International Journal of Advances on Automotive and Technology
Promech Corp. Press, Istanbul, Turkey
Vol. 1, No. 1, pp. 13-18, January, 2017

http://dx.doi.org/10.15659/ijaat.16.07.349
Manuscript Received May 5, 2016; Accepted June 4, 2016.

This paper was recommended for publication in revised form by Co-Editor Yasin Karagoz

PERFORMANCE, EMISSION AND COMBUSTION CHARACTERISTICS OF CI ENGINE USING BLENDS OF METHANOL AND PONGAMIA BIODIESEL

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Keywords: Alternative fuel, diesel engine, performance, emission, and combustion, pongamia biodiesel.
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ABSTRACT

Automobiles emission is one of the major problems in environment. Engine emits the hydrocarbon (HC), carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxides (NO_X) etc. NO_X emission leads to dangerous effect in the environment. Nitrogen oxides are a family of poisonous, highly reactive gases. These gases form when fuel is burned at high temperatures. The present paper investigates the performance, emission and combustion characteristic of a single cylinder, naturally aspirated, water cooled, DI diesel engine running with pongamia biodiesel and blends with methanol 10%, 20% and 30% (P90M10, P80M20, and P70M30) and the experimental results were compared with that of diesel. The result showed that the fuel properties of pure pongamia, viscosity, density, flash point and fire point were found to be higher and calorific value is lower than that of diesel. Based on performance, emission, and combustion characteristics of the various blends, the optimum blend was found to be P90M10.

INTRODUCTION

Alternative fuels, known as non-conventional or advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels. Conventional fuels include petroleum oil, coal, and natural gas as well as nuclear materials such as uranium and thorium, as well as artificial radioisotope fuels that are made in nuclear reactors. Some well known alternative fuels include biodiesel, methanol, ethanol and butane, chemically stored electricity, hydrogen, non fossil methane, non fossil natural gas, vegetable oil, and other bio mass sources [1].

Biodiesel is a form of diesel fuel manufactured from vegetable oils, animal fats, or recycled restaurant greases. It is safe, biodegradable, and produces less air pollutants than petroleum based diesel. Biodiesel can be used in its pure form (B100) or blended with diesel. Common blends include B2 (2% biodiesel), B5, and B20. Most vehicle manufacturers approve blends up to B5, and some approve blends up to B20. Biodiesel are the domestically produced from non-petroleum, renewable resources. It can be used in most diesel engines, especially newer ones and less air pollutants (other than nitrogen oxides), less greenhouse gas emissions, biodegradable, non-toxic [2].

Among the alcohols, methanol has the lowest combustion energy. However, it also has the lowest stoichiometric or chemically correct air-fuel ratio. Therefore, an engine burning methanol would produce the maximum power. A lot of research has been done on the prospect of methanol as an alternative fuel. Methanol, CH_3OH, is the simplest of alcohol and originally produced by the destructive distillation of wood. Methanol can also be produced from many fossil and renewable sources which include coal, petroleum, natural gas, biomass, wood landfills and even the ocean [3]. Today it is produced in very large quantities from natural gas by the reformation of the gas into carbon monoxide and hydrogen followed by passing these gases over a suitable catalyst under appropriate conditions of pressure and temperature [4].

Methanol is the high stoichiometric fuel to air ratio, high hydrogen to carbon ratio and low sulphur content, higher latent heat of vaporization, reducing the soot and smoke, with economics of scale. Methanol could be produced, distributed and sold to consumers at prices competitive with diesel.

Due to high octane rating and similarities with gasoline. Methanol has always considered as a good compression ignition (CI) engine fuel. But bulk of the transport fuel consumed worldwide is diesel. Above all the major contribution to pollution also comes from diesel engines. Therefore, substitution of diesel by potential fuels like methanol (which can be produced from locally available raw materials) by any method has more impact on economy and environment than substitution of gasoline by the same fuel [5].

Murray et al, [6] investigated the performance of methanol coconut oil blends in diesel engines, using coconut oil biodiesel (CME) as a co-solvent. 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 exhibited similar and even better engine performance than diesel operation. And BTE of 28.6% for the 30% methanol blend as compared to 22.9% for diesel operation. Turkcan et al, [7] studied the influence of methanol/diesel and ethanol/diesel fuel blends on the combustion characteristic of an DI diesel engine at different injection timings by using five different fuel blends (diesel, M5,M10, E5 and E10). The tests were conducted at three different start of injection {25°, 20° (original injection timing) and 15° CA before top dead center (BTDC)} under the same operating condition. The experimental results showed that maximum cylinder gas pressure (P_{max}) and maximum heat release rate $(dQ/d\theta)_{max}$ increased with advanced fuel delivery timing for all test fuels. Chu Weitao, [8] investigated the influence of M0, M5and M15 methanol / diesel fuel mixture on diesel engine performance in a single engine ZS195. Test results show that fuel economy was improved and diesel smoke and CO emissions are significantly reduced. NOx emissions are more at M5, but were reduced about 8% at M15. Jikar et al, [9] carried out a comprehensive research on methanol as an alternative fuel. In this study, the diesel engine was tested using methanol blended with diesel at certain mixing ratio of 10:90, 20:80 and 30:70 of methanol to diesel respectively. Experimental results showed that the brake specific fuel consumption for the three mixing ratios was not varying significantly but the lowest was for 30% Methanol and 70% Diesel. Chauhan et al [10], investigated on use of methanol and diesel blends in a single cylinder diesel engine. Results showed that the full load BTE exhibited by M5 was 10% lower than diesel baseline and that of M10 showed a reduction of 28% in full load BTE as compared neat diesel operation. The emission of CO was found to reduce at all loads with increase in methanol composition in the test fuel.

There is a need to study the performance, combustion phenomenon and emission in details for methanol and vegetable oils and their derivatives in duel fuel form. This paper present experimentation on combustion, emission and performance of a single cylinder diesel engine running on methanol and pongamia biodiesel duel fuel mode.

EXPERIMENTAL SETUP AND METHODOLOGY

The engine chosen to carry out experimentation is a single cylinder, four stroke, vertical, water cooled, direct injection computerized Kirloskar make CI engine as shown in Figure 1 and the specification are shown in Table 1. This engine is invariably used in agricultural and transportation in India.

Figure 1: Photograph of experimental setup

Table 1: Technical specifications of the Kirloskar diesel engine

Manufacturer	Kirloskar oil engines Ltd. India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5 mm/110 mm
C.R.	16.5:1
speed	1500 RPM, constant
Rated power	5.2 kW
Working cycle	Four stroke
Injection pressure	200 bar/23 degree before TDC
Type of sensor	Piezo electric
Response time	4 micro seconds
Crank angle sensor	1-degree crank angle
Angle sensor resolution of 1deg	360 degree encoder with

The eddy current dynamometer is connected to the engine which is used to control the load on the engine and AVL Dismoke and five gas analyzer its used for emission monitoring.

RESULTS AND DISCUSSION

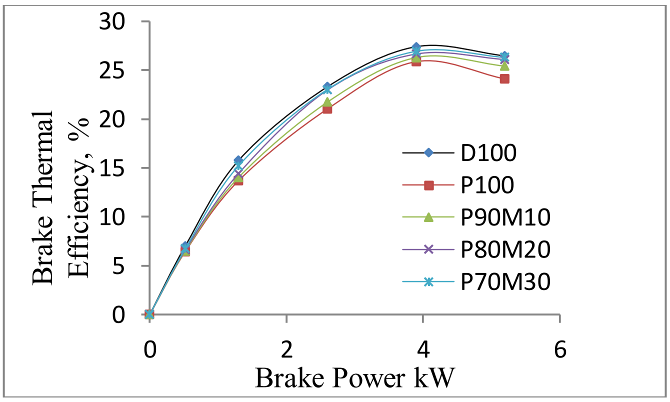

Fig. 2: Variation of brake thermal efficiency with brake power

Figure 2 shows the variation of brake thermal efficiency (BTE) with brake power for diesel, neat biodiesel and blends of methanol - pongamia biodiesel. As the load on the engine increases, brake thermal efficiency increases because brake thermal efficiency is the function of brake power and brake power increases as the load on the engine increases. The brake thermal efficiency of pure pongamia and all the blends are lower than that of diesel, the maximum brake thermal efficiency occurs at 75% of load. Maximum BTE of pure biodiesel is 25.86% against 27.39% for that of diesel on normal engine. By increasing percentage of methanol in biodiesel improves the BTE. The BTE for methanol in 10%, 20% and 30% blend with biodiesel is 4%, 2.7% and 1.7% lower than that of diesel. P70M30 blends give better performance with respect to other blends.

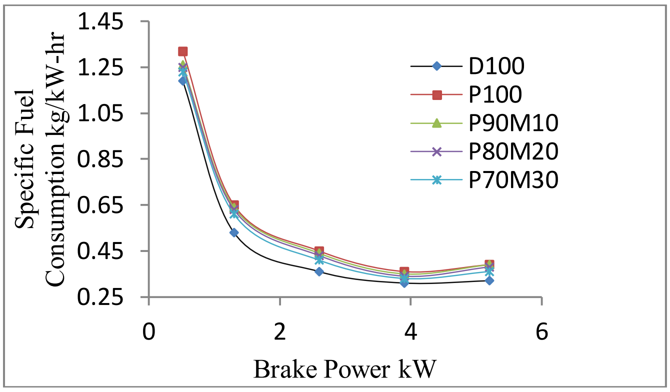

Fig. 3: Variation of specific fuel consumption with brake power

Fig. 3 shows the variation of specific fuel consumption with brake power for diesel, neat biodiesel and blends of methanol-pongamia biodiesel. As the power developed increses the specific fuel consumption decreses for all the tested fuels. The specific fuel consumption of pure biodiesel and all the blends are higher than diesel on normal engine.The minimum specific fuel consumption occur at 75% of load. Minimum SFC of pure biodiesel is 0.36 kg/kW-hr against 0.31 kg/kW-hr for that of diesel on normal engine. By increasing percentage of methanol in biodiesel decreases the SFC. The SFC for methanol in 10%, 20% and 30% blend with biodiesel is 11.4%, 8.8% and 6% higher than that of diesel. P70M30 blends give better performance with respect to other blends.

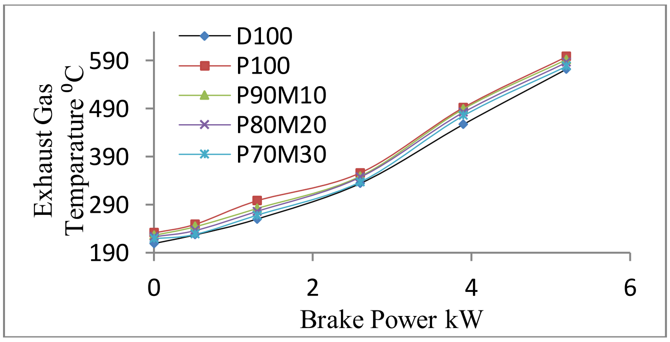

Fig. 4: Variation of exhaust gas temperature with brake power

Figure 4 shows the variation of exhaust gas temperature (EGT) for diesel, pure biodiesel and different blends with respect to the brake power. The exhaust gas temperature for all the fuels tested increases with increase in the brake power. Exhaust gas temperature of pure biodiesel and all the blends is higher as compared to diesel. The maximum EGT occur at full load. Maximum EGT of pure biodiesel is 598° C against 572° C for that of diesel on normal engine. By increasing percentage of methanol in biodiesel decreases the EGT. The EGT for methanol in 10%, 20% and 30% blend with biodiesel is 3.3%, 2.3% and 1% higher than that of diesel.

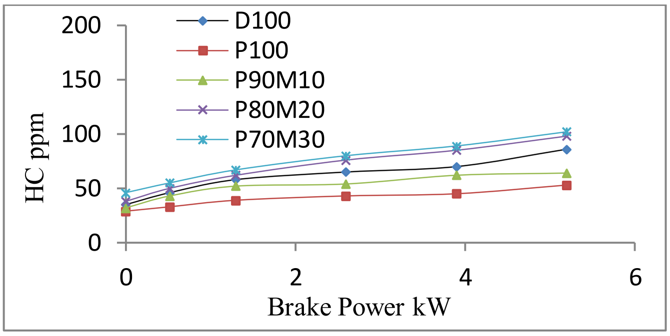

Figure 5: Variation of hydrocarbon with brake power

Figure 5 shows the variation in the quantity of unburnt hydrocarbons with change in brake power. It is observed that for P100 emission of HC is less than that of the diesel and methanol-pongamia blends the emission of HC is more than that of the biodiesel. The maximum HC emission occurs at full load. Maximum HC of pure biodiesel is 53 ppm against 86 ppm for that of diesel on normal engine. By increasing percentage of methanol in biodiesel it increases the unburnt hydrocarbon emission. The HC emission for methanol in 10% blend with biodiesel is 25.5% lower than that of diesel and 20%, 30% blend with biodiesel is 12.2% and 15.6% higher than that of diesel. P90M10 blends give lower emission with respect to other blends.

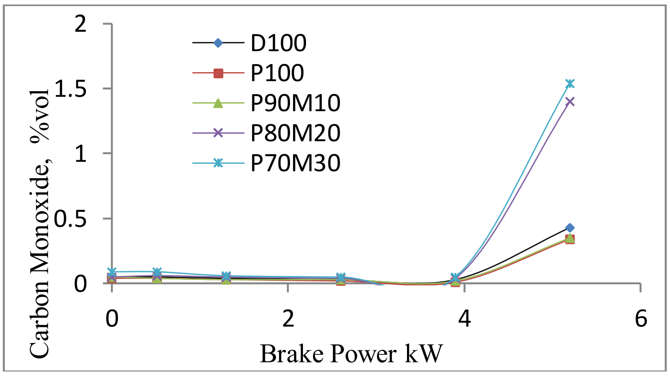

Fig. 6: Variation of carbon monoxide with brake power

Figure 6 shows the variation of carbon monoxide emission with brake power for diesel, pure biodiesel and blends of methanol- pongamia biodiesel in the test engine. The CO emission depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. CO emission of all blends is higher than that of diesel, except the blend P90M10 which has a lower. The maximum CO emission occurs at full load. Maximum CO of pure biodiesel is 0.34% vol against 0.43% vol for that of diesel on normal engine. By increasing percentage of methanol in biodiesel it increases the CO emission. The CO emission for methanol in 10% blend with biodiesel is 18.6% lower than that of diesel and 20%, 30% blend with biodiesel is 69.2% and 72% higher than that of diesel. P90M10 blends give lower emission with respect to other blends.

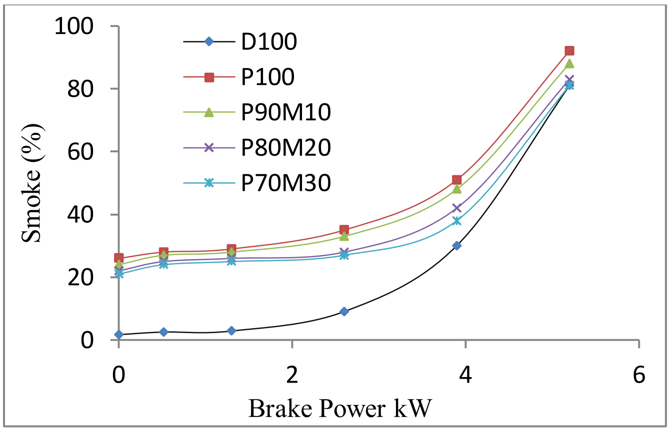

Fig. 7: Variation of exhaust smoke with brake power

Figure 7 shows the variation of exhaust smoke with brake power for diesel, pure biodiesel and blends of methanol - pongamia biodiesel in the test engine. It can be clearly seen that exhaust smoke of pure biodiesel and all blends is higher than that of diesel. The maximum smoke emission occurs at full load. Maximum smoke of pure biodiesel is 92% against 81% for that of diesel on normal engine. By increasing percentage of methanol in biodiesel it decreases the smoke. The smoke for methanol in 10%, 20% and 30% blend with biodiesel is 7.9%, 2.4% and 1.2% higher than that of diesel. The P70M30 blends give better emission with respect to other blends.

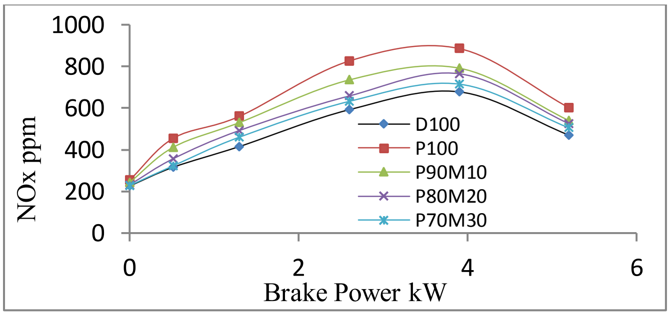

Fig. 8: Variation of NOx with brake power

Figure 8 shows the variation of nitrogen oxides emission with brake power output for diesel, neat biodiesel and blends of methanol - pongamia biodiesel in the test engine. The NO_x emission for pure biodiesel and all blends is higher than that of diesel. The maximum NO_x emission occurs at 75% load. Maximum NO_x of pure biodiesel is 886 ppm against 678 ppm for that of diesel on normal engine. By increasing percentage of methanol in biodiesel it decreases the NO_x. The NO_x for methanol in 10%, 20% and 30% blend with biodiesel is 14.3%, 11.3% and 5.1% higher than that of diesel. The P70M30 blends give lower emission with respect to other blends.

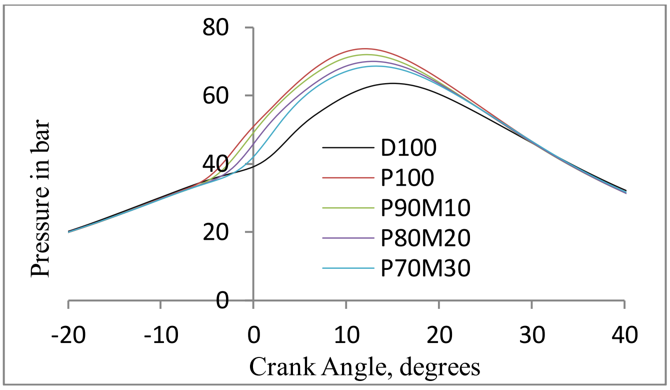

Fig. 9: Variation of cylinder pressure with crank angle

Figure 9 shows the variation of cylinder pressure with respect to crank angle for diesel, pure biodiesel and different blends of methanol- pongamia biodiesel. In a CI engine the cylinder pressure is depends on the fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. Peak pressure of neat pongamia biodiesel and pongamia blends methanol is greater than diesel. Maximum pressure of pure biodiesel is 73.71 bar against 63.54 bar for that of diesel on normal engine. By increasing percentage of methanol in biodiesel it decreases the pressure. The maximum pressure for methanol in 10%, 20% and 30% blend with biodiesel is 11.7%, 9.2% and 7.3% higher than that of diesel.

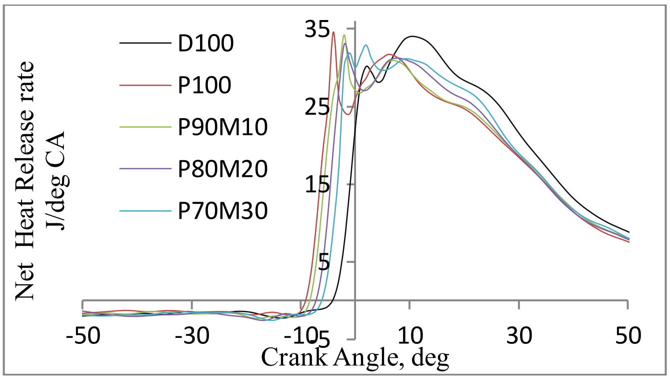

Fig. 10: Variation of net heat release rate with crank angle

Fig. 10 shows the variation of cylinder net heat release rate with respect to crank angle for diesel, pure biodiesel and different blends of methanol - pongamia biodiesel. The net heat release rate for all the tested fuel is more than that of diesel. Maximum net heat release rate of pure biodiesel is 34.9 J/deg against 29.8 J/deg for that of diesel on normal engine. By increasing percentage of methanol in biodiesel it decreases the heat release rate. The net heat release rate for methanol in 10%, 20% and 30% blend with biodiesel is 12.86%, 10.7% and 6% higher than that of diesel.

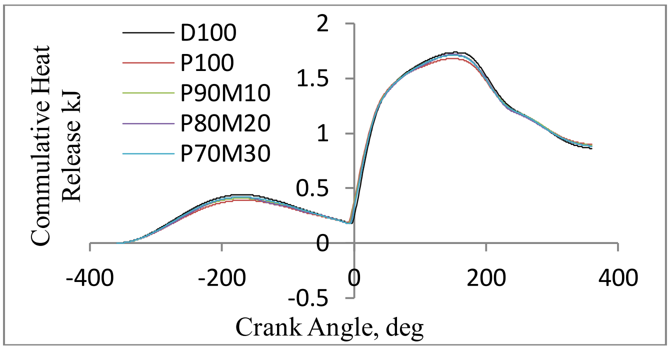

Fig. 11: Variation of commulative heat release rate with crank angle

Figure 11 shows the variation of commulative heat release rate with crank angle. The neat pongamia and blends of methanol and pongamia values are similar to diesel. The two main phases of the combustion process, premixed and diffusion are clearly seen in the rate of heat release curve. If all heat losses (due to heat transfer from the gases to the cylinder walls, dissociation, incomplete combustion, gas leakage) are added to the apparent heat release characteristics, the fuel burn characteristics are obtained. Maximum net heat release rate of pure biodiesel is 1.28 kJ against 1.27 kJ for that of diesel on normal engine.

From the experimental results it can be observed that combustion in the biodiesel starts at 6^{o} before TDC followed by 3^{o} BTDC for diesel. This is because readily available oxygen with the biodiesel than that of diesel. Due to inbuilt oxygen content in biodiesel ignition lag decreases the amount of heat release in biodiesel and its blends with the methanol is higher than that of diesel. Because of early combustion in premixed face, followed by lesser heat release in controlled combustion face. From the commulative heat release rate and EGT we can state that combustion is complete for biodiesels than followed by its blend. By increasing the percentage in the methanol in the biodiesel lesser heat is release due to lower calorific value of methanol, however low density accelerates the combustion. In the diesel though combustion starts little later the sharp increase in rate of pressurise with crank angle which implies fine spray formation and quicker burning after the ignition. Since the biodiesel and its blend with the methanol have better and complete combustion and emits lower CO and HC. Since the major amount of heat release in the diesel takes during controlled combustion indicates much lower smoke emission from the diesel than that of other fuel in the test.

NO emission first increases up to 70-75% load and then decreases for all fuel tested in the engine. The NO emission is higher for the biodiesel than that of diesel. Due to complete combustion of biodiesel, higher EGT and inbuilt oxygen content are the source of higher NO emission. Since available of higher oxygen and temperature during combustion accelerates the dissociation of air inhaled and recombination forms higher NO. By increasing the methanol percentage in the biodiesel reduces the temperature, during combustion due to its lower calorific value of methanol and percentage of oxygen in the fuel. The emission of the NO is lower for diesel, at 75% and above load the more fuel is injected for the same amount of inhaled and mixture becomes rich, and eventually NO reduces.

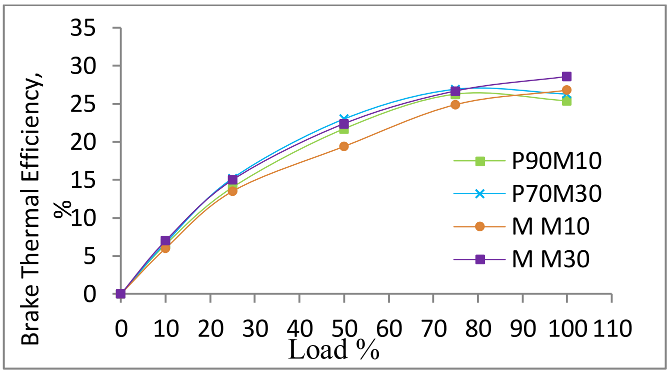

Figure 12: Variation of brake thermal efficiency with load

Murray et al. (2012) [6], conducted the experiment on a single cylinder four stroke CI engine having capacity of 7 kW at 1800 rpm. In this experimentation only the performance of the engine is determined and presented and they have used coconut biodiesel with 10% and 30% methanol added on volume basis.

The results presented by Murray et al, converted on percentage of load basis and these results are compared with my experimental values. Figure 12 shows the variation of BTE with load with different combination of methanol and biodiesel. BTE evaluated in my experiment are in good agreement with that of Murray et al for entire load range excepted at full load. This validates experimental finding of my work.

CONCLUSION

In this project, experimental investigation are carried on a Kirloskar make single cylinder water cooled natural aspirated 5.2 kW diesel engine at 1500 rated rpm. The pongamia biodiesel is prepared in the laboratory using pongamia vegetable oil and their properties are evaluated and presented. Further pongamia biodiesel is blended with 10%, 20% and 30% of methanol then Performance, emission and combustion characteristics are evaluated and presented for diesel, pure pongamia biodiesel and pongamia biodiesel is blended with 10%, 20% and 30% of methanol. The results pertain into biodiesel and their various blends with methanol and compare with that of diesel on normal engine. The conclusions are as follows;

- Biodiesel is prepared and their characteristic has been made density, viscosity, flash point and fire point are higher and calorific value is lower than that of diesel.
- CO and HC emissions are lower in biodiesel than that of diesel. However these emissions increase with increase in percentage of methanol in the biodiesel.
- Smoke emission for the biodiesel and blends methanol is much higher than that of diesel.
- NO emission is higher for biodiesel than that of diesel. The increasing percentage of methanol in the biodiesel

reduces concentration of oxygen in the cylinder consequently NO emission reduces.

- NO emission can be considerably reduced by adding methanol in biodiesel. With 30% addition of methanol BTE / performance is close to that of diesel and NO emission is minimum for this combination. Hence this combination of fuel is optimum.

My experimental values are compared with that of similar work in available and results closely matches with each other. Hence it validate present work.

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