from industry and other organisations as listed below:

The views expressed in articles are those of the authors to whom they are credited. This does not necessarily reflect the opinions or policy of the Journal.

KIT FAI PUN, *Editor-in-Chief*

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Energy Analyses and Operating Costs of Biodiesel Production

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Abstract: *Fluctuating petroleum prices, environmental concerns and the understanding that petroleum is a finite resource have encouraged investigation into alternative fuels. Coconut oil can be potentially be used as the triglyceride feedstock for biodiesel production. The objective of this study was to complete energy performance analyses of four (4) coconut oil biodiesels. The energy performance metrics investigated were net energy ratio (NER), net energy balance (NEB), net renewable energy value (NREV) and fossil energy ratio (FER). NER values ranged from 0.51 to 0.77, NEB from -12.00 MJ/L to -46.21 MJ/L, NREV from 9.00 to 21.31 MJ/L and FER from 1.52 to 2.88. The energy metrics implied that the small-scale transesterification process is neither energy-efficient nor sustainable in Trinidad and Tobago. At the atom efficient 3:1 methanol to oil ratio, the NREV and FER values are improved, however, compared to the 6:1 methanol to oil ratio process. Additionally, since most of their physical properties are already within specification for use in the local vehicular market, all biodiesels are a prospective component of environmentally friendly blends with petrodiesel.*

Keywords: *Coconut oil, biodiesel, energy analysis, operating cost, NER, NEB, NREV, FER*

1. Introduction

Petrodiesel has been established as the preferred fuel for compression ignition engines due to its efficiency, low cost and availability. However, concerns about greenhouse gas emissions (Stern, 2006), the decline of global oil production (IEA, 2010; Hirsch, 2005), and the unpredictability of oil prices due to socioeconomic and political factors (IEA, 2010) have forced investigation into locally available, renewable, environmentally friendly liquid fuels.

Vegetable oils would have been an excellent option as a renewable liquid fuel if not for its high viscosity which is 11-17 times higher than petrodiesel (Meher et al., 2006), resulting in engine deposits due to poor atomization (Knothe et al., 2005). Consequently, four main methods have been investigated to lower the viscosity of the vegetable oils viz. transesterification, pyrolysis, dilution blending with petrodiesel, and microemulsification (Knothe et al., 2005; Balat and Balat, 2008). As carbon deposits and lubricating oil contamination still persist with pyrolysis, blending, and emulsifying (Ma and Hanna, 1999), transesterification is the most frequently used method to decrease viscosity (Knothe et al., 2005).

Transesterification is a chemical reaction whereby the fatty acid alkyl esters are produced from the parent triglyceride via a reaction with an alcohol, usually in the presence of a catalyst (Knothe et al., 2005). The process converts the large triglyceride molecule from the vegetable oil into three smaller alkyl ester molecules. Biodiesel's characteristics of renewability, cleaner emissions (Demirbas, 2008), ability to be used without modifications to the diesel engine (Vega-Lizama, et al., 2015), and high degradability (Veljković et al., 2015) make it one of the most rapidly growing alternative fuels in the world (Babu et al., 2015). The main challenge to biodiesel becoming a competitive alternative to diesel on the market is its price, which is 1.5-3 times more than diesel (Demirbas, 2009). High oil feedstock costs, the main cost component, can be up to 80% of the operating cost (Balat and Balat, 2008). Market implementation of biofuels will not be successful if the process is not economically viable (Müller-Langer et al., 2014). This has led to an interest in the field of energy economics specific to biodiesel production.

Energy metrics are a measure of the technical or overall efficiency of the process and indicate where the investment and production costs are located (Müller-Langer et al., 2014). A detailed understanding of the energy content and economics of a plant's process is the foundation to understanding how to increase energy efficiency and reduce process costs (Thumann and Mehta, 2008) as well as allow for better allocation of resources (Bhattacharyya, 2011). Energy and cost analyses of biodiesel production are therefore of vital importance in determining where resources should be assigned in order to lower production cost. When renewability is being investigated, such as in this biodiesel production study, net energy balance (NEB) and net energy ratio (NER) are the more appropriate

metrics (Fore et al., 2011). Net renewable energy value (NREV) and fossil energy ratio (FER) are also relevant as they indicate the sustainability of the process.

The objective of this study was to determine the potential of coconut oil biodiesel for use in diesel engines based on its energy values. Additionally, the physical properties of the biodiesels of four different locally produced coconut oils were determined for their compatibility in diesel engines in Trinidad and Tobago.

2. Materials

Four locally available coconut oils were used in this study, namely, Eastern Brand, Palmola, Naisa, and Nariel. Analytical grade sodium hydroxide, methanol and sulphuric acid were used.

3. Transesterification Method

Free fatty acid (FFA) content was determined from AOCS Official Method Cd 3d-63 (AOCS, 2010). The FFA content of Eastern Brand, Palmola, Naisa, and Nariel were determined as 1.9%, 0.03%, 0.18% and 0.03%, respectively. Eastern Brand was the only oil with FFA>0.5%, thus requiring an acid esterification step (Meher et al., 2006; Ma and Hanna, 1999). Acid transesterification experimental conditions were 0.5wt% H_2SO_4 (Berchmans and Hirata, 2008; Jain & Sharma, 2010), 0.35 v/v methanol, 1 hour reaction time at 60°C (Nakpong and Wootthikanokkan, 2009) under reflux conditions with vigorous stirring. The top methanol-water layer was removed and the bottom oil layer was washed with 1/5 of the oil volume (Sharma, et al., 2008) of 0.001M NaOH solution at 50ºC until neutral after which it was dried.

Base transesterification experimental conditions were 60ºC (Jain and Sharma, 2010), vigorous stirring (Meher et al., 2006), 6:1 or 3:1 methanol to oil ratio (Meher et al., 2006; Ma & Hanna, 1999), 2 hour reaction time and 1 wt% NaOH (Meher et al., 2006; Ma and Hanna, 1999) under reflux conditions. Post reaction, the bottom glycerol layer was removed using a separatory funnel. The top biodiesel layer was washed to pH7 using warm distilled water. Complete drying was done using anhydrous magnesium sulphate. The physical properties of the final biodiesel product were then determined using ASTM methods and compared with local and international specifications.

4. Characterisation of bio-diesel

A qualitative GC-MS analysis of the reaction products was conducted to confirm that methyl esters were produced by the altered reaction. An Agilent 5975C Series GC/MSD was operated in split mode with 50:1 split ratio using a BD 14103 capillary column, 30m x 0.250 i.d. x 25µm film thickness. The front inlet was heated to 250ºC. Injection volume for all analyses was 2µL. The oven was heated to 60ºC for 2 mins, ramped at 10ºC/min to 200ºC, ramped at 5ºC/min to 240ºC and held for 7 min.

5. Determination of energy metrics

Net energy ratio (NER), net energy balance (NEB) (Fore et al., 2011), net renewable energy value (NREV) (Eshton et al., 2013) and fossil energy ratio (FER) (Mohammadshirazi et al., 2014) were determined using equations 1-4 in Table 1. In order to use these metrics, input and output values were converted to their energy equivalent value using equation 5 (Mohammadshirazi et al., 2014) from Table 1. Inputs were labour cost, coconut oil, methanol, and electricity. The main outputs were the biodiesels and glycerol. The actual quantities that were used in the laboratory were recorded and used in energy equivalent calculations.

Energy equivalent conversion values for labour, alcohol, electricity, biodiesel and glycerol in the biodiesel process were previously determined (Mohammadshirazi et al., 2014, Hossain et al., 2012). However, KOH was used as the catalyst and waste cooking oil was the feedstock in Mohammadshirazi et al. (2014). In Hossain et al. (2012), the biodiesel was derived from coconut oil. The present study used H_2SO_4, NaOH, and refined coconut oil. Lower heating values (LHV), or net calorific values, can be used as energy equivalent conversion values for the coconut oil feedstock (Farobie and Matsumura, 2015). LHVs were determined from net calorific value laboratory analyses of the coconut oils and biodiesel (see Table 2).

Table 1. Metrics equations

Equation #	Metric	Units	Equation for calculation
1	*NER*	-	$= \frac{Energy\ output\ (^{MJ}/_{L})}{Energy\ input\ (^{MJ}/_{L})}$
2	*NEB*	MJ/L	$= Energy\ Output\ (^{MJ}/_{L}) - Energy\ Input\ (^{MJ}/_{L})$
3	*EREV*	MJ/L	$= \text{Energy output of biodiesel}\ (^{MJ}/_{L}) - \text{Fossil energy inputs}\ (^{MJ}/_{L})$
4	*FER*	-	$= \frac{Renewable\ fuel\ energy\ output\ (^{MJ}/_{L})}{Fossil\ energy\ input\ (^{MJ}/_{L})}$
5	*Total energy equivalent*	MJ/L	$= Quantity\ per\ 1L\ of\ biodiesel\ (^{unit}/_{L}) \times Energy\ equivalent\ conversion\ (^{MJ}/_{unit})$
6	*Total cost and income equivalent*	US$/L	$= Cost\ equivalent\ (^{US\$}/_{unit}) \times Quantity\ per\ 1L\ of\ biodiesel\ (^{unit}/_{L})$

Table 2. Calorific values

Property	Test Method	Palmola	Nariel	Naisa	Eastern Brand
Net Calorific Value, BTU/lb	ASTM D4868	17973	18001	17973	18018
Net Calorific Value, MJ/kg	-	41.81	41.87	41.81	41.91

*Conversion Rate:*1 Btu/lb = 2.326 kJ/kg

Since energy can take many forms and is defined as anything that makes it possible to do work (Banks, 2000), it can be assumed that the standard heat of formation, in MJ/mol, of the catalysts is stored as potential energy and can be used as energy equivalent conversion values. The standard heat of formation for NaOH (crystalline) was listed at -101.99 kg-cal/mol (Lange and Forker, 1967), or 426.7 kJ/mol. For concentrated H_2SO_4 (aq), it was –887.3 kJ/mol (Lide, 2004).

6. Results and Discussion

6.1 Fuel Characterisation

All spectra of the biodiesels confirmed the presence of the expected methyl esters at similar retention times. The spectra for Naisa, which is representative of the other brands, is shown in Figure 1.

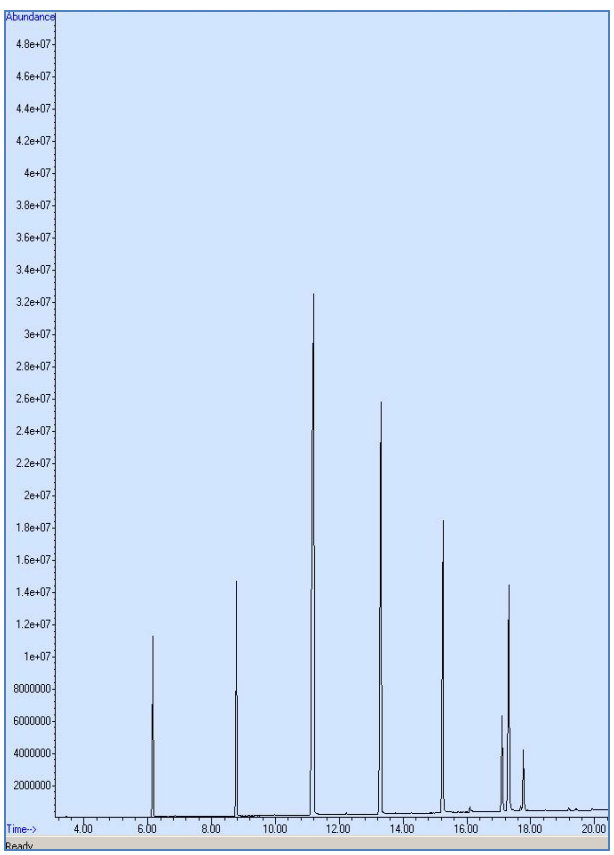

Figure 1. GC spectra for methyl esters present in Naisa biodiesel

Peaks were observed at retention times of 6.154, 8.761, 11.205, 13.279, 15.220 and 17.123 mins for methyl esters of octanoic acid, decanoic acid, dodecanoic acid, tetradecanoic acid, hexadecanoic acid and octadecanoic acid. This agreed with the composition of the expected coconut oil methyl esters present in quantities >5% (Jayadas and Nair, 2006).

6.2 Fuel Properties

The main fuel properties specification used for comparison was the local TTS 569:2011 automotive vehicle specifications (TTBS, 2011). Although international specifications ASTM D975-08a for grade 2D diesel (Jääskeläinen, 2015) and ASTM D6751 and EN 14214 for biodiesel (Knothe, et al., 2005) are also listed in Table 3, it should be noted that this is for comparison only as the test methods differ.

All biodiesel properties were within specifications for the local automotive market except for density and cetane index, which are considered key properties for engine performance (Gülüm and Bilgin, 2015). Density for all biodiesels was higher than the TTS 569:2011 specification. Its value affects the engine output power, fuel consumption, combustion and exhaust emissions (Gülüm and Bilgin, 2015; Chinnamma et al., 2015) and its effect on engine performance is observed immediately (Chevron Corporation, 2015). However, as density values ranged from 873-875 kg/m3 they did fall within EN14214 specifications for biodiesel. Apart from Eastern Brand, all cetane numbers were lower than specification. However, the values, which ranged from 41 to 42 in this study, were similar to the cetane index value of 40.20 determined for coconut oil methyl esters in a previous study (Chinnamma et al., 2015). Low cetane numbers can cause the engine to misfire and slower engine warm-up (Knothe et al., 2005). These biodiesels therefore cannot be used in the local automotive market in their unadulterated form, but can be part of diesel-biodiesel blends that conform to specifications as is done in other countries (Santana et al., 2010).

6.3 Energy Analyses

The yield for acid transesterification of Eastern Brand was 99% to produce the lower FFA oil. Base transesterification yields were 94%, 92%, 94%, and 99%

Table 3. Properties of coconut oil biodiesels

Property	Test Method	TTS 569:2011 specifications	Palmola	Nariel	Naisa	Eastern Brand	International specifications		
							ASTM D975-08a	ASTM D6751	EN 14214
Flash point, ºC	ASTM D93	55 min	112	88	110	136	52	130 min	120 min
Water content, volume %	ASTM D95	0.05 max	<0.05	<0.05	<0.05	<0.05	NS	NS	*
Sediment, mass %	ASTM D473	0.01 max	<0.01	<0.01	<0.01	<0.01	NS	NS	NS
Cetane Index	ASTM D613	46 min	**42**	**41**	**41**	49	NS	NS	NS
Distillation temperature (90% volume recovered), ºC	ASTM D86	282-357	318	314	319	334	282- 338	360 max	NS
Pour point, ºC	ASTM D97	10 max	-9	-9	-9	3	NS	NS	NS
Copper strip corrosion resistance (3h at 50ºC)	ASTM D130	1	1b	1a	1b	1b	No.3 max	No.3 max	1
Kinematic viscosity (at 40ºC), cSt	ASTM D445	1.9-5.0	2.7	2.73	2.74	3.99	1.9-4.1	1.9-6.0	3.5-5.0
Density at 15ºC, kg/m^3	ASTM D1298	820-865	**873**	**874**	**875**	**875**	NS	NS	860-900

Keys: NS- Not specified; *- not specified in volume %; In **Bold** - Out of specification with reference to TTS 569:2011

for Eastern Brand, Palmola, Naisa, and Nariel, respectively.

Energy equivalents were first determined and are listed in Table 4. The total input and output values for each biodiesel from Table 4 were then used to calculate NER, NEB, NREV and FER (see Table 5).

NER, also termed as energy use efficiency, (Mohammadshirazi et al., 2014) values ranged from 0.55 to 0.63 for all biodiesels which meant that the process was 55-63% energy efficient. NER values from other literature included 3.23 for palm oil biodiesel (Cho et al., 2013), 0.92 for canola oil biodiesel (Farobie and Matsumura, 2015), and 1.49 for waste cooking oil (Mohammadshirazi et al., 2014). Values of 0.55-0.63 are therefore comparatively low. In this study, the calculations did not consider the unreacted methanol as an output because it was not purified and this would require additional labour and electricity as inputs. If considering the unreacted methanol similarly to that of other authors (Mohammadshirazi et al., 2014), the NER values increase from 0.79 to 0.89.

NEB was negative for all biodiesels, ranging from -34.41 to -29.09 MJ/L, and compared unsatisfactorily with the NEB of 14.9 MJ/L for waste cooking oil (Mohammadshirazi et al., 2014). A positive value of NEB was required for the fuel to be considered a sustainable source of energy (Kamahara et al., 2010). These negative values indicated that more energy was consumed than produced in the process.

Table 4. Energy analysis of inputs and outputs of biodiesel production (6:1 methanol to oil ratio)

Particulars	Unit	Quantity per 1L of biodiesel (unit/L)				Energy Equivalent Conversion value (MJ/unit)				Total energy equivalent (MJ/L)			
		Palmola	Nariel	Naisa	Eastern Brand	Palmola	Nariel	Naisa	Eastern Brand	Palmola	Nariel	Naisa	Eastern Brand
Inputs													
Human Labour	h	0.25	0.25	0.25	0.5	1.96	1.96	1.96	1.96	0.49	0.49	0.49	0.98
Coconut Oil	kg	0.95	1.02	0.94	0.95	41.81	41.87	41.81	41.91	39.72	42.71	39.30	39.81
Methanol	kg	1	1	1	1.1	33.7	33.7	33.7	33.7	33.7	33.7	33.7	37.07
NaOH	kg	0.008	0.009	0.008	0.009	10.67	10.67	10.67	10.67	0.09	0.10	0.09	0.10
H_2SO_4	kg	-	-	-	0.005	-	-	-	9.14	-	-	-	0.05
Electricity	KWh	0.0005	0.0005	0.0005	0.00075	11.93	11.93	11.93	11.93	0.006	0.006	0.006	0.009
ENERGY INPUT										**74.00**	**77.00**	**73.58**	**78.02**
Outputs													
Biodiesel	kg	0.86	0.86	0.86	0.86	40.37	41.87	40.37	48.95	34.72	36.01	34.72	42.10
Glycerol	L	0.33	0.26	0.3	0.27	25.3	25.3	25.3	25.3	8.35	6.58	7.59	6.83
ENERGY OUTPUT										**43.07**	**42.59**	**42.31**	**48.93**

Table 5. Energy performance metrics for 4 coconut oil biodiesels (6:1 methanol to oil ratio)

Items	Unit	Palmola	Nariel	Naisa	Eastern Brand
NER	-	0.58	0.55	0.57	0.63
NEB	MJ/L	-30.93	-34.41	-31.27	-29.09
NREV	MJ/L	0.92	2.22	0.91	4.98
FER	-	1.03	1.07	1.03	1.13

Net renewable energy value (NREV) and fossil energy ratio (FER) metrics indicate fossil energy content. Fossil energy inputs were, in this study, methanol, sodium hydroxide, sulphuric acid and electricity (Pradhan et al., 2009). NREV values were 2.22 MJ/L for Nariel, 0.92 MJ/L for Palmola, 0.91 for Naisa, and 4.98 MJ/L for Eastern Brand. The positive values indicated that less fossil fuel was used to generate the renewable fuel than was actually produced by the renewable fuel (Eshton et al., 2013). FER was 1.03 for Palmola and Naisa, 1.07 for Nariel, and 1.13 for Eastern Brand. This can be interpreted as 1.03-1.13 MJ/L of renewable energy that was obtained for every 1 MJ/L fossil energy input. Reported FER values were 1.3 for waste cooking oil (Mohammadshirazi et al., 2014), 4.56 (Pradhan et al., 2009) and 3.2 for soybean oil (Sheehan et al., 1998), all values of which were higher than reported in this study.

NEB and FER indicated that the process was not energy efficient. Improvement of these metrics can be achieved by either lowering the energy inputs and/or increasing the energy outputs. Table 4 indicated that coconut oil and methanol were the highest total energy equivalents input values. Whilst the coconut oil quantities cannot readily be changed, the methanol values in the process can be lowered. Although a 6:1 methanol to oil ratio is typically used (Ma and Hanna, 1999), the stoichiometric ratio is actually 3:1. NEB and FER indicated that too much fossil fuel was being utilised to produce the renewable fuel. Since a lowered methanol content should also improve these metrics, a follow-up experiment was conducted using the 3:1 stoichiometric ratio, with all other experimental parameters remaining the same.

Biodiesel yields using a 3:1 methanol to oil ratio for Palmola, Naisa and Nariel continued to be high at 97%, 98% and 94%, respectively. However, Eastern Brand was considerably less at 60% yield as compared to 94% with a 6:1 methanol to oil ratio. The energy analyses and metrics were then recomputed and are listed in Tables 6 and 7.

The metrics heavily dependent on fossil fuel content showed considerable improvement upon use of the 3:1 ratio. NREV increased from 0.92 – 4.98 to 9 – 21.31. FER increased from values close to 1 to values ranging from 1.52 -2.88. NER improved slightly with a lowered methanol to oil ratio, with the range increasing to 0.55-0.63. Although the values are still negative, NEB improved for Palmola, Naisa and Nariel, but not for Eastern Brand. NEB is used to determine loss or gain of energy. It indicates whether the process is sustainable (Cho, et al., 2013). Results show that even using a lowered methanol content, the process is not sustainable as the inputs are too high compared with the outputs. Another high energy input is that of coconut oil. As such, in terms of energy conversions, coconut oil is not a viable feedstock. Within the Caribbean, coconut oil is the most widely available local oil source. However, coconut oil biodiesel may not be a sustainable alternative to petrodiesel. Other feedstock inputs should therefore be investigated for a viable, sustainable process. Specifically, Mohammadshirazi et al. (2014) demonstrated via energy metrics that using waste cooking oil is one of the most sustainable options, and this is an option that can be explored in the Caribbean.

Table 6. Energy analysis of inputs and outputs of biodiesel production (3:1 methanol to oil ratio)

Particulars	Unit	Quantity per 1L of biodiesel (unit/L)				Energy Equivalent Conversion value (MJ/unit)				Total energy equivalent (MJ/L)			
		Palmola	Nariel	Naisa	Eastern Brand	Palmola	Nariel	Naisa	Eastern Brand	Palmola	Nariel	Naisa	Eastern Brand
Inputs													
Human Labour	h	0.25	0.25	0.25	0.50	1.96	1.96	1.96	1.96	0.49	0.49	0.49	0.98
Coconut Oil	kg	0.89	0.94	0.90	1.48	41.81	41.87	41.81	41.91	37.21	39.36	37.63	62.03
Methanol	kg	0.41	0.43	0.41	0.95	33.70	33.70	33.70	33.70	13.75	14.59	13.82	32.02
H_2SO_4					0.01				9.14				0.05
NaOH	kg	0.008	0.009	0.008	0.009	10.67	10.67	10.67	10.67	0.085	0.096	0.085	0.096
Electricity	KWh	0.0005	0.0005	0.0005	0.00075	11.93	11.93	11.93	11.93	0.006	0.006	0.006	0.009
ENERGY INPUT										**51.54**	**54.54**	**52.03**	**95.17**
Outputs													
Biodiesel	kg	0.85	0.86	0.86	0.84	40.37	41.87	40.37	48.95	34.31	36.01	34.72	41.12
Glycerol	L	0.13	0.18	0.21	0.31	25.30	25.30	25.30	25.30	3.29	4.55	5.31	7.84
ENERGY OUTPUT										**37.60**	**40.56**	**40.03**	**48.96**

Table 7. Energy performance metrics for 4 coconut oil biodiesels (3:1 methanol to oil ratio)

Items	Unit	Palmola	Nariel	Naisa	Eastern Brand
NER	-	0.73	0.74	0.77	0.51
NEB	MJ/L	-13.94	-13.98	-12.00	-46.21
NREV	MJ/L	20.47	21.31	20.81	9.00
FER	-	2.72	2.76	2.88	1.52

Cooking oil is one of the top ten imports in the Caribbean, accounting for $246.64M USD in 2011 (FAOSTAT, 2016). In 2013, Antigua and Barbuda, the Bahamas, Barbados, Jamaica, and Monstserrat alone spent 57.7 M USD on edible oils, importing 62,277 tonnes (FAOSTAT, 2016). Waste collection is paid for via taxation in Jamaica, and Belize, through government subventions in Trinidad and Tobago, Haiti, and Suriname, and direct billing or private companies in the Bahamas (Riquelme et al., 2016). In Barbados and Guyana, waste collection is supported via both taxes and government subventions (Riquelme et al., 2016). Through the use of waste cooking oil for biodiesel production, an opportunity exists for the sustainable production of biodiesel, reduction in food import spending, and reduction in the cost of waste collection.

7. Conclusions

The energy performance evaluation of four coconut oil biodiesels revealed the following:

1. With respect to fuel properties, coconut oil biodiesel could be used in the local market as a constituent in environmentally friendly, sustainable blends with diesel fuel.
2. NEB and NER energy metrics indicated that the process was not energy efficient at both the 6:1 and 3:1 methanol to oil ratios.
3. NREV and FER energy metrics indicated that too much fossil energy was being used to produce the renewable fuel when a 6:1 methanol to oil ratio was used. At the 3:1 ratio, NREV and FER values were comparable to the literature values. They can be further improved with added use of bioalcohols in the process, and renewable energy as the heat source.

It should be noted that a conventional energy metrics analysis cannot satisfactorily be reflective of certain important benefits associated with the use of biodiesels such as reducing oil imports and foreign debt, decreasing greenhouse gas emissions, stimulation of domestic agricultural production by expansion of demand for oil feedstock and generating rural employment (Nguyen et al., 2007), as well as conserving on current petroleum reserves. There has also been step-wise reduction of fuel subsidies in Trinidad and Tobago. This created a diesel price increase from TT$1.50/L (US$0.23/L) to TT$2.30/L (US$0.35/L) (GORTT, 2016) over a one-year period. These concerns, coupled with simultaneous concerns about international low oil prices (GORTT, 2016), have encouraged the investigation into alternative fuels as a reliable and competitive alternative to petroleum fuels, ensuring that this study is both timely and relevant.

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Design and Development of a Low-Noise Lawnmower Blade: Application of CAD, CAE and RP Tools and Techniques

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Abstract: *This study involved the design and development of a low-noise lawnmower blade using virtual modeling tools and Rapid Prototyping (RP) principles. Computer Aided Design (CAD) and Computer Aided Engineering (CAE) tools and techniques were used to generate an optimised model of the original lawnmower blade which was prototyped using a Fused Deposition Modelling (FDM) machine. The prototype generates lower noise levels than the original blade and the virtual modeling tools are adequate enough to predict the noise levels of the proposed blade design. Furthermore, the use of RP technology in the fabrication of the blade has potential to reduce developmental cost and time.*

Keywords: *Computer Aided Design, Computer Aided Engineering, Rapid prototyping, Noise, Lawnmower Blade*

1. Introduction

The effects of noise pollution on human health are considerably greater than hearing problems (Chepesiuk, 2005). Elevated blood pressure, loss of sleep, increased heart rate, cardiovascular constriction, laboured breathing and changes in brain chemistry are all caused by noise exposure (Chepesiuk, 2005). Moreover, listening to high decibel sounds over a prolonged period can cause serious hearing loss (Hughes, 2013). Rotary lawnmowers produce an upwards of 120 dB of noise, 80 dB being the Environmental Management Authority's (EMA) upward limit for commercial areas of Trinidad and Tobago during daytime (Environmental Management Authority, 2001). Therefore, there is a need to reduce the noise generated by rotary lawnmowers.

The primary sources of electric lawnmower noise include motor noise and blade noise, the latter of which is more significant (Guentiier et al., 1977). Blade noise is generated from curving vortices formed by the blade tips when rotating. The pressure on one surface of the blade is greater than on the other which results in air flow around the tip from the high pressure area to the low pressure area, which causes noise (Reza et al., 2003). Its effects can be reduced by:

- Decreasing the rotational speed of the blade (Guentiier et al., 1977);
- Sharpening of the blade edges (Guentiier et al., 1977);
- Reducing the thickness and width of blades (Guentiier et al., 1977);
- Adjusting the curves (Moore, 1981); and
- Placing holes and winglets to break the air vortices (Moore, 1981)

Frequency domain and time domain numerical models have been used extensively to analyse rotating blade noise (Mao et al. 2014). However, these methods are tedious and require calculation of retarded times and numerical differentiations that are computationally expensive (Sinayoko et al. 2013). Their applications have been limited to fans, propellers and wind turbines (Farassat and Brentner, 1997). Tauro and Mann (1997) stated that analytical models are impractical due to the complex geometries of lawnmower blades and recommend that an experimental method be employed to analyse blade noise. Bockhoff et al. (2004) stated that experiments need to be performed taking account of the lawnmower's operating conditions for accuracy of results. However, constructing and testing physical prototypes based on trial and error approaches lead to wastage of time and resources (Manivannan, 2010).

Modifications to lawnmower blades to reduce noise are currently being undertaken. A study by Guentiier et al. (1977) showed that sharpening the leading and trailing edges of the blade reduces noise. They also found that reducing the blade speed and thinner, narrower blades reduce the noise generated. The lawnmower company Briggs and Stratton focused on designing a quieter blade by modifying the curves and placing holes to break the turbulent air using a trial and error approach (Cancino, 2014). Reza et al. (2003) used CFD and FEA techniques to optimise a lawnmower mulching blade to increase lift and reduce noise. In this study, the decrease in noise level was assumed to be the decrease in turbulent kinetic energy of the CFD model. The design engineers at lawnmower company, Viking, used ANSYS CFX fluid flow simulation software to

simulate the airflow in their lawn mower deck to determine the sources of noise (ANSYS, 2010). Several variables, such as fast blade rotation, unsteady pressure and high fluctuations of the air velocity within a lawnmower deck, create a complex airflow that makes traditional development and measurement methods almost impossible (ANSYS, 2010). Therefore, there is need of a structured approach to design a low noise lawnmower blade. Thus, the study used a virtual modelling approach by Gokool et al. (2015) which combines Computer Aided Design (CAD) and Computer Aided Engineering (CAE) methods coupled with Rapid Prototyping (RP) principles to efficiently design and develop a prototype blade.

Prototyping is defined as the process of developing an approximation of the product to be produced (Ali et al., 2013). Virtual or analytical prototypes are non-tangible representations of a product, usually a mathematical or simulation model where aspects of the product can be analysed, before manufacturing a physical prototype, to test the form and function of the part (Vaughan and Crawford, 2013). Computational Fluid Dynamics (CFD), Finite Element Analysis (FEA) and various optimisation techniques are commonly used to analyse virtual prototypes. Additive Manufacturing (AM), which includes Rapid Prototyping (RP) or 3D printing, refers to technologies that build three dimensional (3D) models by the addition of material layer upon layer with use of CAD software (Ali et al., 2013). RP technologies include Stereo-Lithography, Selective Laser Sintering (SLS), Multi-Jet Modelling (MJM) and Fused Deposition Modelling (FDM) which will be used in this study. The use of AM is ever-growing in industry, since it enables the quick and cost effective conversion of design ideas with complex geometries into working models and even end-use parts (Yang et al., 2013; Meisel and Williams, 2015).

This study employed a new structured approach to the design and development of a low noise electric lawnmower blade by using CAD, CAE and RP techniques, which saved time and cost. The performance of the physical prototype blade was assessed in its operational environment in terms of noise generation, quality of cut and durability.

2. Methodology

Figure 1 shows the research methodology. The study began with reverse engineering the current blade design to produce a CAD model. Then the blade design is re-engineered using CFD simulation to model the noise generation. Central composite design (CCD) is used to determine the number of experimental runs required to effectively create a prediction model using Response Surface Methodology (RSM). Furthermore, Genetic Algorithm (GA) was utilized to find the optimal parameter condition for minimum blade noise. This was followed by a finite element analysis (FEA) of the optimised blade to determine its structural integrity. Finally, the blade was rapid prototyped and compared to the original design.

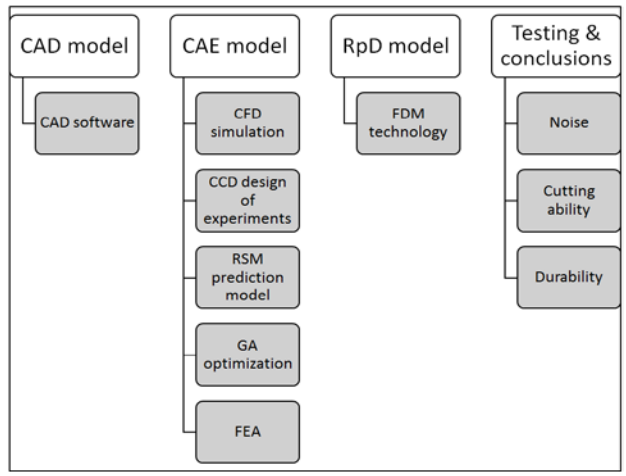


Figure 1. Research Methodology

3. Development of a Computer Aided Design Model

The dimensions of the original blade of the selected lawnmower were used to create a 3D CAD model in SolidWorks™ software. It was assumed that the curves were simple fillets, the cutting edge was straight with a thickness of 1 mm and the blade was straight if seen from the top view. The CAD model of the original blade is shown in Figure 2.

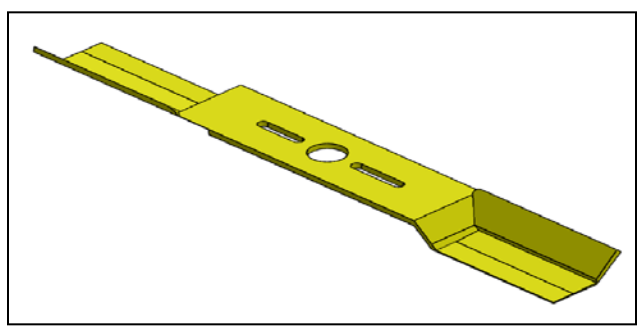


Figure 2. CAD model of the original blade

3.1 Generation of a Computer Aided Engineering Model

SolidWorks Flow Simulation™ module was used to create a CFD model of the rotating blade and it was assumed that the sound pressure was equal to the difference in dynamic air pressure between the top and bottom surfaces of the rotating blade geometry. The settings used while creating the CFD model appear in Table 1. The developed model was validated by means of CFD-based noise-angular speed and physical test

runs. The results appear in Figure 3. The average deviation of the noise level was 3.58 dB. This value includes allowance for experimental errors. The material of the blade had little effect on the noise generated. Polycarbonate (PC) material was used for the virtual model and the original blade was fabricated from an unidentified plastic with metal and fiberglass reinforcements, yet there was no significant difference in noise levels. Thus, the developed virtual model was determined to be acceptable to conduct simulation runs.

Table 1. Settings of the CFD model

Option	Setting
Temperature	293 K
Pressure	101.3 kPa
Angular Velocity	3000 rpm
Angular Acceleration	0 rad/s^2
Air Flow	Laminar and Turbulent
Material	Polycarbonate

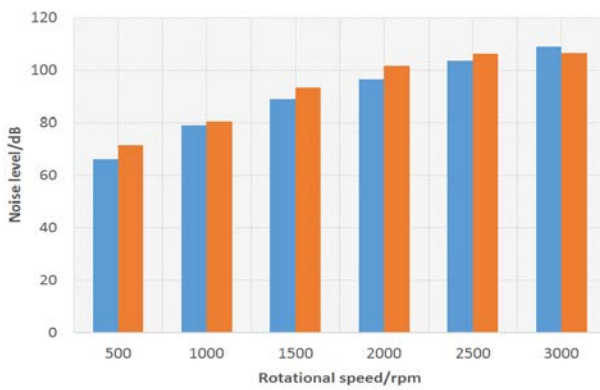


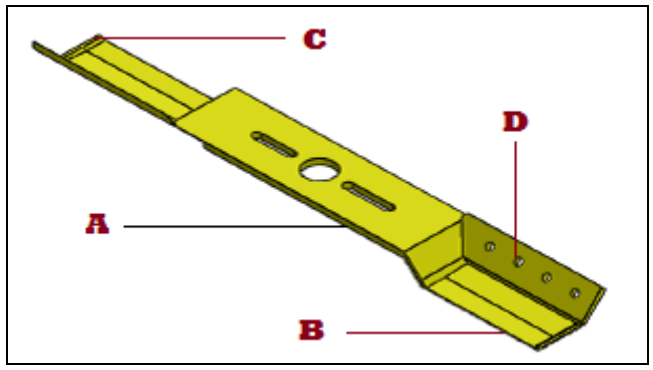
Figure 3. Comparison of the noise levels from virtual and physical tests

Central Composite Design (CCD) was used to determine the number of experimental runs required to optimise the four selected geometrical parameters. These parameters include blade thickness (A), cutting edge thickness (B), height of winglets at the blade edge (C) and diameter of added holes (D). These parameters were chosen based on previous research (Guentiier et al., 1977; and Moore, 1981). The elements of the blade—A, B, C and D—are depicted in Figure 4. To conduct experiments these parameters were set at three levels based on the geometrical constraints of the lawnmower deck and mounting. The parameters along with selected levels are in Table 2. The thirty-one experimental runs were performed using the CFD model.

The results of the experimental runs were analysed using the Response Surface Modelling (RSM) tool which is available in Minitab software (refer to Table 3.) and then the regression equation (1) was generated where the noise level was given by N_L. Equation (1) was tested and found to be in agreement with the experimental data. Figure 5 shows the deviation in experimental and calculated noise levels.

Table 2. Parameters and levels

No.	Parameters	Levels		
		-1	0	+1
1	Thickness of blade, A (mm)	5.08	6.67	8.26
2	Thickness of cutting edge of blade, B (mm)	0.8	0.9	1
3	Height of winglet, C (mm)	0	25	50
4	Diameter of air passage holes, D (mm)	0	6	12



Legend: A: Blade Thickness, B: Blade Cutting Edge Thickness, C: Height of Winglet, and D: Air Passage Hole Diameter

Figure 4. CAD model showing the four parameters under study

Table 3. Statistical Analysis of Predicted Model

Estimated Coefficients for Noise Level		
Predictor	Coefficient	P value
Constant	134.49	0.000
A	2.22	0.245
B	-1.14	0.545
C	8.31	0.000
D	-1.55	0.414
A^2	1.36	0.783
B^2	-7.11	0.162
C^2	-3.46	0.486
D^2	2.50	0.613
A^B	2.62	0.199
A^C	2.41	0.234
A^D	2.04	0.313
B^C	-2.68	0.188
B^D	-1.76	0.381
C^D	-3.24	0.116

Analysis of Variance					
Source	DF	Adj SS	Adj MS	F	P
Model	14	2392.26	170.88	2.80	0.026
Linear	4	1399.24	349.81	5.73	0.005
Square	4	391.04	97.76	1.60	0.222
Interaction	6	601.98	100.33	1.64	0.199
Error	16	976.33	61.02		
Total	30	3368.59			

$$N_L = 134.49 + 2.22\,A - 1.14\,B + 8.31\,C - 1.55\,D + 1.36\,A*A - 7.11\,B*B - 3.46\,C*C + 2.50\,D*D + 2.62\,A*B + 2.41\,A*C + 2.04\,A*D - 2.68\,B*C - 1.76\,B*D - 3.24\,C*D \quad \textbf{(1)}$$

Equation (1) was optimised by use of the GA tool, where the optimum noise level was obtained relative to the experimental parameters. The default GA tool settings of the MATLAB programme were used. The optimised results are presented in Table 4. The optimised design was tested with respect to stress, strain and deflection to ensure that the design was mechanically feasible, using the Simulation Xpress module of the SolidWorks software, before being prototyped.

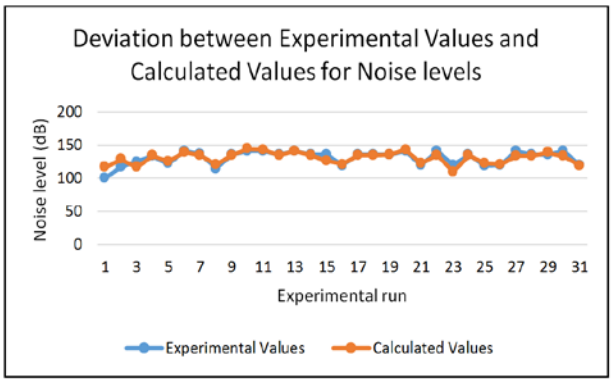


Figure 5. Deviation in Experimental and Calculated Values

Table 4. Optimised Results

Parameter	Optimum Value
Thickness of central section of blade, A (mm)	5.08
Thickness of cutting edge of blade, B (mm)	1
Height of winglet, C (mm)	1.803
Diameter of air passage holes, D (mm)	6
Noise Level (dB)	99.96

3.2 Production of a Rapid Prototype

The optimised blade model was fabricated using the Fortus FDM 400mc and PC material. The optimal blade design in STL file format was sliced and prototyped. After completion of the four-hour printing process, the RP model was allowed to cool and the support material was subsequently removed. Figure 6 shows the photograph of the 3D-printed blade. In Figure 7 the 3D-printed blade is shown alongside the original blade, displaying the design differences in terms of the added air passage holes and winglet.

Figure 6. 3D-printed blade with support material removed

Figure 7. Original and redesigned lawnmower blades

4. Discussion of Results and Inferences

4.1 Results and Analysis

Table 5 shows the noise-distance test results. It can be seen that the noise level of the lawnmower decreases as distance from it increases. Although the operator experiences 82.7 dB of noise when the original blade was used, a bystander at 3 m away from the lawnmower only experienced 78.8 dB of noise which is significantly quieter. Also, the prototype was less noisy than the original blade. The operator experienced a difference of 4.5 dB using the prototype blade which is clearly noticeable according to Bies and Hansen (2009). The prototype produced an average of 5.025 dB less noise than the original blade. However, upon cutting the 4th metre of grass, the prototype blade broke, resulting in a discontinuation of the noise-distance test. The prototype blade was not durable.

Table 5. Results of the Noise-Distance Test

Distance/m	Noise level (in dB)		Deviation (dB)
	Original blade	Prototype blade	
0	82.7	78.2	4.5
1	81.9	76.6	5.3
2	79.6	74.8	4.8
3	78.8	73.3	5.5
Average deviation			5.025

Figure 8 illustrates the comparison of grass length cut by the two blades. As seen, the original blade provides a shorter cut, removing 1.35 inches of the grass. Whereas the prototype removed 1.20 inches of the grass, the quality of cut produced by the prototype is thus comparable to that of the original blade.

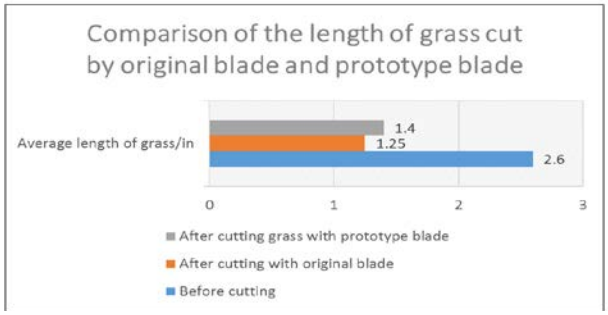


Figure 8. Comparison of quality of cut by means of grass length for the original and prototype blades

4.2 CAD and CAE Model Results

A low noise lawnmower blade was designed using CAD and CAE modelling tools and techniques. The CAD process involved the reverse engineering of the original blade to create a 3D geometrical model for use in the simulation and analysis of the CAE phase. The CAE phase involved the use of CFD and GA optimisation tools to re-engineer the blade in order to reduce the noise it generated.

The CFD model predicted the generated noise levels of the blade geometries. This saved time and cost in executing the experimental runs but simplifying a complex phenomenon such as the generation and propagation of sound lead to errors. Also, since the simulated geometries were different, the location of the sound pressure waves may have been different which could have led to inaccurate readings that were introduced in every subsequent step.

The optimisation of the parameters by use of CCD, RSM and GA was a novel approach employed to design a low noise lawnmower blade (Gokool et al., 2015). This method proved effective and can be further improved to produce less noise.

4.3 Rapid prototyping

Producing a physical prototype using the Fortus FDM 400mc enabled the faster and cheaper production of the artefact. This prototype enabled the assessment of the study objective, reduction in blade noise. Moreover, it was found that the prototype generates less noise than the original blade.

Normally material selection will affect a prototype's strength and durability (Hague et al., 2004). In the study, PC was used for the prototype, which is strong in tension and poor in impact strength compared to the other FDM thermoplastics (Fischer, 2011). Additionally, the lack of reinforcement of the blade contributed to its quick failure. It may be argued that the comparison of a reinforced blade with an unreinforced one is invalid since reinforcement introduces more factors into the investigation other than pure geometry. However, no research in the literature was encountered that showed any relationship between reinforcement and blade noise, or more so material and blade noise. This should be investigated further but until then the comparisons made in this investigation hold.

The FDM based RP technique also influenced the performance of the redesigned blade. As seen in Figure 9, the material was deposited as layers which are visibly noticeable in the produced part. These layers allow for the build-up of shear stresses which can lead to mechanical failure especially in thin sections such as the cutting edge of the blade. It is suggested therefore that if the final product is to be produced on a commercial scale, the blade should be manufactured using the process of injection moulding which provides more durable final product. If RP technique is to be used to manufacture the functional part then reinforcement and surface finish are two significant areas that need to be addressed in design and development of the blade.

The generated CAD model of the study contained a flaw where the extruded faces met. The flaw manifested as a narrow channel which might be a cause for the blade failure. This may have been prevented by using a 3D scanner to convert the physical object geometry to CAD model.

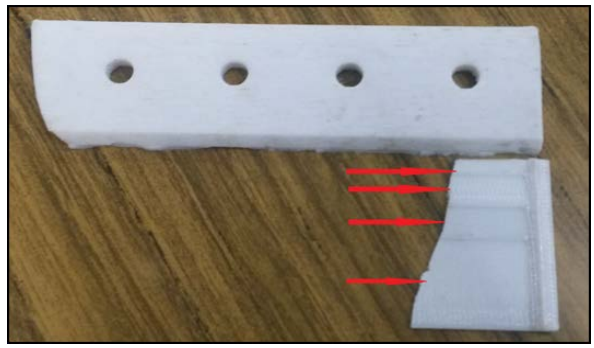


Figure 9. Broken pieces of the prototype blade showing the material layers

4.4 Environmental Impact

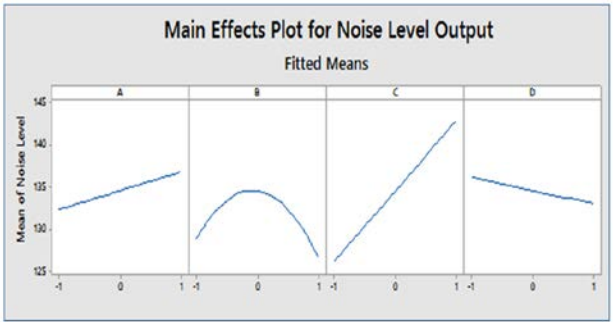
Rotary lawnmower blades have two potential environmental impacts, noise and solid waste pollution. Noise pollution affects people and animals. Although noise dissipates relatively quickly, its effects can last a lifetime such as permanent hearing impairment. The design of this low noise blade decreases the sound made by the lawnmower, which reduces the likelihood of permanent health effects. The blade design was not reinforced which simplifies its recycling at the end of life.

4.5 Relationship between Blade Noise and Parameters

The method of CCD did not only develop the fitness function for optimisation by the GA but also established relationships between the investigated parameters and blade noise which is shown in Figure 10. It can be seen that blade noise increases with an increase in blade thickness (A) and winglet height (C), and a decrease in diameter of air passage holes (D). Also, it can be inferred that the blade noise increases with an increase in cutting edge thickness (B) until a maximum is reached, after which it decreases with an increase in cutting edge thickness.

5. Conclusion

This study presented the design and development of a low noise lawnmower blade. It has shown that CAD and CAE techniques can be incorporated to create a novel



Legends: A: Blade Thickness, B: Cutting Edge Thickness, C: Winglet Height, D: Air Passage Hole Diameter)

Figure 10. Main effects plot showing the relationship between each parameter and blade noise output

redesign of a blade for minimum noise, and AM led FDM 400mc can be used to create prototypes with minimal cost and time. The prototype generated an average 5.025 dB less noise than the original blade, gave a comparable quality of cut by removing 1.20 inches of the grass stalk but its durability was greatly affected by the PC based RP process.

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The Dry Sliding Wear Behaviour of Aluminum Composites: A Review

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Abstract: *Aluminum composites has been of wide applications in the automobile, aerospace, defense and other engineering sectors especially where dry sliding wear plays major role. Many processing techniques have been used over time depending on various predetermined criteria. This review presents effects of dry sliding parameters (sliding speed, sliding distance and load) coupled with process parameters (stir cast and reinforcement parameters) on the dry sliding (adhesive) wear behaviour of aluminum composites produced by stir casting technique. Many investigative works have been done on the impact of sliding speed, load and distance but only few of such studies linked stir casting and reinforcement parameters with the wear properties of aluminum composites.*

Keywords: *Aluminum composites, dry sliding wear, stir casting, specific wear*

1. Introduction

Metal matrix composites (MMC) are engineered non monolithic materials which consist of a metal or an alloy as the continuous matrix and a reinforcement that can be particle, short fibre or continuous fibres. The evolvement of MMCs has initiated feasible combination of different material properties (mechanical, physical and tribological) resulting into availability of large pool of materials used in applications such as aerospace, automotive, building construction, industrial, and sports (Sallahauddin et al., 2015). Metals such as aluminum, titanium and magnesium have been used as matrix over time because of their high strength to weight ratio, high resistant to corrosion, excellent thermal properties among others. However, aluminum alloy has continued to enjoy a more prominent usage because of its properties, performance, economic and environmental benefits (Saravanan et al., 2015). Most of the aluminum alloys chosen as matrix are A356, 2000 and 6000 alloys (Dasgupta et al., 2010).

The need to reinforce aluminum alloy with other materials to produce aluminum matrix composites (AMC), which is useful in applications where aluminum alloy cannot be used is due to poor response of aluminum alloy to such conditions as wear resistant conditions. However, AMCs have proved to be a reliable and efficient wear resistant material especially for sliding wear applications (Dasgupta, 2012). The suitability of materials for wear applications requires good understanding of the concept of wear. Wear has been described as the result of full interaction between surfaces in relative motion or the continuous loss of matter from surfaces as an effect of relative motion (Sergio, 2004; Yust, 1985). Wear is experienced in different modes in diverse engineering applications. It is understood that complete knowledge of wear mechanism ultimately results in better specification of materials including composition and properties (Rabinowitcz, 1965). Wear is affected by several factors, from operational, topography of the surface contact, geometry, speed, load, coefficient of sliding friction, material (hardness, temperature, elasticity, breakage, thermal properties), environmental, the type and degree of lubrication and surface cleanliness parameters (Riyadh, 2012). When wear as experienced in dry sliding surface contacts is examined, it is referred to as dry sliding wear.

Dry sliding wear behaviour of a material could be evaluated from sliding wear parameters and stir cast parameters, such as stirring speed and time, particle size, type and volume fractions (Ashok et al., 2012). The sliding wear behaviour of composites has been found to depend on the volume fraction and particle size of reinforcements, hardness and strength of matrix alloy, applied load and environmental temperature (Umanath et al., 2011; Senthil et al., 2016).

In the production of AMCs, different processing routes have been used over time. These processing routes influence the tribological properties as a result of agglomeration, distribution and segregation of the reinforcing particles in the composites that occurred during production (Raghavendra and Ramamurthy, 2014). The processing routes are based on the state of matter of the matrix metal and can either be solid state process (i.e., powder metallurgy, high energy ball milling, friction stir processing, diffusion bonding, vapour deposition techniques) or liquid state process (i.e., stir casting process, compo-casting, in situ reaction,

squeeze casting, ultrasonic assisted casting, plasma spraying or spray co-deposition) (Wahab et al., 2009; Yuan and An, 2012). The choice of a particular processing route may depend on the size of production, surface finish, material properties and the specific materials application. In this paper, the effect of dry sliding wear and process parameters on the dry sliding wear behaviour of aluminum composites produced by stir cast technique is reviewed.

2. Stir Casting

Stir casting is a simple and cost effective liquid metallurgical technique that is deployed in the production of MMCs especially when the reinforcements are discontinuous fibres or particulates (Rahdika et al., 2011). While there are varieties of processing techniques available for particulate or discontinuous reinforced MMCs, stir casting technique has enjoyed patronage for the production of large quantity of components in commercial practice (Mathur and Barnawal, 2013). Its attractiveness is due to simplicity, flexibility and it is mostly economical for large sized components production (Hashim et al., 1999). Stir casting technique involves application of mechanical energy to stir the mixture of the liquid matrix and the reinforcements to aid uniformity in the distribution of the reinforcement in the liquid matrix.

Uniform distribution of reinforcement is very important for good tribological properties. Uniform distribution or homogenisation of reinforcements in the matrix depends on materials properties and process parameters like wetting condition of the particles with the melt, strength of mixing, relative density of melt, geometry and position of the mechanical stirrer in the melt, stirring speed and time, melting and holding temperature, rate of solidification, holding time, mould material and the characteristics of the reinforcing particles. Hence, uniform distribution can be achieved through good selection of process parameters. These are important factors to be considered in the production of cast metal matrix composites, as these have an impact on quality and properties of casting (Adat et al., 2015; Nahar et al., 2003; Shankar et al., 2013; Kumar et al., 2013; Pradeep et al., 2014; Subramani et al., 2014; Sharma et al., 2008).

3. Effect of Dry Sliding Wear Parameters

This describes the dry sliding wear behaviours of materials thus by extension it determines the suitability of materials for wear resistant operations especially in engineering applications that were dry sliding contacts being expected. Dry sliding wear parameters commonly investigated are sliding speed, sliding distance and load.

3.1 Sliding Speed

Sliding speed is an important parameter in the measurement of wear. The wear behaviour of composites can also be determined by the sliding speed (Jha et al., 2011). Dasgupta et al. (2010), reinforced a 7075 Al alloy with 10 vol.% Silicon carbide (SiC) and conducted a sliding wear test using a vertical pin-on-disc wear testing machine with loads of 9.8, 29.4 and 49 N and speeds of 400 and 640 rev/min. The test specimens include as produced composite and extruded composites.

Out of the three loads it was observed that for the extruded composite at a load of 9.8 N, the volume loss after a sliding distance of approximately 2,000 m becomes relatively constant irrespective of the speed. Higher sliding speed results in less material loss under a constant load, while more load results in higher material loss under the same rotation speed.

Babić et al. (2013) investigated the basic tribological properties of A356/10SiC/1Gr of compo casted hybrid composites in conditions with lubrication. Tribological tests were carried out using advanced and computer supported tribometer with block-on-disc contact pair under three different values of sliding speed and it was observed that with increasing sliding speed, wear rate of the hybrid composite A356/10SiC/1Gr and the base material decreases.

Manikandan and Karthikeyan (2014) investigated the dry sliding wear characteristics of 7075 aluminium alloy and the composites (Al7075/B4C, Al7075/Alumina, Al7075/SiC) under different load conditions. The applied load is varied from 20N to 60N with sliding velocity of 1-3 m/s for 2000 m sliding distance. The wear rate decreases with increasing sliding velocity in all conditions, the AMCs remains more resistant compared to Al7075 matrix in the order Al7075/B4C < Al7075/Alumina < Al7075/SiC. The result is attributed to the fact that metal to metal contact is high at low sliding velocity and it tends to plough the surface and cause high wear.

3.2 Sliding Distance

Another common measure of wear is the volume of material removed per unit sliding distance. The ratio of the wear in units of volume removed per unit sliding distance to the real interfacial area of contact is a meaningful dimensionless quantity useful in wear studies and is called the dimensionless wear coefficient, or simply the wear coefficient, Kok and Ozdin (2007) investigated the wear resistance of aluminum alloy and its composites reinforced by Al_2O_3 particles. Sliding wear tests on 10, 20 and 30 wt.% Al2O3 particles reinforced 2024 aluminum alloy composites fabricated by a vortex method (stir casting). These tests were carried out by using a pin-on-disc abrasion test apparatus where the sample slided against SiC abrasive papers of 20 μm (600 grit), 46 μm (320 grit) and 60 μm (240 grit) under the loads of 2 and 5 N at room conditions. The effects of sliding distance with other parameters (Al_2O_3 particle content and size, SiC abrasive grit size and wear load) on the wear properties of the composites were

systematically investigated. It was observed that wear resistance increased as the sliding distance increases.

Reddappa et al. (2011) studied the dry sliding wear behaviour of Al6061–beryl composites containing four different weight percentages (2, 6, 10 and 15wt. %) of beryl fabricated using stir casting method. A pin-on-disc wear testing machine was used to carry out the dry sliding wear tests on both composites and matrix alloy over a load range of 5-15 N and sliding velocity of 1.66m/s for various sliding distances of 1-6 km. The specific wear rate was determined as a function of sliding distance. It was observed that the specific wear rate decreased with sliding distance for all the compositions indicating improved wear resistance for longer distances.

However, a reverse behaviour was observed in the study by Suresh et al. (2010) on the effect of sliding distance on the wear properties of eutectic Al–Si alloys produced by Stir casting route with fly ash reinforcement (from 1-10 vol. %). It was observed that the wear increased with the increases in distance.

Basavarajappa et al. (2006) investigated the wear behaviour of as-cast aluminium alloy, aluminium alloy (2219) reinforced with SiC particles and aluminium alloy reinforced with SiCp-graphite. The sliding wear test was conducted using unlubricated pin-on disc wear test apparatus to examine the wear behaviour of the aluminium alloy and its composites. It was observed that as the sliding distance increases, the wear of the composites and alloy also increases. Moreover, the wear of the unreinforced alloy is more than that of the composites for all sliding distances. The wear volume loss decreased with the addition of SiC particles and further decreased with the incorporation of graphite reinforcement. At the initial phase, little change in volume loss was recorded for the composites, as the sliding distance increased more change in the wear was observed.

Kumar et al. (2015) investigated the effect of sliding distance on tribological behaviour of Al6061-T6 alloy and its composite reinforced with hard ceramic constituent alumina (3 wt. %) and solid lubricant graphite (3 wt. %) fabricated through stir casting technique. It is observed that wear results exhibited an increasing trend of specific wear rate of Aluminum Hybrid Metal Matrix Composite (AlHMMC) for sliding distance which is absolutely lesser than Al6061 alloy.

3.3 Load

As the applied load and the resulting temperature increases during a sliding wear test, the accumulation of discrete particles on the counter face results in aggregation of larger clusters on the surface of the disk. These clusters subsequently break away from the disk forming loose wear debris and the resulting wear rate becomes severe. It is believed in some quarters that the dominating parameters contributing to the sliding wear of a given system are the loading and the relative sliding of the contact (Priit and Soren, 1999). Also, applied load has been observed to be the only parameter which largely influenced the coefficient of friction (Ashok et al., 2012); hence applied load is a very important parameter in determining the tribological behaviour of composites.

Sallahauddin et al. (2015) studied the effect of B_4C particulates addition on wear properties of Al7025 alloy composites. The 3 and 6 wt. % of B_4C particulates were added to the base matrix. A pin-on-disc wear testing machine was used to evaluate the wear rate, in which a hardened EN32 steel disc was used as the counter face. It was observed that the volumetric wear loss and wear rate increases with increase in applied load in all conditions. The authors' review of the micrographs shows that the wear rate is dominated by load factor and sliding speeds. The increase in loads led to a significant increase in the volumetric wear loss and wear rate.

Umanath et al. (2011) studied the wear resistance as a function of applied load and volume fraction of the particles of aluminum hybrid composites reinforced with mixtures of SiC and Al_2O_3 particles produced from a stir casting technique. Results showed that load has an intense effect on the wear rate of the aluminum hybrid composites.

Sulardjaka and Wildan (2010) developed a wear rate prediction model for aluminum based composites reinforced with 10 and 30 wt. % in situ aluminum diboride flakes using Taguchi's method. The experimental results showed that the normal load and reinforcement ratio were the major parameters influencing the specific wear rate for all samples.

4. Effect of Process Parameters

Optimising the input process parameters is crucial in enhancing the wear behaviour of aluminum composites (Rhadika et al., 2015). The process parameters will be studied under stirring parameters and reinforcement parameters.

4.1 Stirring Parameters

Stirring parameters such as stirring speed and time, blade angle, pouring temperature and so on have been observed to affect the wear behaviour of composites. These are parameters that are associated with the stirring mechanisms in the stir cast technique.

Haque et al. (2014) studied the effect of process parameters (stirring speed and pouring temperature) on wear rate and microstructure of Al6061-Cu reinforced with SiC by stir casting. The dependent variable was chosen to be the wear rate by pin on disc wear method while the independent parameters include five levels of pouring temperature and stirring speed: 675, 700, 725, 750 and 775 °C, and 50, 200, 400, 600 and 800 rpm at a constant pouring speed of 2.5 cm/s that were considered. The optimal values of wear rate are observed between

ranges of 200 to 600 rpm stirring speed while at high speed (800 rpm) the wear rate increases drastically. The wear rates are stable in range of 700 to 750 °C of pouring temperature, except at stirring speed of 800 rpm.

Rajeshkumar and Parshuram (2013) studied the effect of number of blade angle and pouring temperature on microstructure of aluminum hybrid composites with SiC, alumina and graphite as the reinforcement. The study asserts that for uniform dispersion of material, blade angle should be 45° or 60°C and number of blade should be 4. Also, for good wet ability, operating temperature need to be kept in the semisolid stage i.e., 630 °C for Al (6061) and that at full liquid condition it is difficult to attain uniform distribution of the reinforcement in the molten metal. Mould preheating is noted to help in reducing porosity that will expectedly increase the wear resistance.

Sadi et al. (2015) studied the optimisation of stir casting process parameters to minimise specific wear of Al-SiC composites by Taguchi method. Using Al-Si as the matrix alloy and SiC as the reinforcement, among the variables considered are melt temperature, stirring speed and duration, each with 4 levels or variations. The study observed that optimum stir casting process parameters are melt temperature of 740 °C, stirring speed of 300 rpm and stirring duration of 10 minutes.

4.2 Reinforcement Parameters

Reinforcement parameters such as the volume fraction, nature and size of particles in reinforced composites affect the wear behaviour of composites (Mehtap and Mehtap, 2011). Wear volume of metals decreases with incorporation of particles into matrix on the condition that those particles have higher hardness than the matrix material. Material removal in a ductile metal such as aluminum alloy matrix is due to the indentation and ploughing action of the sliding indenters. Incorporation of hard particles as reinforcements in metal matrix restricts such ploughing action of sliding indenters and improves the wear resistance expectedly. However, the effect of particle (reinforcement) size on the wear resistance of composite was more significant than that of its volume fraction (Kok and Ozdin, 2007).

Altinkok et al. (2013) produced Al_2O_3/SiC particulate reinforced composites by stir casting method and investigated its dry sliding wear behaviour. The 10 wt. % Al_2O_3/SiC with different SiC particles sizes was added to a liquid aluminum matrix (A332) alloy with mechanical stirring between solidus and liquidus temperature under inert conditions. The reinforcements reduced weight loss due to wear in the composites especially where SiC with large grain size was used. The improvement in wear resistance of the hybrid ceramic reinforced metal matrix composites was attributed to the ability of the larger SiC particles to carry a greater portion of the applied load, as well as in protecting the smaller alumina particles from being gouged during the wear. The composites with fine reinforcement particles had the reinforcements more easily pulled out whole from the matrix when compared to the composite with coarse reinforcement particle size.

Also, Ashok et al. (2012) studied the wear and frictional properties of Al6061 reinforced with SiC particles (10 and 15 wt. %) using dry sliding wear test on a pin-on-disc wear tester. Experiments were conducted based on the plan of experiments generated through Taguchi's technique. A L9 orthogonal array was selected for analysis of the data. Effect of applied load, sliding speed and sliding distance on wear was studied. It was observed that for Al – 6061/ 10 wt. % SiC composites sliding distance has the highest (62.5%) influence on wear rate followed by sliding speed (37.5%) and applied load (1.25%) respectively. However, for the Al – 6061/ 15 wt. % SiC composites, applied load has the highest (57.2%) influence on wear rate followed by sliding distance (7.1%) and sliding speed (7.1%).

Das et al. (2007) observed that composites reinforced with zircon particles of size 44–74 um (with 4.5 wt. % Cu–Al as the matrix) blunts SiC abrading particles before the larger size reinforcement composite (74-105 um), after sliding duration of one minute. This shows higher wear resistance than the later. This was attributed to the action of the sharp edges of the small particles in assisting to cut and blunt the abrading silicon carbide particles more effectively. Hence, the shape of the small particles also plays an important role in decreasing composite' wear volume.

Kumar et al. (2012) studied the aluminum alloy composites reinforced with fly ash particles and observed that coarse fly ash particles reinforced composite exhibit superior wear resistance to those reinforced with fine fly ash particles. Table 1 shows the dry sliding behaviour of various aluminum composites produced from stir casting.

Different types of reinforcements such as SiC, Al_2O_3, B_4C, Zircon TiC, TiB_2 and graphite have been used in many studies to investigate the sliding wear properties of the aluminum MMCs produced by stir casting technique (Kumaran et al., 2015; Ramesh and Prasad 2007; Chen et al., 2015; Panwar and Pandey, 2013; Saravanakumr et al., 2013; Yilmaz et al., 2001).

Kumar et al., (2016) investigated the influence of silicate on the wear behaviour of LM 24/4 wt. % fly ash hybrid composite with 4, 8, 12, 16, 20, and 24 wt.% of silicate using stir casting technique. Tribological properties were evaluated under different load (15, 30, 45, 60, and 75 N); sliding velocity (0.75, 1.5, 2.25, and 3 m/s) condition using pin on disc apparatus. It was observed that the properties of the hybrid composites containing 24 wt. % silicates exhibit superior wear resistance. Moreover, Sivakumar et al. (2014) had shown the influence of fly ash on wear resistance of aluminum alloy. The aluminum MMCs was successfully produced using stir casting route up to 20 wt. % fly ash and the

Table 1. Dry Sliding Behaviour of Aluminum Composites Produced from Stir Casting

S/N	Alloy	Reinforcement	Dry Sliding Wear Behaviour	Authors
1.	7075 Al alloy	10% vol SiC	Wear reduces at higher sliding speed.	Dasguta et al. (2012)
2.	A356	10SiC/1Gr	Wear rate decreases with increasing sliding speed.	Babić et al. (2013)
3.	Al 7075	B_4C, Alumina and SiC	Wear rate decreases with increasing the sliding velocity.	Manikandan and Karthikeyan (2014)
4.	Al2024	Al_2O_3	Increasing wear resistance as the sliding distance increases.	Kok and Ozdin (2006)
5.	Al6061	beryl	Specific wear rate decreased with sliding distance.	Reddappa et al. (2011)
6.	Al–Si alloy	fly ash	Wear increases with increase in distance.	Suresh et al. (2010)
7.	Al2219	SiC	Wear of the composites and alloy increases as sliding distance increase.	Basavarajappa et al. (2006)
8.	Al6061-T6 alloy	3 wt.% alumina and 3 wt.% graphite	Increasing trend of specific wear rate with sliding distance.	Kumar et al. (2015)
9.	Al7025	B_4C	Volumetric wear loss and wear rate increases with increase in applied load.	Sallahauddin et al. (2015)
10.	Al6061	SiC and Al_2O_3	Load had an intense effect on the wear rate.	Umanath et al. (2011)
11.	Al(99.9%)	10 and 30wt.% in situ aluminum diboride	Normal load and reinforcement ratio were the major parameters influencing the specific wear rate.	Sulardjaka et al. (2010)
12.	Al6061-Cu	SiC	Optimal values of wear rate are observed between ranges of 200 to 600 rpm stirring speed.	Haque et al. (2014)
13.	Al-Si	SiC	Optimum values of specific wear are SiC content of 15 wt.% SiC, melt temperature of 740 ^{0}C, rotation speed of 300 rpm and stirring duration of 10 minutes.	Sadi et al. (2015)
14.	Al6061	SiC	Wear behavior is a function of the wt.% of reinforcement.	Ashok et al. (2012)
15.	A332	Al_2O_3/SiC	Wear reduces with presence of reinforcement.	Altinkok et al. (2013)
16.	4.5wt. %Cu–Al	Zircon	Smaller size reinforcements shows higher wear resistance when compared to the larger sizes.	Das et al. (2007)
17.	Al/3.25Cu/8.5Si	fly ash particles	Coarse reinforcements show higher wear resistance when compared to fine reinforcements.	Kumar et al. (2012)
18.	LM 24	fly ash and SiC	SiC showed higher wear resistance than fly ash.	Kumar et al., (2016)
19.	LM 24	Fly ash	Fly ash increases the composites wear resistance.	Sivakumar et al. (2014)

wear rates was observed to decrease significantly with the incorporation of fly ash.

5. Conclusion

This review shows that a lot of efforts have been made to improve the dry sliding wear behaviour of aluminum composites produced by stir casting technique. Process parameters largely influence the dry sliding wear behaviour of aluminum composites. Understanding of the degree of influence of the process parameters on the dry sliding wear behaviour of aluminum composites is highly important as its helps in the optimal combination of process parameters in the course of its production. The following were observed:

1) Considerable works have been done using stir casting techniques to produce aluminum matrix composites due to its simplicity, flexibility and cost effectiveness especially for large volume production.
2) Prominent wear apparatuses used in wear test are the pin-on-disc tools and the parameters commonly evaluated are load, sliding velocity and sliding distance.
3) Load and sliding velocity plays a major role in assessing the dry sliding wear behaviour of composites.
4) Wear resistance of aluminum matrix composites produced by stir casting technique depends also on the type of reinforcement and volume fraction, and
5) The trends observed for the effect of sliding distance and reinforcement size vary and could depend on the type and nature of reinforcement used in composites' production.

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Management of Knowledge and Ignorance in the Context of Organisational Learning: A Research Agenda

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Abstract: *Nowadays, a company's competitive advantage is based on the decision to exploit, to develop the power of knowledge as a source of competencies. Recent research asserts that knowledge management (KM) is the management of the known, whilst the management of the unknowns poses a greater risk to organisations. There is an emerging view that the KM approach disregards the unknown and leads to the creation of ignorance and organisational ignorance (OI). The management of ignorance or ignorance management (IM) is to prevent OI, and would therefore facilitate positive outcomes with organisational learning (OL). This paper discusses the need for fostering KM practices with IM towards OL, with particular reference to the business environment in Trinidad and Tobago (T&T). It elaborates a research initiative, and outlines the purposes, hypotheses and areas for devising a KM/IM capability model. This paper serves as its purpose as a research agenda for a three-stage approach of the study. Built upon the present Stage 1 of literature review, the next two stages would be empirical data acquisition and model development and testing that would evaluate the applicability and efficacy of the model using the empirical data to be acquired in manufacturing enterprises in T&T.*

Keywords: *Knowledge management, ignorance management, organisational learning, research agenda*

1. Introduction

Knowledge management (KM) has since the 1990s come to the forefront in academia and organisational practices as a general approach in the management of knowledge (Wiig, 1997; McAdam and McCreedy, 1999). Yiu, Sankat and Pun (2013) regard KM as the "managerial activity that develops, transfers, stores and applies knowledge". The theories of KM and organisational learning (OL) are closely interrelated or symbiotic (Pun and Nathai-Balkissoon 2011). Argote (2012) consolidated the view of many researches to define organisational learning (OL) as "a change in the organisation's knowledge that occurs as a function of experience". KM and OL are distinguished, such that KM is considered to focus on the content of the knowledge that is acquired, created, processed and utilised by the organisation versus OL emphasis on process (King 2009).

As the rate of change accelerates and competition intensifies globally, a company's survival is dependent on how well it can position itself and how it manage its efforts with 'knowledge'. KM has become significant for organisation effectiveness and development (Pun and Nathai-Balkissoon 2011). Core KM themes relate to: 1) the creation of knowledge repositories; 2) the improvement of knowledge acquisition; 3) the enhancement of the knowledge environment; and 4) the management of knowledge as an asset. The impact of KM on an organisation's performance is strongly tied to the ability of an organisation to identify where KM will be of most value (McAdam and McCreedy, 1999; Bose, 2004).

Thornton (1998) asserts that the "future belongs to organisations that aggressively manage what they are not aware of. Lambe (2002) adds that in conditions of uncertainty, "organisations must get to the top of what they do not know". Organisational ignorance (OI) impacts the capabilities and potential of organisations in evaluating opportunities to learn and identify and/or create new knowledge. The management of ignorance, or in short, ignorance management (IM), is to prevent OI on one hand, and facilitate positive outcomes with organisational learning (OL) on the other. King (2009) contends that "the goal of KM" is to achieve OL. This study explores the concepts OI and related IM approaches in an attempt to derive a KM/IM capability model for fostering OL in organisations.

2. Literature Review

2.1Organisational Knowledge Defined

The term 'knowledge' signifies an area of conflict for many years. Diakoulakis et al (2004) advocate that this is

attributable to the existence of resemblant concepts, such as data and information, which can easily approximate some forms of knowledge. Knowledge as defined by the Oxford Dictionary is familiarity gained by experience. It is product of human reflection and experience, while data is raw observations of the past, the present or the future and information is the pattern(s) that individuals instill on data (1997). It is generally accepted that there is a hierarchical relationship among data, information, knowledge, and wisdom, with data seen as a primary or raw form, information being a processed form that gives usefulness to data, and knowledge being the result of judicious application of information (2006).

Polyani (1958) firstly defined tacit and explicit categorisations of knowledge. According to Roth (2003), knowledge has two dimensions; firstly, it exists on the individual, group and organisational levels of a firm; and secondly, it is either explicit or tacit. Explicit knowledge is described as a codified form of knowledge, recorded facts theories and principles (Leiponen, 2006). This type of knowledge is more tangible and can be found in written documents. On the other hand, tacit knowledge is difficult or impossible to be articulated in written documents and is tacitly transmitted and learned. Tacit knowledge resides innately in people and tends to be embedded by way of their experiences, values, intuition, values, and contextual information. This type of knowledge is highly subjective and difficult to capture or convey in a straightforward manner (Wilcox King and Zeithaml, 2003; Yiu, Sankat and Pun, 2013).

In organisations, knowledge often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices, and norms. In other words, corporate culture, best practices, core competencies, skills, or strategic visions are critical parts of the total stocks of knowledge in an organisation (Bose 2004; Diakoulakis et al., 2004). It becomes essential to continue developing and managing company's knowledge so as to keep abreast of continuing change from the environment and to gain advantages (Yiu, Sankat and Pun, 2013). Organisational knowledge is thus the ability of the organisation to perform differentiating it from competitors and obtaining competitive advantage. Wilcox King and Zeithaml (2003) put forward three (3) characteristics that define organisational knowledge more definitively such that 1) it is the ratified perspective of multiple knowers, 2) it is bounded within scope and context, and 3) apprehended through language.

2.2 Knowledge Management and Organisational Learning

Knowledge management is both a science and an art (Pun and Nathai-Balkissoon 2011), and is a relatively new and evolving discipline that has garnered interest from both academicians and practitioners (Migdadi, 2009; Ma and Yu, 2010). Lytras and Pouloudi (2003) describe KM as a holistic approach to management studies and practice. Hung et al. (2005) regard KM as a managerial activity that develops, transfers, transmits, stores and applies knowledge. According to Malhotra (2005), KM embodies organisational processes that seek synergistic combination of data and information-processing capacity of information technologies, and the creative and innovative capacity of human beings. KM is primarily concerned with the design and development of practices, policies and technologies that can provide a basis for the organisational approach for the utilisation and management of knowledge (Nifco, 2005; Luhrman and Cunliffe, 2013).

Wong and Aspinwall (2005) contend that KM is an emerging set of organisational design and operational principles, processes, organisational structures, applications and technologies. King (2009) adds that KM is "the planning, organising, motivating and controlling of people, processes and systems in the organisation to ensure that knowledge-related assets are improved and effectively employed". This is a strategic management concept drawing from various disciplinary areas (2009) and has emerged as a phenomenon with wide-ranging implications for organisational performance and competitiveness (Yiu, Sankat and Pun, 2013). The KM processes are divisible into a number of inter-connected activities that depend on the particular industry, the nature of the firm and the strategy it adopts (Wang and Ahmed, 2005). Table 1 depicts the eight components of the knowledge value-adding process. KM contributes towards organisational learning (OL) and helps build a learning organisation (LO).

Table 1. Components of the knowledge value-adding process

KM Processes	Descriptions
1. Knowledge Identification	Searching for, and locating new information, ideas and knowledge that are relevant to the organisation.
2. Knowledge Acquisition	Acquiring knowledge identified to be relevant, and absorbing such knowledge in the specific organisational context.
3. Knowledge Codification	Codifying tacit knowledge, categorising knowledge acquired and labelling knowledge.
4. Knowledge Storage	Recording knowledge, retaining and maintaining knowledge, and clearly signposting the knowledge directory.
5. Knowledge Dissemination	Retrieving knowledge stored, making it available to knowledge seekers and users.
6. Knowledge Refinement	Improving, transferring and adapting existing knowledge to changed situations, or using existing knowledge in a new way.
7. Knowledge Application	Putting knowledge into action, utilising knowledge to produce organisational outcomes.
8. Knowledge Creation	Nurturing, seeding and incubating new ideas, and generating new knowledge that leads to major breakthroughs.

Source: Taken from Wang and Ahmed (2005)

Anders (2001) made a distinction between OL and a LO. OL refers to "processes or activities" of learning whereas LO is a form of an organisation "in and of itself". The concepts of KM are integrally linked with that of OL, as depicted in Figure 1. Some recent studies found that OL results from shifts in the 'state of knowledge', and includes the acquiring of knowledge, the sharing of understanding, and the exploitation or application of the knowledge to draw insight into activities (Rowley, 2006; Pun, and Nathai-Balkissoon, 2011). It is stressed that a continuum of knowledge (whether pertaining to process, system or culture) with 'emergence of new knowledge' on one end, and 'embedding' or adoption of new knowledge, on the other. Wang and Ahmed (2005) also contend that organisations actively encourage, support, and reward OL by focusing on collective individual learning, process or system, culture or metaphor, KM, and continuous improvement. Figure 2 shows a mapping of four key areas of OL and KM. Pun and Nathai-Balkissoon (2011) argue that as both KM and OL continue to develop, they will naturally merge.

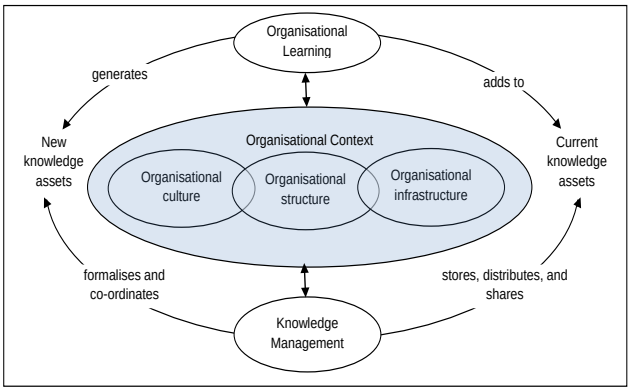

Figure 1. The OL and KM Relationship
Source: Abstracted from Pemberton and Stonehouse (2000)

Figure 2. Mapping of Key areas of OL and KM
Source: Lurhman and Conliffe (2013)

2.3 Organisational Ignorance and Ignorance Management

Ignorance is usually treated as either the absence or the distortion of true knowledge and uncertainty as some form of incompleteness in information of knowledge (1989). Disputes over ignorance and knowledge exist as far back as Socrates's assertion of wisdom lying in what he did not know (2012). In the taxonomy of ignorance, non-knowledge is seen as a sub-type of ignorance (Svetlova and van Elst, 2012). Notwithstanding, Ayyub (2010) categorises ignorance into two types, blind and conscious and shows the hierarchical relationship amongst its various sources and nature.

In the fifteenth century, Nicollas of Cusa developed a concept of "learned ignorance". This doctrine taught that "the more a wise person knows that he is unknowing the more learned he will be" (Hopkins, 1981, p. 3). Nicollas of Cusa viewed learned ignorance as a reasonable way of combining knowledge and ignorance through awareness of limitations of knowledge Moreover, Harvey et al. (2001) specified four (4) types of ignorance to be considered at work in organisations, which are, populistic, pluralistic pragmatic and/or pragmatic (see Table 2).

Sankaran, Kouzmin, and Hase (2005) identify ignorance as becoming critical in the existing micro- and macro-climate of rapid change due to fast progressing globalisation and hyper-competition. Table 3 illustrates the nature of knowledge gaps that widen in an organization particularly when the environmental context (globalisation) of decision making is changing dramatically (Harvey et al., 2001). Halbesleben and Ronald Buckley, 2004; Halbesleben et al., 2007) contend that pluralistic ignorance is a situation in which an individual holds an opinion, but mistakenly believes that the majority of his or her peers hold the opposite opinion. This is a complex phenomenon that has important consequences for organizations, particularly as it relates to the behavior of individuals in organizations. Davies and McGoey (2012) add that ignorance should not be treated as dualistic opposites or the absence of knowledge since knowledge has restrictions and on the other hand ignorance has no perceptible parameters.

Organisational ignorance (OI) is emerging as a "legitimate corollary to that of organisational knowledge" (2008). However, definitions of OI are very few and a small insight is given as to how OI arises. According to Harvey et al. (2001), OI can be viewed as a multidimensional concept, which emerges in specific contexts of organisational dialogue that can influence the perceptions of constituencies both inside the organisation, as well as outside the organisation. Sankaran, Kouzmin, and Hase (2005) derived from Zack (2000) that a comprehensible framework to define and manage OI is required to mitigate four (4) knowledge processing problems articulated. These are:

1) Uncertainty (insufficient information)

Table 2. Dialogical contexts engendering four types of organisational ignorance

Type of dialogue **Issue/type of ignorance**	**Evaluation** **Pluralistic**	**Interpretation** **Populistic**	**Inquiry** **Probabilistic**	**Negotiation** **Pragmatic**
1. Nature	Epistemic	Symbolic	Hypothetical	Dialectical
2. Source	Policy	Culture	Service	Practice
3. Criterion	Credibility	Solidarity	Information	Utility
4. Reference	Future perfect	Past	Present	Future
5. Process	Normalising	Confirming	Disconfirming	Affirming
6. Emphasis	Influence	Understanding	Analysis	Identification
7. Goal	Interpretation	Persuasion	Testing	Action

Source: Harvey et al. (2001, p.452)

Table 3. Managing toward global knowledge creation

Managing global knowledge 'gap'	**Domestic paradigm building**	**Global paradigm building**
1.Managing from knowing	- Knowledge based (proven point, accepted facts)	- Not knowing plus recognition of the need to know new knowledge
2. Managing from unknowing	- Ignorance of knowledge (tacit ignorance)	- Ignorance of ignorance (tacit ignorance)
3. Managing from ignorance	- Suppressed knowledge (taboos and denials) - Pluralistic ignorance	- False knowledge (errors and false truths) - Probabilistic ignorance

Source: Abstracted from Harvey et al. (2001, p.460)

2) Complexity (processing more information than comprehensible)
3) Ambiguity (a conceptual framework to interpret information not available)
4) Equivocality (numerous contending frameworks).

Harvey et al. (2001) argue that organizations would experience myopia in their evaluations of opportunities to create new knowledge in the prevailing dynamic context, if they fail to realise how the concept of organizational ignorance would enhance both their capabilities and potential for innovation.

On the other hand, ignorance management (IM) is the process by which ignorance, in all of its various and sundry forms, is captured, tagged, stored, mapped, managed, manipulated, and last but certainly not least, corrected (Galvin, 2004). According to Israilidis, Lock, and Cooke (2013), IM is a process of discovering, exploring, realising, recognising and managing ignorance outside and inside the organisation through an appropriate management process to meet current and future demands, design better policy and modify actions in order to achieve organisational objectives and sustain competitive advantage. There is a gap in literature to properly define and support the theory towards IM and new ways of addressing knowledge related problems by providing an alternative perspective is emerging through the concept of IM.

Moreover, Lambe (2002) advocates that an agenda of IM would address such issues as 1) relationship between organisational culture and structural capital, 2) organisation's adaptability to and recognition of risk, and 3) individuals and their interpretations of uncertainty require the authority that changes judgments into value-creating practices with an enterprise.

3. A Research Agenda

Nowadays, many industry leaders are engaging in KM and OL in order to leverage knowledge both within their organisation, and externally, to their shareholders and customers. The embedding and embracing of KM/OL within an organisation requires attention to objectives, types of knowledge, technologies, and organisational roles (Pun and Nathai-Balkissoo, 2011). Okes (2005) advocates that questions to be addressed include: 1) what knowledge is critical to the organisation? 2) Where and how does the organisation gain that knowledge? 3) What does the organisation do with it? 4) How is it used, distributed and stored? 5) To whom does the organisation go for help, and who comes to the organisation for help? and 6) what metrics are used to track the management of knowledge? One challenge for today's organisations is thus to match and align performance with corporate strategy, structures and culture. This implies an integration of OL and KM and deployment of performance measures so that the results are used and acted upon to attain competitive performance (Pun and Nathai-Balkissoo, 2011).

Moreover, Zack, Cortada, and Woods (2000) put forward that it is more important to manage ignorance despite the widely held approach of managing organisational knowledge. There is an emerging view that the KM approach disregards the unknown and leads to the creation of ignorance. Roberts (2009) argues that KM is the management of the known whilst the management of the unknowns poses a greater risk to organisations. The goal of ignorance management (IM) is to prevent organisational ignorance.

The Industrial Engineering Office of The University of the West Indies has initiated a research project with

the aims to 1) identify the factors affecting KM and IM, and 2) develop a KM approach with IM initiatives to foster organisational learning in line with performance goals in manufacturing enterprises of T&T. The study sets forth two (2) hypotheses as follows:

- Hypothesis 1: The commonalities between KM and IM facilitate their integration in organisations.
- Hypothesis 2: Manufacturing enterprises developing KM/IM capability would strengthen organisational learning.

A generic KM/IM capability model is proposed (see Figure 3). The model attempts to incorporate the features of both inputs-driven and outcomes-driven paradigms of KM. On one hand, the inputs-driven paradigm considers KM primarily as a means of processing information for various business and operations activities (Malhotra, 2005). It would include reactive and corrective feedback loops of activities that incorporate IM initiatives to prevent organisational ignorance. On the other hand, the outcomes-driven path would be built in double-loop process that can enable a paradigm of KM/IM. This ensures that relevant processes and activities, as well as, related technologies are adopted and/or modified to enhance organisational learning and performance.

Execution of this research agenda combines the results of extensive literature review, acquisition of empirical data via industry survey and interviews, and the development and testing of the proposed KM/IM capability model. There are eight steps in two stages to suit the purpose of this study which would last for a period of two years based in T&T. The methods and processes of respective stages are depicted in Table 4.

At Stage 1, an extensive review of relevant literature constitutes the integral part of the study on building the conceptual foundation and understanding of key KM processes, IM attributes, performance metrics and variables. At stage 2, the study would go through the design, planning and execution of empirical data acquisition in the targeted manufacturing sectors in T&T. A breadth of views would be acquired via the conduct of surveys, case studies and interviews with industry practitioners, experts and academia. Cross-referencing of actions and feedback between individual steps would be made throughout the process. The collated results would contribute towards the development of the KM/IM capability model.

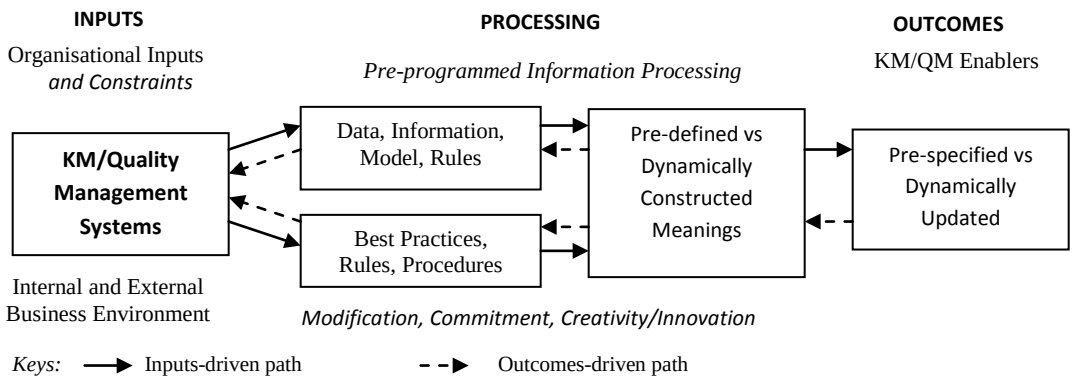

Figure 3. A proposed KM/IM capability model

Table 4. A three-stage approach of the study

Stage I: Literature Review	
1	Conduct a desk research focusing on literature published in referred journals in areas of KM and IM practices with particularly reference to those for the Caribbean region.
2	Elicit documents and materials from industries, universities, research institutes and other sources based in T&T and other nations of the Caribbean region.
Stage II: Familiarisation and Data Acquisition	
3	Investigate into the approaches of KM/IM practices, systems and performance measurements in manufacturing enterprises.
4	Identify the factors and attributes that contribute to the development of the KM/IM capability model.
5	Design study instruments for acquiring empirical data via the conduct of survey, case studies and interviews of industry practitioners, experts and academics.
Stage III: Model Development and Testing	
6	Use the literature and empirical data acquired from the first two stages to identify input, control and output elements for the KM/QM capability model.
7	Re-visit the participating organisations and interview senior management and representatives to evaluate the model and the accompanied attributes, process and guidelines of implementation.
8	Document the process and identify the specifications, changes or refinements for facilitating the adoption and implementation of the model.

The final stage is concerned with the development and testing of the model. Based on the findings from the previous two stages, the input, control and output elements would be identified and then tested. Senior management and representatives from the participating organisations would be interviewed, so as to evaluate the model and validate the use of the accompanied attributes, process and guidelines of implementation. Changes and/or refinements of the model would be made for facilitating the adoption and implementation of the model.

4. Conclusion

KM/IM capabilities are not simply designed and implemented, but they also evolve over extended periods of time. Differences emerge when examining how these capabilities link measurement to strategic and operational performance. Other differences arise when examining how each framework promotes communication about what is important (and what is not important) in the management and work practices.

It can be seen that little research stressed the integration of KM practices with and IM initiatives in organisations, although researchers are hinting that this is an area worthy of further study. A research agenda outlining purposes, hypotheses and areas for devising a KM/IM capability model with implementation guidelines, was presented. The agenda is one of the first to systematically determine the factors affecting KM/IM and measure the KM/IM capabilities in manufacturing enterprises in T&T.

Effective KM/IM requires a systematic examination of the organisation's internal factors of processes, culture and technology. Organisations should dedicate efforts to building infrastructures that enhance knowledge systems, knowledge culture, organisational memory, knowledge sharing, and knowledge benchmarking (Wong and Aspinwall, 2005). It is anticipated that this study initiative will enrich the understanding of IM and its link with KM towards OL. The identification of the attributes/parameters/determinants of KM/IM would constitute the proposed KM/IM capability model. Besides, the development of accompanied KM/IM metric and implementation guide would provide a reference base for manufacturers to foster their KM practices with IM towards OL and becoming a learning organisation with particular reference to the business operations/environment in Trinidad and Tobago.

As business and operational situations vary in organisations and industry sectors, managing the KM practices with MI will only succeed if they are implemented as a long-term organisational paradigm shift, but not a quick fix. Integrating KM practices with IM and performance improvement is a never-ending process. The development of the KM/IM capability model would be a supplement to the literature on the KM/IM studies in T&T and a wider Caribbean region.

Built upon the present Stage 1 of literature review, the next two stages would be empirical data acquisition and model development and testing. Future work would evaluate the applicability and efficacy of the model in both SMEs and larger organisations. Comparative evaluations and case studies are suggested to examine the parameters of the model and impact of its adoption in firms across different industrial sectors.

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The Entrepreneurial Motivations of Engineering Students: Case of a Small Island Developing State from the Caribbean

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Abstract: *Studies on entrepreneurial motivations conducted in the Caribbean and globally, have considered factors such as parents' occupations, business ownership by parents or relatives, sex and ethnicity. This exploratory study focused on the entrepreneurial motivations of more than 200 engineering students and recent graduates in Trinidad and Tobago (T&T), to gauge whether, among this group, some of these traditional factors are associated with higher order or 'pull' entrepreneurial motivations such as taking advantage of market opportunities, the need for control and independence, and desire for a challenge. A comprehensive self-reporting questionnaire tool was electronically distributed and results coded and analysed using the IBM SPSS Statistics 24 software. It was found that the respondents primarily displayed higher order 'pull' motivators for entrepreneurship with eighty-four percent (84%) identifying welcoming a challenge, controlling their future or taking advantage of opportunities as potential motivators. The study revealed no statistically significant correlation between entrepreneurial motivation of the respondents and ethnicity, sex, parents' occupation, or training. Age of first exposure to assisting in a business also had no significant impact on the entrepreneurial motivation of the engineering student or graduate. Birth order and actual experience running or managing a business were in fact, the only intrinsic characteristics discovered to have a statistically significant impact on the nature of the entrepreneurial motivation of the students and graduates. 'Middle born' and 'only' children crave independence. Fifty percent (50%) of middle born and 52% of 'only' children would start businesses to take more control of their lives. 'Last borns' expressed the highest order 'pull' motivations in that forty-five percent (45%) were most likely to become entrepreneurs to take advantage of an opportunity in the marketplace. Not surprisingly, 'first born' and 'only' children were the most motivated to follow family traditions for entrepreneurship. Further studies would be useful to establish a typology for engineering entrepreneurs from T&T and other small island developing states. This exploratory study, conducted in T&T, suggests that engineers may exhibit different entrepreneurial patterns to the rest of the population or to engineers in larger economies. Further exploration of this knowledge may be useful in supporting students and graduates of engineering programmes.*

Keywords: *Entrepreneurial motivation, engineering students, Trinidad and Tobago, SIDS*

1. Introduction

The countries within the Caribbean region are all challenged by factors affecting small island developing states such as extreme vulnerability to economic and environmental shocks and lack of economies of scale. In addition, the islands' economies remain largely undiversified with continued heavy reliance on natural resources and tourism (Ramkissoon-Babwah, 2013). Auty (2017) argues that government policies may drive sustainable growth despite the inherent characteristics of small island states, comparing the case of Trinidad and Tobago (T&T) with its unsustainable hydrocarbon resource wealth, to resource poor Mauritius, which achieved economic sustainability through diversification based on manufacturing for export. Danns (1994) and Ramkissoon-Babwah (2013) postulate that throughout the history of the Caribbean, entrepreneurial activity has focused on the exploitation of natural resources and the retail of imported goods as opposed to creating value through intellectual property and higher order value adding activities.

The history of entrepreneurship within the Caribbean region, however, is quite interesting. A study by Danns (1994), which has been cited over 400 times, defined five (5) types of traditional Caribbean entrepreneurs. Danns' (1994) iconic study appears to insinuate that large sections of the population have traditionally been discouraged from engaging in entrepreneurship through lack of access to knowledge or finance, by design of the 'ruling' classes. In spite of the fact that large numbers of entrepreneurs exist in Danns' Type 3, Type 4 and Type 5 categories, their sustainability and capacity to impact the economy is limited by factors such as education, technology and finance (Danns 1994). These types of entrepreneurs, prevalent in the Caribbean Community (CARICOM), lack the innovation and knowledge to become serious contributors to their countries' economies. In the case of

T&T,

2. Entrepreneurial Motivation

Khadan (2016) argues, the current entrepreneurs are not suitable for the task of economic diversification, citing factors such as the age of the enterprises, structure, family ownership, lack of innovation and poor export readiness, as responsible. According to Khadan (2016), 23% of enterprises in T&T are declining, 59% are stagnant and just 18% are expanding with 41% of the enterprises in T&T naming their number one obstacle to be an inadequately educated workforce. This is just slightly more than in the rest of the commodity-dependent small economies in world where 39% of enterprises list the education of the workforce as not suitable. Danns' typology is shown in Figure 1, with a brief synopsis of their characteristics, in each case.

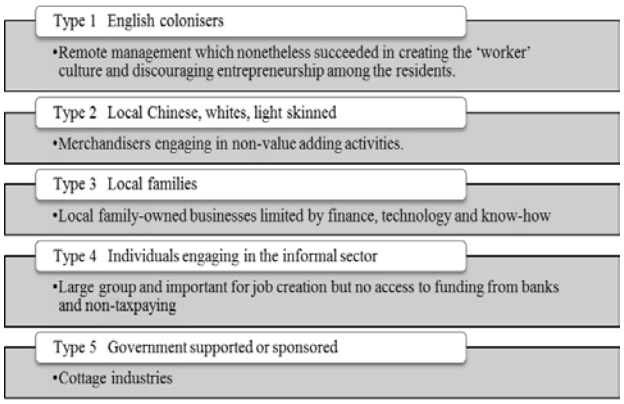

Figure 1. Dann's Historical Typology for Caribbean Entrepreneurs
Source: Adapted from Danns (1994)

2.1 'Push' vs 'pull' factors

Entrepreneurial motivation is important because it influences the type of enterprise formed, its sustainability, and potential for growth and impact. A comparison of the "push" vs "pull" factors which motivate potential entrepreneurs is therefore imperative. Individuals sometimes start a business because there is no other way of adequately meeting their financial needs (Mohan, Strobl, and Watson, 2017 and Dawson and Henley, 2012). Generally, the factors that lead a person to start a business due to necessity which may include job loss, a dismal job market or inadequacy to meet financial needs even when fully employed, as opposed to opportunity are called 'push' factors (Mohan, Strobl, and Watson, 2017). Persons who experience difficulty when seeking employment because of immigration status, a prior conviction in the court, lack of skills or poor education may also become entrepreneurs based on 'push' factors. Low on motivational drive, 'lifestyle' entrepreneurs are happy to eke out a basic living, without plans for growth or expansion, once their general financial and lifestyle goals are being met.

Conversely, 'pull' factors include taking advantage of opportunities in the marketplace, acting on a desire to solve a problem or effect a change in the world or pursuing a dream to create something new or make a lot of money (Dawson and Henley, 2012). Individuals exhibiting 'pull' motivational factors are highly driven entrepreneurs who aim for continuous improvement and growth in their enterprises. In their research on 101 Spanish entrepreneurs, Barba-Sánchez and Atienza-Sahuquillo (2012) found that the ability to self-manage or earn money did not adequately explain why people chose to be in business. A depiction of 'push' and 'pull' motivators separating internal and external causes is shown in Figure 2.

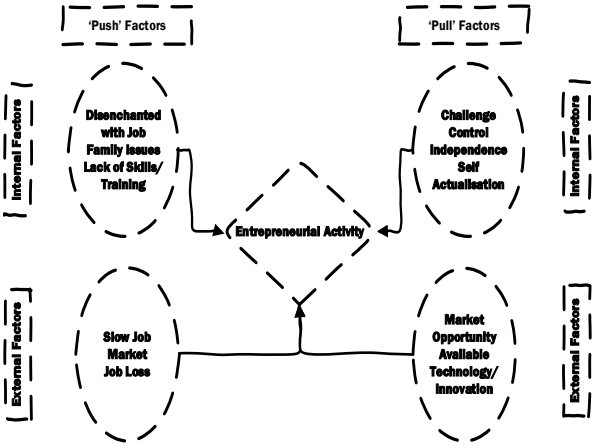

Figure 2. Motivational factors of Entrepreneurs
Source: Adapted from Dawson and Henley (2012)

2.2 Entrepreneurial motivations of students

A number of studies have been conducted on the entrepreneurial motivations of students. Tong et al (2011) cited previous studies which concluded that: i) African-American students were highly motivated to be entrepreneurs because of the desire for independence and ii) entrepreneurial fathers had a strong influence on students in Australia and Singapore. Their study of 196 students in Malaysia, however, did not identify the need for independence as a motivator. Instead, they discovered that among these students, a family history of being in business, as well as social pressure and the need for achievement were the strongest entrepreneurial motivators (Tong et al, 2011).

Jin et. al (2015) argued that gender was a significant factor in the entrepreneurial intent of students, with female students being less interested in being entrepreneurs and assessing their abilities in the area lower than that of males. Corroborating this, were Yeng Keat and Ahmad (2012) who found that gender and birth order significantly influenced the entrepreneurial intentions of university students in Malaysia, and

business experience did not.

While these authors have indicated that entrepreneurial motivation may be linked to factors such as gender, parental occupation or influence, perceived social pressure, a need for achievement, birth order, the need for independence or autonomy and the desire for eking out a subsistence living, an empirical study is necessary to determine which, if any, of these factors may exist among a different demographic of students.

2.3 Engineering Entrepreneurship in a Developed Economy – Case of the United States

In the case of the United States of America (U.S.), Pistrui et al, (2011) and Byers et al (2013), maintain that national competitiveness depends on the creation of innovative, entrepreneurially minded engineers. Jin et.al (2015) and Bodnar, Clark and Besterfield-Sacre (2015) further contend that universities in the U.S. have made a concerted effort to offer entrepreneurial training within their engineering programmes based on this general recognition of the critical role that engineering graduates play in the creation of new enterprises and the sustainability of existing ones. This is in contrast to traditional engineering programmes which have focused on teaching logical thinking in technical areas while placing less emphasis on the creative and critical thinking skills (Pistrui et. al., 2011).

There are however, two (2) major types of entrepreneurial engineers. The first, are those who would conceptualise and initiate their own enterprises, taking satisfaction in the challenge or feeling of control. The second type of entrepreneurial engineer favours the contribution of his entrepreneurial expertise as a team member in an existing establishment. Concerning the latter, Dabbagh and Menascé, (2006) ~~and~~argues that students exposed to training in engineering entrepreneurship become more valuable professionals than those who were not, as they are better able to contribute to the success of their organisations by identifying and realising opportunities in the marketplace.

The modern engineering graduate seeking employment in existing firms, is therefore now expected to have an 'Entrepreneurial Mindset', where he is able to be creative and skilled at recognising opportunities for company growth (Bodnar, Clark and Besterfield-Sacre, 2015; and Byers et al, 2013). Feedback from industry generally expresses satisfaction with the technical competencies of engineering graduates, concerns are usually expressed about the ability of these engineers to function effectively in devising innovative solutions in response to the needs of customers.

The case of the U.S. is used to demonstrate aspects of engineering entrepreneurship programmes. An investigation of the top 15 engineering programmes offered in the United States (US) shows that they all offered entrepreneurship training to students. These programmes consist of courses as well as other activities such as start-up weekends, incubators and accelerators, business plan competitions and entrepreneurship boot camps. Engineering undergraduates are able to access these within the engineering college, within the university, or both.

Table 1 shows a summary of the investigation. The information was gleaned from the respective websites of the various universities. While the 15 top colleges all have entrepreneurship programmes, 13 execute these programmes within their engineering departments and four (4) feature centres for entrepreneurship within the university that may be accessed by engineering students.

Table 1. Engineering Entrepreneurship in the U.S.

U.S. RANK	WORLD RANK	NAME OF INSTITUTION	ENTREPRENEURSHIP PROGRAMME	
			ENG DEPT	UNIVERSITY
1	1	California Institute of Technology		
2	2	Stanford University	√	
3	4	Massachusetts Institute of Technology	√	√
4	6	Princeton University	√	
5	10	University of California, Berkeley	√	
6	13	University of California, Los Angeles		√
7	13	Georgia Institute of Technology	√	
8	15	Carnegie Mellon University	√	√
9	16	University of Illinois at Urbana-Champaign	√	
10	17	University of Michigan-Ann Arbor	√	
11	21	Northwestern University	√	
12	22	Cornell University		√
13	24	University of California, Santa Barbara	√	
14	25	University of Texas at Austin	√	
15	26	Columbia University	√	

The top ranked engineering school, California Institute of Technology or Caltech, features an entrepreneurship club which provides support to students and alumni in starting their technology-based businesses (CIT, 2015). Activities within the entrepreneurship club centre around mentorship, guidance and knowledge transfer toward creating new businesses. Businesspersons are brought in to mentor the club members, venture capitalists are solicited, and start-up support is provided. Support is also provided through the Office of Technology Transfer and Corporate Partnerships (OTTCP). This assistance is provided for high-technology start-ups.

Second ranked Stanford University features, within its School of Engineering, the 'Stanford Technology Ventures Program' (STVP). This is a holistic combination of university courses and support activities toward the development of extraordinarily powerful technology-based businesses (Stanford University, 2017). Massachusetts' Institute of Technology (MIT), ranked 3rd in the U.S., and 4th in the world, introduces students to working with industry partners to create products aimed at solving problems. The MIT Innovation Initiative (MITii), is a campus wide movement to encourage this type of creative problem solving throughout the university. Recently, in 2016, the School of Engineering and Sloan School of Business, teamed up to offer a joint minor in Entrepreneurship.

University of California's Berkeley Campus (UC Berkeley) uses a multi-faceted approach to produce entrepreneurial engineers. Academics, research, incubators, industry partnerships and mentoring are some of the methods employed by the Center for Entrepreneurship and Technology which is based in the US Berkeley College of Engineering (UCB, 2017).

2.4 Engineering programmes in the Caribbean

In the anglophone CARICOM region, this study identified a number of engineering programmes with the programme at The University of the West Indies, St. Augustine Campus (UWISTA), instituted in 1961, being the oldest. The University of the West Indies in Jamaica (UWIMONA), The University of Trinidad and Tobago (UTT), the University of Technology in Jamaica (UTECH) and the University of Guyana, also offer Bachelor of Science degrees in engineering. The Engineering Department at the University of Belize offers associate degrees in engineering. Despite the fact that the UTT, established in 2004, is the newest of all the universities mentioned, it was the first to establish a business incubator, named the UStart Incubator in support of its entrepreneurial mission (UTT, 2017). The UTT describes itself as an entrepreneurial university in its mission statement. In fact, this institution appears to provide the most entrepreneurial support to its students. This support is university-wide, and not concentrated in the engineering programmes.

The study specifically focuses on the entrepreneurial motivations of students and recent graduates from engineering programmes. This paper reports on a study conducted in the SIDS of T&T where participants from UWISTA and UTT participated in an empirical study conducted over a period of six (6) months. As with other studies among different demographics cited in this paper, participants were considered highly motivated if they were motivated by 'pull' rather than 'push' factors.

3. Research Method

This study was conducted between October 2015 and March 2016 and involved 250 respondents who were citizens of the Small Island Developing States of the Caribbean and current students or graduates of engineering programmes in two T&T universities, namely, The University of the West Indies, St. Augustine Campus (UWISTA) and The University of Trinidad and Tobago, O'Meara and San Fernando Campuses (UTT). The participants had graduation years ranging from 2010 to 2019. This study is an exploratory study which is really the first part of more extensive research on the potential for engineering entrepreneurship in the SIDS of the Caribbean and the Pacific Islands.

The Faculty of Engineering at UWISTA has been delivering engineering degree programmes since 1961, which is longer than any other institutions in the English-speaking Caribbean. As such, it was deemed appropriate to start this study with students from this institution. Ease of access and convenience were also considered in the decision to conduct this pilot study with students from UWISTA and also from engineering programmes within the relatively new, but entrepreneurial university, UTT, established in 2004. This study therefore covers the main engineering programmes within T&T.

A comprehensive self-reporting questionnaire tool was developed and electronically distributed. Two hundred and fifty responses were received. These responses were culled for missing sections and the result was the removal of twenty (20) questionnaires from the final sample. Responses were coded and the tau-equivalent reliability, more commonly referred to as Cronbach's alpha statistic (Cronbach's alpha), was calculated for the study. A Cronbach's alpha of 0.65 to 0.7 or higher is considered acceptable as a measure of reliability of the dataset. In this case, the Cronbach's alpha was 0.827, which exceeded the minimum requirements.

The data was then analysed using descriptive statistics, correlations and crosstabs in the IBM SPSS Statistics 24 software. The students' sex, ethnicity, parents' occupations, business experience, age of first introduction to business, entrepreneurial knowledge and entrepreneurial training were all investigated for correlations with entrepreneurial motivation. Initial areas investigated are shown in Table 2.

Table 2. Areas Investigated

Key	Description
School	UWISTA, UTT
Graduation	2010-2019
Major	BSc or BASc in any Engineering discipline
Age	Under 15, 15-17, 18-20, 21-24, 25-29, 30-34, 35-40, 41-50, 51-60, Over 60
Sex	Male or Female
Ethnicity	African Descent/Black, Asian, Caucasian/White, East Indian/South Asian, Hispanic/Latino, Middle Eastern, Mixed.
MrOccupation	Mother's Occupation – Public Service, Private Sector, Entrepreneur/Self Employed, Other
FrOccupation	Father's Occupation - Public Service, Private Sector, Entrepreneur/Self Employed, Other
BirthOrder	First Born, a Middle Child, Last Born, Only Child
BusExperience	Business Experience YES/NO
FBusExperience	First Business Experience NEVER, <5, 5-12, 13-19, 20-25, 25-30, >30
ENTKnowledge	Entrepreneurial Knowledge – Scale of 1-5 where 5 is highest
ENTTraining	Entrepreneurial Training
ENTMotivation	Entrepreneurial Motivation i) My family is in business ii) To take advantage of an opportunity iii) For the challenge iv) To be my own boss/control my life and future v) because the job market is dismal vi) If I get laid off from my job vii) I will NEVER start a business.

The questionnaire had been designed to determine whether students were motivated to be entrepreneurs and whether their motivators were 'pull' motivators such as taking advantage of an opportunity or 'push' motivators such as being forced to enter business because of a dismal job market or job loss. Where significant correlations were found, further investigation was done using the crosstabs function in descriptive statistics in SPSS.

4. Findings and Analysis

4.1 Participants

This study was limited to engineering students or graduates only with graduation dates from 2010 to 2019. A total of two hundred and fifty (250) engineering students and graduates participated in the study conducted over a period of approximately six (6) months. Twenty (20) survey returns were discarded due to incomplete sections of the questionnaire. The first two (2) sections out of three (3) form the basis of this study so incomplete survey responses were culled where necessary to ensure that a proper representation of the population was used. Two hundred and twenty-seven (227) responses were needed for a 90% confidence level with a margin of error of 5%, and this figure was exceeded.

4.2 Descriptive Statistics

There were sixty-three percent (63%) male respondents and thirty-seven percent (37%) female. The majority of participants, eighty-seven percent (87%), were from UWISTA and thirteen percent (13%) were from UTT. All of the students had gained or were pursuing either a Bachelor of Science or Bachelor of Applied Science Degree with forty-four percent (44%) representing Mechanical Engineering, twelve percent (12%) Civil Engineering, eleven percent (11%) Electrical Engineering and nine percent (9%) Manufacturing Engineering (see Table 3).

Table 3. Degree Specialisation

Degree Specialisation	Response Percent
BSc Chemical Engineering	7%
BSc Civil Engineering	12%
BSc Electrical Engineering	11%
BSc Geomatics	6%
BSc Industrial Engineering	7%
BSc Land Management	1%
BASc Manufacturing Engineering	9%
BSc Mechanical Engineering	44%
BSc Petroleum Geoscience	2%

Ninety-three percent (93%) of the respondents were between the ages of 18 and 29, as follows: 18-20; 26%, 21-24; 57% and 25-29; 11% (see Figure 3).

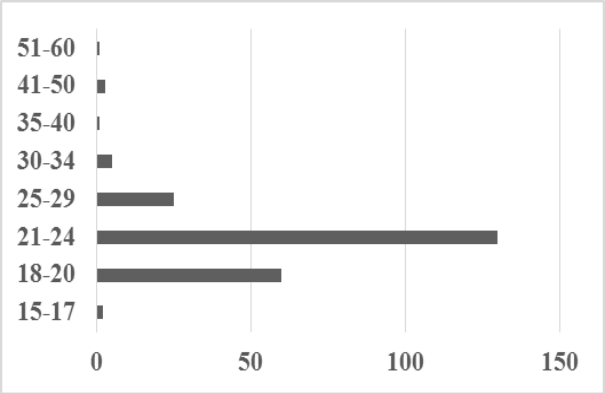

Figure 3. Age of respondents

Furthermore, 80% had graduation dates between 2016 and 2018 as follows: 38% in 2016, 25% in 2017, 17% in 2018. Ethnicity of the respondents was also recorded, as the literature identified links between ethnic origin and entrepreneurial motivations. In this case, the majority of the engineering students and graduates in the study were of East Indian/South Asian descent (40%), followed by African descent/black (30) and mixed (25). These three (3) categories represent 95% of the respondents (see Table 4). Regarding birth order, eleven percent (11%) of participants were 'only' children, thirty-one percent (31%) were 'first' borns, forty-one percent (41%) were 'last' borns and seventeen percent (17%) were 'middle' borns (see Figure 4).

Table 4. Ethnicity

Degree Specialisation	Response Percent
African Descent Black	31%
Asian	1%
Caucasian White	0%
East Indian/ South Asian	40%
Middle Eastern	1%
Mixed	26%
Other	1%

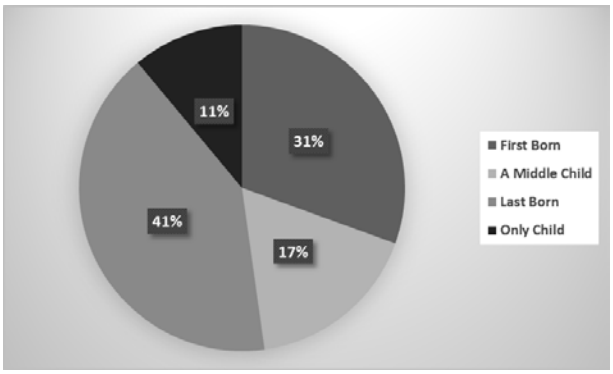

Figure 4. Birth order of respondents

The occupations of the parents of the respondents are shown in Table 5. Thirty-four percent (34%) of survey participants had experience on running a business and sixty-six percent (66%) had never run or assisted with managing a business. The age of first exposure to running or helping in a business is shown in Figure 5.

Table 5. Parents' occupations

Description	FrOccupation	MrOccupation
Public Service	28%	38%
Private Sector	40%	26%
Entrepreneur/ SE	16%	11%
Homemaker		15%
Other	16%	9%

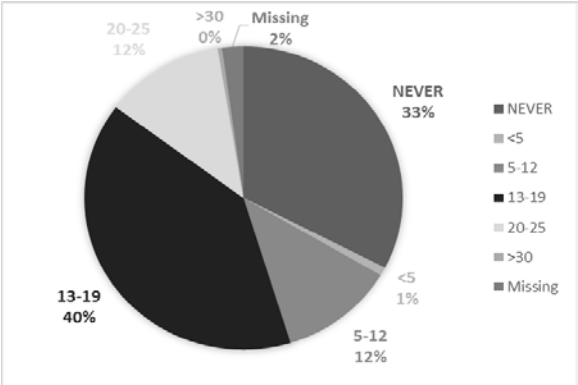

Figure 5. Age first exposed to running/helping in a business

Participants were asked to rate themselves regarding their knowledge on entrepreneurship. They were asked "On a scale of 1 to 5, where 1 is lowest and 5 is highest, how would you rate your skills and knowledge regarding entrepreneurship and what it entails? The responses are shown in Figure 6. The respondents also indicated their formal training in entrepreneurship, shown in Table 6.

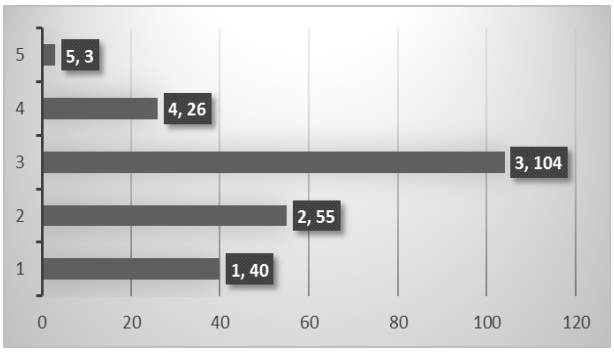

Figure 6. Entrepreneurial Knowledge

Table 6. Formal Training in Entrepreneurship

Details	Percent
No - none that I can remember at all	31%
No - and it was barely mentioned at University	20%
Yes - some basic training at University	19%
Yes - but not at the University	7%
Yes - for a semester or more at University	13%
Yes - both at the University and elsewhere	9%

The students and graduates indicated the reasons why they would start a business and the most frequent answers were "To be my own boss/control my life and future" (41%) and "To take advantage of an opportunity" (37%). These are both "pull" factors for entrepreneurship with the first being internal motivation and the second, external motivation. Few respondents cited push factors such as being downsized (2%) or a dismal job market

(5%) as the main reason why they would start a business (see Table 7).

Table 7. Entrepreneurial Motivation

Description	Percent
I will NEVER start a business	1%
If I get laid off from my job	2%
Because the job market is dismal	5%
My family is in business	8%
To be my own boss control my life and future	41%
For the challenge	6%
To take advantage of an opportunity	37%

4.3 Correlation Analysis

Interesting correlations were identified when the data was processed. Unlike the other studies cited in this paper, sex, ethnicity and parents' occupation were not significantly correlated with entrepreneurial motivation. Birth order and business experience were found to be the only factors in this study correlated with the entrepreneurial motivation of the engineering students. Statistically significant correlations included:

1. Birth order (BirthOrder) and entrepreneurial motivation (ENTMotivation) (Corr 0.162)
2. Business experience (BusExperience) and entrepreneurial motivation (ENTMotivation) (-0.176)
3. Birth order (BirthOrder) and business experience (BusExperience) (Corr 0.160)
4. Birth order (BirthOrder) and first business experience (FBusExperience) (Corr -0.137)
5. Sex (SEX) and first business experience (FBUSExperience) (0.137)
6. Business experience (BusExperience) and entrepreneurial knowledge (ENTKnowledge) (-.313)
7. First business experience (FBusExperience) and entrepreneurial knowledge (ENTKnowledge) (0.295)
8. Entrepreneurial training (ENTTraining) and entrepreneurial knowledge (ENTKnowledge) (0.196)
9. Ethnicity (ETHNICITY) and entrepreneurial knowledge (ENTKnowledge) (0.138)
10. Ethnicity (ETHNICITY) and entrepreneurial training (ENTTraining) (0.142)

Birth order was correlated with entrepreneurial motivation (Corr 0.162) whereby more than 50% of the 'middle' born and 'only' children reported wanting to start businesses for the independence and control it offered. Among the 'last born' siblings, 45% would engage in entrepreneurial activity to take advantage of an opportunity. This potentially makes them the most progressive entrepreneurs since their entrepreneurial motivation, based on pull factors, was mainly based on the potential for a product or service in the marketplace. This suggests that last born engineering students may prove to be the ones who would have the most impact on economic development since they should be able to respond most decisively to opportunities within the market.

First borns were most likely to enter business because the family was in business (14%). This was not surprising, as first born children are often expected to accept the responsibility of managing the family business after the parents have died or retired. The 'only child' was 2nd in reporting that their motivation for making a career in business was the fact that the family was in business. This was somewhat expected, since like the first born, the expectation of continued family ownership would fall on this individual (see Table 8).

Apart from birth order, business experience was the only other factor in this study which correlated significantly with level of entrepreneurial motivation. Engineering graduates with no business experience were more likely to become entrepreneurs than those with actual business experience (8% vs 2%). Similarly, none of the respondents with business experience reported that they would consider becoming entrepreneurs as a response to being laid off from their job. In contrast, three (3) percent of the engineering graduates with no business experience would consider entrepreneurship when laid off from their job.

Eighty-nine percent (89%) of the engineering students and graduates who had prior experience managing or assisting in running a business exhibited higher order 'pull' motivations, both internal and external. Eighty-three percent (83%) of the respondents with no business experience would be motivated by 'pull' factors (see Table 9). These results are quite interesting. They run true to the major conclusion that the respondents were strongly motivated by 'pull' factors. The small number of respondents motivated by push factors are not really dedicated to the idea of being

Table 8. BirthOrder * ENTMotivation Crosstabulation

		ENTMotivation						
		I will NEVER start a business	If I get laid off from my job	Because the job market is dismal	My family is in business	To be my own boss control my life and future	For the challenge	To take advantage of an opportunity
BirthOrder	First Born	2%	4%	8%	13%	38%	6%	29%
	A Middle Child	0%	3%	3%	0%	50%	9%	34%
	Last Born	0%	0%	6%	5%	36%	6%	45%
	Only Child	0%	0%	0%	10%	52%	5%	33%

Table 9. BUSExperience * ENTMotivation Crosstabulation

		I will NEVER start a business	If I get laid off from my job	Because the job market is dismal	My family is in business	To be my own boss control my life and future	For the challenge	To take advantage of an opportunity
BusExperience	Yes	0%	0%	2%	9%	38%	9%	42%
	No	1%	3%	8%	6%	43%	5%	35%

entrepreneurs and, should conditions change, would be tempted to pursue other interests involving full time employment.

First borns were most likely to have had experience (45%) managing or assisting in a business. This may have occurred as a result of parents' 'grooming' them for eventual ownership of the family business. Even though the 'only child' was the second (2nd) most likely to enter the family business, they were most likely to not have early business experience (see Table 10). This was an unexpected result and could be further investigated in a subsequent phase of this study.

Table 10. BirthOrder * BusExperience Crosstabulation

		BusExperience	
		Yes	No
BirthOrder	First Born	42%	58%
	A Middle Child	34%	66%
	Last Born	30%	70%
	Only Child	24%	76%

Even though the 'only child' was least likely to have business experience, the first business experience was earlier in life with 24% gaining this experience by age twelve (12), inclusive of four percent (4%) by age five (5). As with business experience, attribution cannot be immediately determined regarding the observation of the case of 'only child'. Among all age ranges, however, the first business experience most typically occurred during the teenage years, between 13 and 19 (see Table 11). Note that the overall figures for business experience differ because respondents would not have considered childhood ventures.

Table 11. BirthOrder * FBusExperience Crosstabulation

		FBusExperience					
		NEVER	<5	5-12	13-19	20-25	>30
Birth Order	First Born	25%	1%	10%	47%	15%	1%
	A Middle Child	32%	0%	16%	32%	21%	0%
	Last Born	39%	0%	10%	43%	8%	0%
	Only Child	40%	4%	20%	24%	12%	0%

Respondents who were exposed to business before age twelve (12), were more likely to report higher levels of entrepreneurial knowledge than those whose first business experience occurred at a more advanced age. Though the quantity of respondents was smaller for these categories, fifty percent (50%) of those exposed to business before age five (5) and thirty-three (33) percent of those whose first experience occurred between ages five (5) and twelve (12), scored themselves four (4) on a scale of one (1) to five (5) for entrepreneurial knowledge. In contrast, only thirteen (13), seven (7), and zero (0) percent respectively, of respondents in later age ranges rated themselves a four (4) or five (5) on entrepreneurial knowledge (see Table 12).

Table 12. FBusExperience * ENTKnowledge Crosstabulation

		ENTKnowledge				
		1	2	3	4	5
FBusExperience	NEVER	28%	33%	35%	3%	1%
	<5	0%	50%	0%	50%	0%
	5-12	15%	11%	41%	33%	0%
	13-19	11%	22%	54%	11%	2%
	20-25	18%	21%	54%	7%	0%
	>30	0%	0%	100%	0%	0%

East Indians, African descent/black and mixed race individuals constituted the majority of respondents for the study. Of these, East Indian engineering students and graduates scored evaluated their entrepreneurial knowledge highest, with 65% scoring themselves three (3) or higher. Mixed race (60%) and African descent/black (48%) followed (see Table 13).

Table 13. Ethnicity * ENTKnowledge Crosstabulation

		ENTKnowledge				
		1	2	3	4	5
Ethnicity	African Descent/Black	20%	31%	41%	7%	0%
	Asian	100%	0%	0%	0%	0%
	Caucasian White	0%	0%	100%	0%	0%
	East Indian	15%	20%	55%	9%	1%
	Middle Eastern	0%	0%	50%	50%	0%
	Mixed	14%	26%	36%	21%	3%
	Other	33%	0%	67%	0%	0%

5. Discussion

The main finding from this study was the fact that engineering students and graduates from a society not traditionally known for producing highly entrepreneurial engineering graduates, actually exhibit high-order entrepreneurial motivation factors. The desire to be the 'boss' in the enterprise or challenge themselves could be

described as internal 'pull' factors while responding to a need or opportunity in the environment would be an external 'pull' factor. In no case would circumstances force these respondents into entrepreneurship. This was even more impactful considering that, unlike other studies cited in this paper, no significant correlation was found between entrepreneurial motivation and factors such as sex, age, ethnicity or parents' occupations.

These results cannot be extended to include university students and graduates from other disciplines or other individuals within the society. Also, a clear distinction must be made between the terms entrepreneurial motivation, entrepreneurial intention and entrepreneurial behaviours. The latter two (2) point to decisive action impending, or executed. These respondents completed the questionnaire in such a manner as to leave no doubt as to the terms and conditions under which they would pursue entrepreneurial activity. It does not mean that they intend to pursue such activity or ever would. In fact persons with low level 'push' entrepreneurial motivations may be more likely to be entrepreneurs if conditions demand. Individuals motivated by 'push' factors such as job loss or a dismal job market are, however, likely to abandon the entrepreneurial journey when conditions change.

The conditions under which the majority of the respondents could be motivated to creative enterprises could form the basis for another study on entrepreneurial intentions. This study would be descriptive as opposed to explorative as it would require in-depth analysis of the behaviour of engineering students and graduates. The two factors that correlated significantly with level of entrepreneurial motivation, namely birth order and business experience could also be further explored.

It was interesting to discover that engineering graduates with actual business experience were less likely to be 'pushed' into creating businesses because of a poor job market or job loss. Their motivations are based on their own desires for independence and control or favourable factors within the environment. Training in business was one of the factors explored in this study but this was found to have no significant influence on the entrepreneurial motivation of the respondent. Regarding birth order, middle born and only children were more likely to desire a business for independence and control of their destiny while last born children identified taking advantage of an opportunity as their motivation. Somewhat expected, was the fact that first born participants were more likely than any other groups to indicate their entrepreneurial motivation as joining the family business. This study did not determine whether this was seen as a welcome opportunity or an expected but unwelcome duty.

This study was an exploratory study, seeking to understand the latent potential motivators for entrepreneurship among students and graduates not typically noted for participating in entrepreneurial activities. A further longitudinal study would be useful to define the archetypes for Caribbean engineering entrepreneurs. Furthermore, since the study seems to suggest that entrepreneurial engineers are not born, but 'made', and are highly motivated, this knowledge may be useful in supporting graduates of the regional engineering programmes.

6. Conclusion

Engineering students and graduates in T&T who participated in this study, overwhelmingly display high-order entrepreneurial motivational factors such as the need for control or desire to respond to opportunities within the environment. Unlike other entrepreneurship studies, no significant correlation was found between the entrepreneurial motivation of the respondents and ethnicity, sex, parents' occupation, or training in entrepreneurship.

Entrepreneurial motivation was, however, significantly correlated with birth order and experience running or assisting in managing a business. Further studies are proposed to better understand the factors which could affect the entrepreneurial intentions or behaviour of engineering students and graduates.

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Raymond Francis Charles (1951-2017): A Historical Note of a Civil Engineer

Mr. Raymond Francis Charles was born in 1951 in the St. James district of Port-of-Spain. He received his early education at the St. Crispin's EC Primary School in Woodbrook. From there he went to the Fatima College. There he won the school prize for Mathematics at the GCE O' Level examinations in 1968, and was the Head Prefect from 1968 to 1970. At Fatima, he proved himself to be an avid sportsman, was the captain of the basketball team and 'Victor Ludorum' at several of the schools' annual sports meetings. He went on to The University of the West Indies (UWI) and obtained a BSc (Hons.) in Civil Engineering in 1974 and an MPhil in Highway Geotechnics in 1989. He joined the Department of Civil and Environmental Engineering as a member of academic staff in 1981 and served as the Head of Department from 1999 to 2006, and again from 2013 to 2016. In his youth, Mr. Charles was exposed to a rich steelpan culture and a thriving sporting environment in the St. James district, and extended this experience to the management of the Steelband 'Kool and the Gang' in St. James, as well as being the president of the Real Maracas Football Club in Maracas, St. Joseph.

Trinidad is known globally, especially in those regions of the World not affected by the fascinating game of Cricket, for its Pitch Lake. Moreover, Civil Engineering students across the world learn about the Lake Asphalt; which has been used in runways of major airports (London Heathrow and JFK in New York), paving of ceremonial boulevards in Europe (the Mall in London and the Avenue des Champs-Élysées in Paris) and tunnels (Lincoln and Holland in New York). However, the measured engineering properties of Trinidad Lake Asphalt were not known in public domain. Mr. Charles was one of the first persons to scientifically study the engineering properties of Trinidad Lake Asphalt, and make the results of the same known in public domain through research publications and codes of practice (such as those of the American Society of Testing Materials). His research contributed to the opening of new markets for Trinidad Lake Asphalt in Brazil, China and India, and inspired his students. Fittingly, his pioneering work in this area did not go unnoticed, and in 2006 he received an Award of Excellence from the Caribbean Asphalt Association for his contribution to the asphalt and road pavement industry in the Caribbean.

The Commonwealth Caribbean is defined by its seascapes. Yet, the dichotomy between the Civil Engineering Curriculum at UWI and its physical environment was a source of disbelief; until Mr. Charles took a bold initiative in 2003 to concurrently launch an optional undergraduate course in Coastal Engineering as well as an MSc/Diploma in Coastal Zone Engineering & Management. The MSc/Diploma programme was re-structured in 2008 and is now comparable to reputable programmes elsewhere, and its graduates in the private and public sector are making a difference in the coastal zone management.

In late 1990s, the Engineering Council in the United Kingdom prescribed a major change in the minimum academic requirements for becoming a Chartered Civil Engineer. Specifically, a BSc degree was deemed insufficient and accordingly universities converted their three-year BSc programmes to a four-year MEng programmes. However, such a change was not considered feasible in the context and circumstances of

The UWI. Mr. Charles, as Head of Department of Civil and Environmental Engineering, solved this dilemma in an ingenious manner by introducing, in 2003, two MSc programmes to provide further learning to The UWI Graduates in Civil, and Civil with Environmental, Engineering, for meeting the current academic training needed for becoming Chartered Civil Engineers. The MSc degree programmes in Civil Engineering and Civil with Environmental Engineering were the first MSc programmes at The UWI to receive accreditation by the United Kingdom (UK) Engineering Council.

Mr. Charles served as a Director of the Public Transport Service Corporation of Trinidad and Tobago, and Director and Deputy Chairman of the Board of Lake Asphalt of Trinidad and Tobago Ltd in the 1990s. In addition, he was a Founding member and Director of the Pan American Institute of Highways (PIH) which was set up by the Organisation of the American States in 1989 to develop and extend solutions to road and highway design and maintenance issues across Latin America and the Caribbean. In 1999, he ended his contribution as a Director of the PIH and was subsequently given an Award by the Federal Highways Administration, USA, for his outstanding contribution to the formation and development of the PIH.

The World Bank, in collaboration with the Caribbean Development Bank, selected Mr. Charles as a member of an international expert user group set up to pioneer the practice of life-cycle evaluation of roads and highway projects across the developing world. Between 1996 and 1999, he organised several regional conferences, seminars and short courses for the Permanent International Association of Roads Congress. In 1996, he was among a group of international collaborators that founded the World Interchange Network (WIN) headquartered in Brussels, and had responsibility for the English speaking Caribbean region up to 1999.

As mentioned previously, there was no facility at UWI until 2003, for advanced training in Coastal Engineering. Not surprisingly, lack of regional technical expertise in this study field was laid bare in the aftermath of Hurricane Lenny in 1999, which had a devastating impact on the tourism industry of the Windward and Leeward Islands. A forensic engineering review of the damages revealed an ignorance of wave/structure interaction and coastal sediment transport by the practicing (mostly UWI trained) Civil Engineers. Mr. Charles perceived the need for training in Coastal Engineering, and more importantly, given the geographic and financial constraints, to take such training to the affected islands.

Mr. Charles obtained financial support from USAID/OAS for a training programme in Coastal Engineering. Specifically, 155 training opportunities were provided for participants from eight (8) Commonwealth Caribbean island states during 2001 to 2002. Needless to say, the Commonwealth Caribbean is now better equipped to design hazard resistant coastal infrastructure. It was in recognition of his aforesaid contribution to the Engineering profession he was elected as the Fellow of the Institution of Civil Engineers in London in 2005.

It was my privilege to be associated with Mr. Raymond Francis Charles for over thirty (30) years. He endeared many in the department, staff and students alike, by his unassuming and forgiving nature, and by his unwavering commitment to the department. To many, he was more than a colleague or a teacher: he was a friend and mentor. He will live in the memory of his students and colleagues.

Gyan S. Shrivastava,
Former Professor,
Department of Civil & Environmental Engineering,
The University of the West Indies, St. Augustine.

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