ISSN 0511-5728
The West Indian Journal of Engineering
Vol.34, Nos.1/2, January 2012, pp.52-58

An Investigation of Methanol-Coconut Oil Fuel Blends in Diesel Engines for Caribbean Power Generation Using Bio-diesel as a Co-solvent

Renique J. Murray [aΨ], Sharaaz Hosein[b] and Solange Kelly [c]

The University of Trinidad and Tobago, Pt. Lisas Campus, Esperanza Road, Brechin Castle, Trinidad and Tobago, West Indies

[a]E-mail: renique.murray@gmail.com
[b] E-mail: sharaaz.hosein@utt.edu.tt
[b] E-mail: solange.kelly@utt.edu.tt

[Ψ] *Corresponding Author*

(Received 18 May 2011; Revised 20 October 2011; Accepted 07 November 2011)

Abstract: *The development of alternative fuel sources is a crucial area of research today, in light of diminishing global crude oil reserves and increasing prices of fossil fuels. This is a critical issue for the countries of the Caribbean, as the small and delicate economies of the region are unable to treat with these price increases indefinitely. Two potential alternative fuel sources for the region, which can utilise diesel engines for power generation, are methanol and coconut oil. However, neither of these achieves optimum performance individually, without engine modification. This work investigates the performance of methanol-coconut oil blends in diesel engines, using coconut oil biodiesel (CME) as a co-solvent. It was found that CME does serve as an effective co-solvent, allowing for the formation of stable blends of up to approximately 30% methanol content by volume. Consequently, six fuels were tested in a diesel engine test unit; diesel, neat CME, neat coconut oil, a coconut oil-CME blend, a blend containing 10% methanol by volume and another containing 30% methanol by volume. It was found that the methanol blends had better engine performance, when compared to neat coconut oil operation. Further, it was found that the methanol blends exhibited similar and even better engine performance than diesel operation, with a BTE of 28.6% for the 30% methanol blend as compared to 22.9% for diesel operation. Consequently, this work proposes that methanol-coconut oil blends using CME as a co-solvent, can serve as potential fuel replacements for diesel in the countries of the Caribbean.*

Keywords: *Methanol, biodiesel, coconut oil, diesel engine*

1. Introduction

Fossil fuels are the most prominent type of fuel worldwide. Collectively, crude oil, coal and natural gas account for more than 85% of the world's total energy consumption (EIA, 2007). However, recent studies have shown that the combustion of fossil fuels has, and continues to contribute significantly to the rapid increase of anthropogenic greenhouse gases. As such, much work has been directed towards developing methods to reduce the emissions of diesel and other fossil fuels from engine combustion processes, such as the work done by Yao et al. (2008). However, there is still some difficulty in reducing the various types of emissions all at the same time (Huang et al., 2004). As such, this continues to be an issue under investigation.

Additionally, it is well known that fossil fuels are a non-renewable resource. Although there are discrepancies among many scientist and researchers, the general consensus is that crude oil has a much shorter projected life span than that of natural gas (Campbell, 2002). Accordingly, it is expected that as crude oil resources deplete, its price and that of its derivatives will increase.

The countries of the Caribbean region, like many other regions, have become significantly dependent on diesel and other fossil fuels for power generation and other energy uses. In 2005, it was recorded that more than 90% of the Caribbean territories were dependent on diesel as their main fuel source for electrical power generation (EIA, 2007). As a result, many of these countries are finding it difficult to accommodate the increasing cost of diesel fuel and are currently seeking more sustainable sources of energy (Hertzmark, 2006).

A key potential energy source for the Caribbean region lies in its capacity to convert vegetable matter into fuel, i.e., bio-fuels. A number of studies have been done within recent times that indicate that there is a significant bio-fuel potential to be harvested in the region. A report by the United Nations Biofuels Initiative has indicated that of the many potential sources, coconut oil is one of the best options, as it has the greatest potential in the region (The Energy and

Security Group, 2006). Other possible sources include corn, cotton seed and palm. In addition, as these are all indigenous, it is likely that their use would encourage other social benefits within the region, as was the case with the use of coconut oil in the Pacific (Cloin, 2005). Further, the environmental benefits and the potential for sustainable energy arrangements are two other key advantages.

Natural gas presents another potential energy source for the Caribbean region. Natural gas, because of its chemical composition, is a much cleaner fuel than diesel and it is also less costly. Natural gas has been proposed as a potential fuel alternative for the Caribbean region by many experts, due to the fact that there are significant reserves located in the region, mainly in Trinidad and Tobago (Kromah et al., 2003). However, most of the territories in the region are separated by the surrounding Caribbean Sea. This presents a crucial challenge in transporting the natural gas from Trinidad and Tobago to the other countries in the region. Methanol has been proposed as a potential solution in cases of stranded gas markets (Olah et al., 2006), and may have relevance for this scenario. Murray and Furlonge (2009) have shown that methanol originating in Trinidad and Tobago, can be economically used as a fuel for both gas turbine and diesel engines. The latter being more economical and of greater interest, as most of the countries in the region either generate most or all of their electricity using diesel generator sets.

2. Review of Work on Fuel Blends in CI Engines

The use of vegetable oils as fuels for diesel engines has long been a subject of research, but in recent times has seen renewed efforts, in the light of a growing need to develop alternative energy sources. A consideration of their use requires treatment of some key setbacks, namely low pour point temperatures, high viscosities and the presence of other contaminants such as fat and protein, due to the process of extraction. Perhaps the most critical of these to the combustion process is that of the higher viscosities, as this generally results in poor atomisation and consequently higher levels of incomplete combustion. Many investigations have sought to improve the effectiveness of vegetable oil fuels by developing blends with other fuels. Agarwal and Rajamanoharan developed diesel and karanja oil blends, ranging from 10% to 75% karanja oil (Agarwal and Rajamanoharan, 2008). They found that blending with diesel improved BTE as compared to neat karanja oil operation and concluded that the blends can serve as an adequate fuel replacement for diesel.

Haldar et al. (2008) proposed another alternative process of pretreating the vegetable oil called "degumming", which served to remove foreign materials such as proteins and fats. The method was tested on three oils that were locally developed and available in India, i.e. Putranjiva oil, Jatropha oil and Karanja oil. Haldar et al. (2008) used the pretreated oils to develop blends with diesel, and reported that the blends with 20% diesel showed the best engine performance. In a similar manner, Senthil Kumar et al. (2002) sought to improve vegetable oil engine performance by using hydrogen and they reported increased engine performance with hydrogen addition at all loads.

In general the use of neat methanol in CI engines requires large compression ratios and other mechanical modifications, such as enhanced exhaust gas scavenging to address the issue of its high auto-ignition temperatures. Seko and Kuroda (1998, 2001) have conducted a number of investigations on the use of neat methanol in CI engines. Consequently, if extensive mechanical modification is not the preferred option, methanol is generally limited to smaller percentages and is used as an additive.

The use of methanol as an additive in CI engines has been investigated by a number of researchers. In general it has been found that its addition improves engine performance, as indicated by higher BTEs. Senthil Kumar et al. (2003) investigated the impact of methanol on Jathropha oil as a fuel for diesel engines. Bayraktar (2007) conducted experiments on methanol diesel blends; Huang et al. (2004) also conducted similar experiments. However, methanol is immiscible with diesel and vegetable oils because of its high affinity for water. Consequently, this necessitates the use of a dual-fuelling approach or of specialised fuel additives to facilitate blend formation, such as dodecanol or iso-butane, as utilised by Bayraktar and Huang et al respectively.

The use of fuel blends between methanol and vegetable oils is a potential prospect that is particularly suitable for the Caribbean territories, given the availability and relative abundance of both fuel types. However, the desire to minimise costs omits the option of engine replacement and limits the extent of engine modification possible. Further, the use of rare and highly specialised chemical solvents and/or blend enhancers that must be imported to the region, would incur additional costs along the value chain, and lead to higher power generation prices. In a region with predominantly small economies, already facing various challenges, this is not desirable. As such, locally developed and more readily available alternatives would be more suitable. Consequently, this work seeks to examine the performance of coconut oil-methanol fuel blends, using biodiesel as a co-solvent.

3. Blend Development

As alluded to earlier, methanol does not readily mix with coconut oil. However, previous work has shown that individually both methanol (Cheng et al., 2008) and vegetable oils blend well with bio-diesel. Consequently, this work sought to use bio-diesel as a co-solvent. Bio-diesel is potentially a more economical co-solvent for this scenario, as compared to other solvents presented in previous work, because it can be produced locally from most of the variety of vegetable oils available in the region.

Interestingly, Kwanchareon et al sought to use biodiesel as a co-solvent for diesel and ethanol (Kwanchareon et al., 2006). They sought to develop mixtures of ethanol and diesel, using different purities of ethanol and bio-diesel as the co-solvent in all cases. They found that for mixtures containing ethanol of 99.5% purity, the inter-solubility of the three components was not limited; however, for mixtures of lower ethanol purity the solubility limitations were evident, resulting in phase separation. It was found that the biodiesel served as a surfactant, and allowed for a simplified blending process.

The experiments conducted here sought to determine the impact of biodiesel on the inter-solubility of methanol and coconut oil, in order to produce a stable blend for use in CI engines. The purity of methanol used was 99 % and the coconut oil used was produced locally in Trinidad and Tobago. The biodiesel used was coconut oil methyl ester (CME) and was also developed locally at the laboratories of The University of Trinidad and Tobago.

Mixtures of various concentrations of methanol, coconut oil and CME were tested. The general procedure involved developing a 20ml mixture of the three components. The proportions of each of the components were varied systematically. This was done by first fixing the percentage of methanol in the 20ml mixture at 10% by volume. Subsequently, the percentage of the CME was varied from 10% to 50% in intervals of ten, with the remaining percentage being coconut oil. Given that CME was being used as the co-solvent, it was deemed necessary to limit its percentage to 50%; for larger proportions, CME would no longer be considered the co-solvent agent but the main component. This was repeated for methanol concentrations of 20%, 30% and 40% and the mixtures were examined for level of solubility and phase stability. All tests were conducted at a laboratory temperature of 19° C.

Figure 1 shows the results of the blend mixing tests conducted. The x-axis shows the CME percentage content, while the y-axis shows percentage coconut oil. The methanol content of the mixture can be calculated by finding the arithmetic difference of 100 and the sum of the x and y coordinates. So, for a point (20, 50) on the chart, the blend proportion is as follows: 20% CME, 50% coconut oil and 30% methanol. The sizes of the bubbles on the chart represent blend solubility; the large bubbles represent full solubility, while the smaller ones represent partial solubility.

The results of the tests indicate three main things. The first of these is that CME does serve as an effective co-solvent for coconut oil-methanol mixtures. The three fuels fully mixed with one another, producing colloidal blends that were stable for more than one hour. The second of these concerns the proportions in which full solubility is attainable.

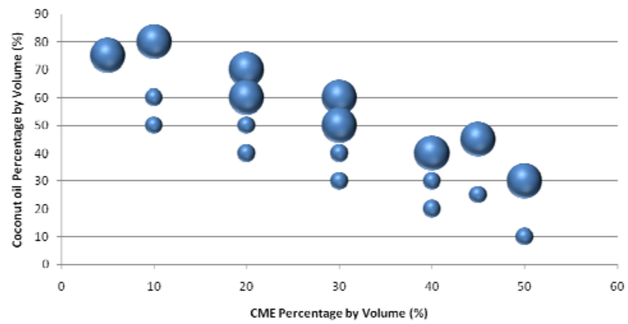

Figure 1. Solubility chart for test results

As can be seen in Figure 1, the sizes of the bubbles decrease as one moves in a diagonal direction across the graph, from the top right hand corner to the bottom left hand corner. This movement represents an increase in methanol content. As such, as methanol percentage increases the inter-solubility of the blend decreases. Consequently, there is a limit on the methanol percentage that can be added before the blend becomes unstable. The limit found in these tests is around 30%. The third main finding is that methanol solubility increased as the proportion of CME increased.

It should be noted that phase stability is a key concern for these mixtures. For most of the mixtures where there was only partial solubility, the mixtures appeared to be fully mixed immediately after agitation. However, when these mixtures were allowed to settle, they separated within a few minutes, with a large proportion of the methanol coming out of solution, while a small volume remained in solution. In comparison, the mixtures identified as fully mixed, remained in solution for up to one hour and more. Although not represented in the chart of Figure 1, it was generally found that as methanol content increased, the length of the stable period for the mixtures identified as fully mixed, decreased; i.e., phase stability increased with decreasing methanol content. The implication of this for fuel delivery purposes, is that blends with higher methanol content will have to be agitated at some point prior to injection. It should also be noted that blend stability is likely to increase with temperature, as was found by Kwanchareon et al. (2006). Consequently, at temperatures of around 30° C, which are average for the Caribbean, there is a likelihood of longer periods of stability.

4. Experimental Setup and Engine Testing Methodology

The test unit used in these experiments was a single cylinder, four-stroke, compression-ignition reciprocating diesel engine. The specifications for the engine are given in Table 1. The unit contained a coupled dynamometer from which the engine load was varied and instrumentation for measuring air consumption, cooling water flow rate and temperatures and dynamometer force. Additionally, exhaust temperature was obtained by installing a thermocouple at the exhaust of the engine. The engine speed was measured using a tachometer.

Table 1. Engine specifications

Manufacturer	**Plint Engineers (UK)**
Bore/mm	87.3
Stroke/mm	110
Swept volume/cm^3	659
Compression ratio	16.5:1
Rated speed rev/min	1800
Capacity /kW	7

Six different fuels were tested in the engine unit (see Table 2. These are diesel, neat coconut oil, neat CME, a coconut oil CME blend containing 70% coconut oil by volume (referred to as coco-CME); a blend containing 10% methanol, 27% CME and 63% coconut oil by volume (referred to as M-10); and a blend containing 30% methanol, 21% CME and 49% coconut oil by volume (referred to as M-30). Based on the fuel mixing tests done previously, 30% methanol content was chosen as the highest limit of methanol to avoid phase separation. In addition, it should be noted that although increasing CME content increased methanol solubility, CME percentage was limited as it was being used for co-solvent purposes in these tests.

Table 2. Fuel Properties

Fuel	**Density (kg/m^3)**	**Heating value (kJ/kg)**
Diesel	834	45822
Methanol	790	22700
Coconut oil	930	37260
CME	860	38000
Coco-CME	909	37482
M10 blend	897	36000
M30 blend	873	33050

To facilitate the tests, a second fuel tank was added to the engine unit. The setup was such that the engine could be switched from one fuel tank to the other during operation. Additionally, the tank was strategically positioned to allow the engine's vibration to agitate the fuel in the tank. The general test procedure was as follows: the engine was started on the highest load condition using diesel and allowed to run for ten minutes, until it arrived at steady state. The engine was then switched to the additional fuel supply tank, which contained one of the six fuels identified previously. It was further allowed to run for another ten minutes to achieve steady state conditions using the new fuel. The engine was then unloaded in six gradations, with no load being the last. For each loading condition, the engine was run for approximately five minutes to achieve steady state conditions before readings were taken. This procedure was repeated for all six fuels and the results are presented in the following section.

5. Results and Discussion

Figures 2 and 3 show plots of BTE versus load for the various mixtures tested. As expected, engine efficiency increases with increasing load. It can be seen from the figures that the highest levels of engine efficiency are recorded for operation with neat CME and the M30 blend. The values of BTE for neat CME and M30 are generally similar in most instances; however the M30 blend has a slightly higher BTE than neat CME for most load conditions tested. More importantly, the BTE for the M30 blend surpasses that for neat diesel operation at the highest loads, with values of 28.6% and 22.9% respectively.

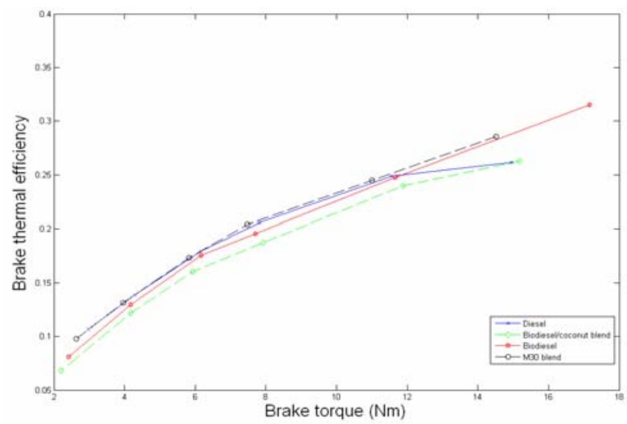

Figure 2. BTE vs. Brake torque for diesel, coconut oil, M10 blend and M30 blend operation

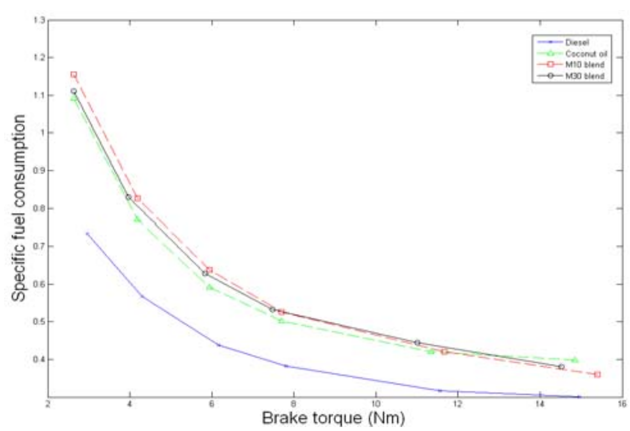

Figure 3. BTE vs. Brake torque for diesel, coco-CME blend, CME and M30 blend operation

Conversely, the lowest engine efficiencies occur for neat coconut oil operation; efficiency for operation with neat coconut oil is lower than operation using standard diesel, with a BTE of 18.9% at the highest load. The latter is a somewhat expected result. As indicated in the literature, the higher viscosities of vegetable oils tend to result in poorer atomisation, leading to more incomplete combustion and ultimately lower BTEs. The presence of CME in the coco-CME blend, improves overall performance as can be seen by the higher BTEs than neat coconut oil. This is most likely due to the lower viscosity of CME and a better combustion process as a result.

Figure 2 shows that BTE for M10 and M30 blends is close to that of standard diesel at lower loads, but surpasses it at higher loads. As expected, the values of BTE for M30 are higher than those for M10. Further, the values of BTE for the M10 and M30 blends are all higher than those for neat coconut oil and also for the coco-CME blend. These results clearly indicate that efficiency increases with methanol addition. This is in keeping with the results put forward by many other researchers, as discussed earlier. The increase can be attributed to methanol's higher auto-ignition temperature and its faster burning rate. It is likely that as the methanol content increases, a greater proportion of combustion occurs in the premixed phase as opposed to the diffusion phase, due to delayed ignition. Coupled with the faster burning rate of methanol, the result is a more complete combustion process, leading to higher BTEs. As expected, as methanol volume increases, from M10 to M30, the effect of a longer premixed phase is greater, leading to increases in efficiency.

The higher BTEs for the M10 and M30 blends at higher loads when compared to standard diesel, is a welcomed result, as most engines being used for electricity generation usually operate at medium to full load. As such, the M10 and M30 blends can potentially act as diesel replacements for electricity generation purposes.

Figures 4 and 5 show the plots of SFC versus load for the six fuels tested, respectively. In general, these results further corroborate what was illustrated by the plots of BTE versus load. Once more as expected, SFC decreases with increasing load. The lowest values of SFC are recorded for diesel operation with a value of 0.343 kg/kJ.min. This result is in keeping with the fact that of the six fuels tested, diesel has the highest calorific content. Consequently, lower volumes of diesel are required to generate the same values of brake power than those required for the other fuels having lower calorific contents.

Conversely, the highest values of SFC are recorded for neat coconut oil and the M30 blend; the M30 blend having higher SFCs at lower load conditions. The higher values of SFC for the M10 and M30 blends are a result of methanol's lower calorific value; it is approximately half that of diesel (see Table 2). However, the calorific value of coconut oil is second only to diesel among the six fuels tested. As such, as stated earlier, the higher values of SFC can be attributed to a poorer combustion process for neat coconut oil. As a consequence of this, greater volumes of coconut oil are required to generate the same power output, and there is a consequent increase in SFC. It should be noted that the values of SFC for the M10 and M30 blends are lower than that of neat coconut oil at the highest load condition, despite the lower calorific value. Once more, this points to a more complete combustion process, due to the presence of methanol. Thus, this further validates that the presence of methanol enhances the combustion of the neat coconut oil, resulting in lower SFC for the blend.

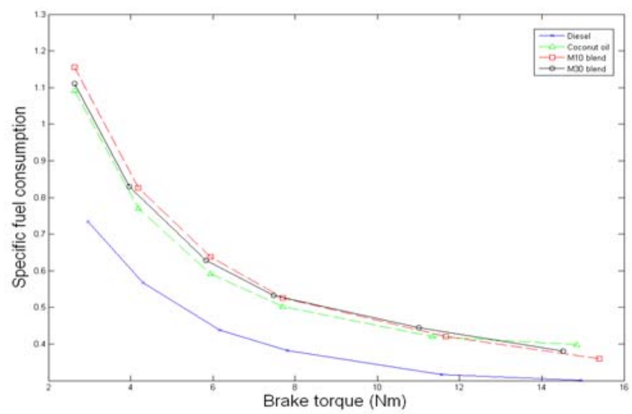

Figure 4. SFC vs. Brake torque for diesel, coconut oil, M10 blend and M30 blend operation

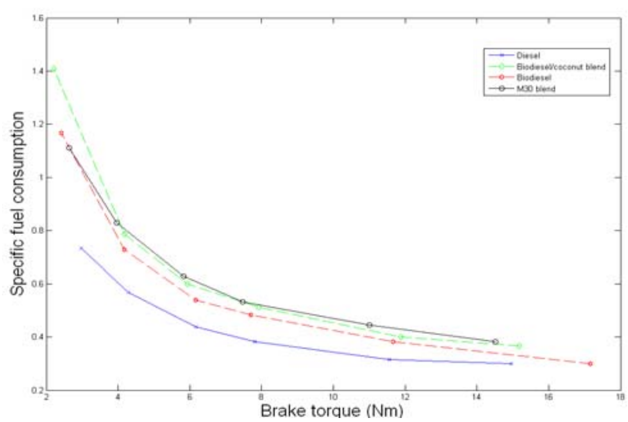

Figure 5. SFC vs. Brake torque for diesel, coco-CME blend, CME and M30 blend operation

6. Summary and Conclusion

The work presented here examined the use of coconut oil, CME and methanol blends as a fuel for diesel engines. The following are the main findings that have emerged from these tests:

- Mixtures of coconut oil and methanol were developed using CME as a co-solvent. The presence of CME allowed for the development of coconut oil/methanol mixtures at room temperature, without heating or any additional processing.

- It was found that for mixtures of methanol and coconut oil where CME is the co-solvent, methanol solubility and phase stability increases with increasing CME proportion, but decreases with increasing methanol content.
- Engine tests were conducted on a single cylinder compression ignition engine test unit for six fuels including, diesel, neat coconut oil, neat CME, a CME-coconut oil blend, a 10% methanol blend and a 30% methanol blend. The methanol blends exhibited higher engine efficiencies than diesel for high load conditions, with the highest BTE value recorded for the M30 blend being 28.6% as compared to 22.9% for diesel operation.
- The addition of methanol to coconut oil produces a mixture with better engine performance. This was evident as BTE increased from 24.2% for neat coconut oil at the highest load condition, to 27.8% and 28.6% for the M10 and M30 blends, respectively. The M10 and M30 blends also exhibited lower SFC values than coconut oil at the higher engine loads. This increase in performance can be attributed to a better combustion process for the mixture.
- Based on the comparable and higher efficiencies of the methanol blends and the lower greenhouse gas emissions, it is proposed that methanol-coconut oil blends can potentially serve as diesel replacements for electricity generation in the countries of the Caribbean region.

In the consideration of replacing diesel with the proposed M10 and M30 blends, the issue of emissions would also be of particular significance. The M10 and M30 blends offer a cleaner fuel alternative than diesel. This is due mainly to the large proportion of vegetable oils in the mixture, whose net carbon emissions are close to zero, as is the case with most bio-mass fuels. In addition, methanol, which is a derivative of natural gas, also generates much lower levels of carbon emissions during combustion, as a consequence of the lower carbon content as compared to diesel. The levels of nitrogen and sulfur oxides are also greatly reduced as a consequence of methanol's composition and its combustion. The general result is that mixtures of coconut oil and methanol generate significantly lower levels of greenhouse gases, when compared to fossil-based diesel.

The work presented here focuses specifically on the development and testing of methanol-coconut oil blends and their performance in a diesel engine test unit. However, these results are likely to be generally applicable to the wider class of methanol-vegetable oil blends. As is well known, there are several types of vegetable oils developed in the Caribbean, based on the vegetable matter indigenous to the region. The authors of this work consider it as a first step in the wider investigation of these types of blends and intend to conduct further experimentation, along with the development of simulation models to facilitate further work.

Acknowledgements:

The authors of this paper would like to acknowledge Professor Edwin I. Ekuwe of the Department of Mechanical and Manufacturing Engineering and Mrs. Sherry Mungal of the thermodynamics laboratory, the Department of Mechanical and Manufacturing Engineering, The University of the West Indies. The authors would also like to acknowledge Dr. Ejae John of the Natural Gas Institute of the Americas, The University of Trinidad and Tobago for her significant contributions to this work. The authors recognise that without these contributions, this work would not have been possible and would like to express their gratitude.

References:

Agarwal, A.K and Rajamanoharan, K. (2008), "Experimental investigations of performance and emissions of Karanja oil and its blends in a single cylinder agricultural diesel engine", *Applied Energy*, Vol.86, pp.106-112

Bayraktar, H. (2007), "An experimental study on the performance parameters of an experimental CI engine fueled with diesel-methanol-dodecanol blends", *Fuel*, Vol.87, pp.158-164

Campbell, J.C. (2002), "Peak oil: an outlook on crude oil depletion", available at: http://www.greatchange.org/ov-campbell,outlook.html [Assessed 11 December 2008]

Cheng, C.H, Cheung, C.S., Chan, T.L., Lee, S.C., Yao, C.D. and Tsang, K.S. (2008), "Comparison of emissions of a direct injection diesel engine operating on biodiesel with emulsified and fumigated methanol", *Fuel*, Vol.87, pp.1870-1879

Cloin, J. (2005), "Biofuels in the Pacific", *Refocus*, Vol. 6,pp.45-48

EIA (2007), *The Energy Information Agency International Data page*, available at: http://www.eia.doe.gov/fuelelectric.html [Assessed 31 October 2007]

Haldar, S.K, Ghosh, B.B. and Nag, A. (2008), "Studies on the comparison of performance and emission characteristics of a diesel engine using three degummed non-edible vegetable oils", *Biomass and Bioenergy*, Vol.33, pp.1013-1018

Hertzmark, D. (2006), "OECS energy issues and options", *Energy Sector Management Assistance Programme*, Report 317/06, February

Huang, Z., Lu, H., Jiang, D., Zeng, K., Liu, B., Zhang, J. and Wang, X. (2004), "Combustion behaviors of a compression-ignition engine fuelled with diesel/methanol blends under various fuel delivery advance angles", *Bioresource Technology*, Vol.95, pp.331-341

Kromah, M., Thomas, S. and Dawe, R.A. (2003), "Transporting natural gas around the Caribbean", *West Indian Journal of Engineering*, Vol.25, No. 2pp.18-32

Kwanchareon, P., Luengnaruemitchai, A. and Jai-In, S. (2006), "Solubility of a diesel-biodiesel-ethanol blend, its fuel properties, and its emission characteristics from diesel engine", *Fuel*, Vol. 86, pp.1053-1061

Murray, R.J. and Furlonge, H.I. (2009), "Market and economic assessment of using methanol for power generation in the Caribbean region", *The Journal of The Associations of Professional Engineers of Trinidad and Tobago*, Vol.38, No.1, pp.88-99

Olah, A.G., Goeppert, A. and Prakash, G.K. S. (2006), *Beyond Oil and Gas: The Methanol Economy*, WILEY-VCH Verlag GmbH, Weinheim, Germany

Seko, T. and Kuroda, E. (1998), “Methanol lean burn in an auto-ignition DI engine”, *Society of Automotive Engineers technical paper series*, No. 980531

Seko, T. and Kuroda, E. (2001), “Combustion improvement of a premixed charge compression ignition methanol engine using flash boiling fuel injection”, *Society of Automotive Engineers technical paper series*, No. 2001-01-3611

Senthil Kumar, M., Ramesh, A. and Nagalingam, B. (2002), “Use of hydrogen to enhance the performance of a vegetable oil fuelled compression ignition engine”, *International Journal of* Hydrogen Energy, Vol.28, pp.1143-1154

Senthil Kumar, M., Ramesh, A. and Nagalingam, B. (2003), “An experimental comparison of methods to use methanol and Jatropha oil in a compression ignition engine”, *Biomass and Bioenergy*, Vol.25, pp.309-318

The Energy and Security Group (2006), “Background Data Collection on Bio-Energy in the Caribbean and Central America”, Report prepared for the United Nations Biofuels Initiative with Support of The UN Foundation and the Italian Ministry of the Environment, United Nations

Yao, C., Cheung, C.S., Cheng, C., Wang, Y., Chan, T.L. and Lee, S.C. (2008), “Effect of diesel/methanol compound combustion on diesel engine combustion and emissions”, Energy Conversion and Management, Vol.49, pp.1696-1704

Authors’ Biographical Notes:

Renique J. Murray *currently functions at The University of Trinidad and Tobago (UTT) as a Researcher in the field of power generation and an Instructor in mechanical engineering. He has been conducting postgraduate research on several aspects of power generation and power generation machinery for the past eight years. He has recently served at The University of the West Indies as a Part-time Lecturer in the subject of Engineering Dynamics, before which he conducted research at the university as a Research Assistant. Mr. Murray holds a Bachelor of Science degree in Mechanical Engineering from The University of the West Indies, as well as a Master of Philosophy degree from the said university, in the area of vibration analysis of rotating machines. He is currently a doctoral candidate at The University of Trinidad and Tobago in the area of fuel technology and power generation.*

Sharaaz Hosein *has sixteen years of industrial experience in the Energy sector, in both the supply and demand-sides. His work in demand-side management concerned primarily energy conservation in the commercial and industrial sectors, and its link with the environment, and exploring alternative fuels, including renewables. His supply-side experience came as an Industry regulator, from his role as a Mechanical Engineer with the Ministry of Energy of Trinidad and Tobago (MOETT). His research at Cranfield University, UK looked at the extent to which a comprehensive cogeneration Energy-policy proposal would translate into savings for T&T’s primary-energy resource, i.e. natural gas. Dr. Hosein is now an Assisant Professor at The University of Trinidad and Tobago (UTT) and researches in alternative fuels for power generation, and feasibility of natural-gas vehicles in T&T.*

Solange Kelly *has fifteen years of postgraduate research and industrial experience in process optimisation, exergy analysis, exergoeconomic analysis, air-conditioning and manufacturing. She worked as a Research Assistant at The University of the West Indies (UWI) for two years where she conducted research work in exergy analysis of absorption chillers and gas turbine systems. She was also a Research Assistant at The Technical University of Berlin where she conducted research work in the optimisation of thermal systems using exergoeconomics with emphasis on splitting the exergy destruction (irreversibilities) into its endogenous and exogenous parts. With over seven years experience in the manufacturing Industry, Dr. Kelly has also developed expertise in discrete manufacturing and air-conditioning design and operation. Dr. Kelly is now an Assistant Professor at The University of Trinidad and Tobago (UTT) and researches in the area of Renewable Energy and Ethics and Professionalism for Engineers.*

■