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PARAMETRIC ANALYSIS OF COCONUT OIL AND WASTE VEGETABLE OIL IN A DIESEL ENGINE

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Abstract*-The experiment aims to study the prospects and opportunities of introducing coconut oil and waste vegetable oil as fuel in diesel engines. Vegetable oils present a very promising scenario of functioning as alternative fuels to fossil diesel fuel. The properties of these oils can be compared favorably with the characteristics required for internal combustion engine fuels. In this experiment Model R175A test engine is run by diesel fuel at three different speeds of 2600, 2400 and 2200 rpm and all the necessary parameters are recorded and different performance parameters are calculated to check the engine's reliability as a test engine. Then the performance tests are carried out using 100% coconut oil preheated to 80^{o}C and 100^{o}C and 80% coconut oil is blended with 20% diesel preheated to 100^{o}C. The same experiment is also carried out by waste vegetable oil. When coconut oil and waste vegetable oil is heated up to 80-100^{o}C, then viscosity and density of coconut oil becomes close to that of diesel. Because of high viscosity and poor volatility the bsfc values of heated coconut oil and waste vegetable oil is higher than that of diesel in the entire load range of the engine. On the other hand brake thermal efficiency of coconut oil at 80^{o}C and 100^{o}C temperatures and blends of coconut oil and diesel is increased.*

Keywords: Diesel Engine, Performance, Coconut oil, Waste vegetable oil.

1. INTRODUCTION

Rudolf Diesel, the inventor of the diesel engine, used peanut oil as fuel in one of his engines at the Paris exposition of 1900. But it is only in the last few decades that researchers around the world have been performing systematic studies on alternative fuels in diesel engines. Research is going on to find out suitable alternatives to diesel fuel, which do not require major engine modifications. For diesel engines, alternative renewable fuels are mainly vegetable oils referred to as bio-oils and transesterified bio-oil more popularly referred to as biodiesel. Medium speed diesel engines can operate well on the use of straight and unprocessed vegetable oil such as coconut oil, and soybean oil. Compared to of biodiesel, vegetable oils considerably reduce fuel cost in such engines.

The main purpose of this study is not to convert edible oil into fuel but to carry out an experiment whether different grades of waste vegetable oil and coconut oil could be converted into economically viable fuel. According to WHO (World Health Organization) edible oil after being burnt several times loose quality for human consumption and coconut oil is chosen as it is not popular as edible oil in Bangladesh. Such type of oil could be converted into fuel to meet the fuel short fall.

Masjuki carried out dynamometer tests to evaluate performance, emission and wear characteristics of an indirect injection diesel engine when fueled by 10, 20, 30, 40 and 50% blends of coconut oil with diesel oil. The test was conducted for 100 h using each of the test fuels to monitor the effect of coconut oil blends on the wear and lubricating oil performance. Diesel oil was also used for comparison purposes [1].

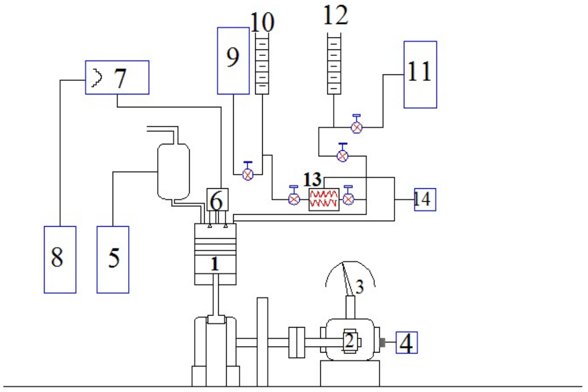
Dorado et. al tried to determine the feasibility of running a 10% waste vegetable oil-90% diesel fuel blend during a 500-h period in a 3-cylinder direct-injection, 2500 cm^3 Diter diesel engine. A waste vegetable oil-diesel fuel blend was recycled used frying oil, which was essentially a waste product. The long-term performance of this fuel was monitored by measuring the viscosity of the lubricating oil, abnormal functioning of the engine, power loss, and excessive smoke output compared to straight diesel fuel. The results revealed an approximately 12% power loss, slight fuel consumption increase, and normal smoke emissions. Combustion efficiency dropped slightly during the testing period [2].

2. EXPERIMENTAL SETUP

The experimental works had been divided in two parts a) fuel property testing and b) engine performance testing. Initially different properties (heating value, density, viscosity, cetane number) of diesel fuel were determined as base data. Those data were then compared with those of pre heated waste vegetable oil and coconut oil at different preheating temperatures, Waste vegetable oil and diesel fuel blends mixed at different proportions by volume and compare their properties with base data. Same blends were tested for coconut oil with diesel.

Model R175A test engine is run by diesel fuel at three different speeds of 2600, 2400 and 2200 rpm and all the necessary parameters are recorded and different performance parameters are calculated to check the engine's reliability as a test engine. Then the performance tests are carried out using 100% waste soybean oil preheated to 80^0C and 100^0C and 80% waste vegetable oil blended with 20% diesel preheated to 100^0C. The experiments are repeated at the same speed with pure coconut oil and blend of pure coconut oil and raw diesel in 80:20 volumetric basis preheated at the same temperatures.

In this study, the experimental set up consists of a diesel engine ,engine test bed with a water brake type dynamometer which is used to apply desired load on the engine, waste soybean oil, and coconut oil supply system, different along with the test engine. Waste soybean oil, and coconut oil feed system consists of an electric heater placed in a heater box. Oil is allowed to pass through the heater which is controlled by a temperature controller circuit which senses the inlet temperature of the oil before it enters the fuel injection pump. The schematic view of the experimental set up is shown in Fig. 1. Experiments are carried out on a single cylinder diesel engine of model R175A having a rated output of 4 kW at a rated speed of 2600 rpm. In this study, BS standards for engine performance test BS 5514: Part I: 1982, equivalent to ISO 3046 and J 1349, ISO and SAE standards for the same respectively, has been followed. Any other additional guidelines required are taken from the procedures used by Plint and Böswirth [3].



1. Engine	8. Manometer
2. Dynamometer	9. Vegetable Oil Tank
3. Load Indicator	10. Burette of Vegetable Oil Tank
4. Speed Sensor	11. Diesel Tank
5.Exhaust Gas Temperature Indicator	12. Burette of Diesel Tank
6. Intake Manifold	13. Heater Box
7. Air Drum	14. Temperature Controller

Fig. 1: Schematic Diagram of the experimental setup

The gravitational force feeds the fuel to the injector. A coil is inserted into the waste soybean oil and coconut oil container for the purpose of heating the oil up to a desired temperature. A controller circuit arrangement is there to sense the temperature of the oil just before entering the injector. By sensing the temperature of oil entering the injector the controller the controller cuts off or connects the electric circuit to raise the temperature up to the desired limit. A sensor is used for this purpose at the fuel line just before the injector rail which is connected to the controller circuit through an overload relay. The overload relay is nothing but a transducer which is sensitive to thermal change in the form of voltage change. Whenever any rise in fuel temperature over the set temperature is sensed by the sensor, the voltage difference is changed in the thermal overload relay and at the instant the relay breaks the circuit.

3. RESULTS AND DISCUSSION

A series of performance tests were carried out at three different speeds (2600, 2400, and 2200 rpm) under variable loading condition using diesel fuel. The experiments are repeated at the speed of 2600 rpm with waste soybean oil (termed 'WVO' from now on) and blend of WVO and raw diesel in 80:20 volumetric basis preheated at two different temperatures (80^oC and 100ºC). The experiments are repeated at the same speed with pure coconut oil and blend of pure coconut oil and raw diesel in 80:20 volumetric basis preheated at the same temperatures. The data obtained are analyzed to produce performance parameters from the viewpoints of first law of thermodynamics. Engine speed has been maintained within ± 5 rpm and the temperature has been maintained within ± 2^0C of the desired temperature.

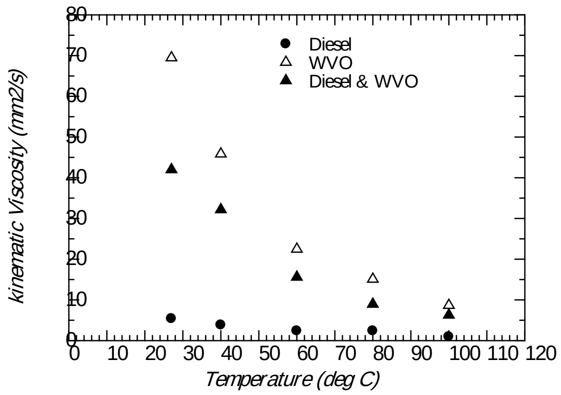


Fig. 2(a): Effect of temperatures on the viscosities of WVO and Diesel

Kinematic Viscosity of fuel was evaluated by ASTM D445 standard. The variation in viscosity of oils with temperature is shown in Fig. 2(a) and Fig. 2(b). The viscosity of WVO and coconut oil is nearly 10-12 times higher than that of diesel fuel at room temperature (27^oC). But when WVO is heated up then its viscosity reduces significantly, viscosity of WVO and diesel blends decrease with increase in temperature and becomes close to that of diesel at temperature above 80^oC. Coconut oil and its blend with diesel show similar characteristics. The percentage of change in viscosity of diesel, WVO and WVO- diesel blend shows a gradually downward trend. In each of the three cases, percentage change in viscosity falls in the range of 70-85 percent at 100^{o}C with respect to the room temperature value. The highest change is observed in case of WVO-diesel blend and lowest for diesel. Coconut oil and its blend with diesel show similar characteristics.

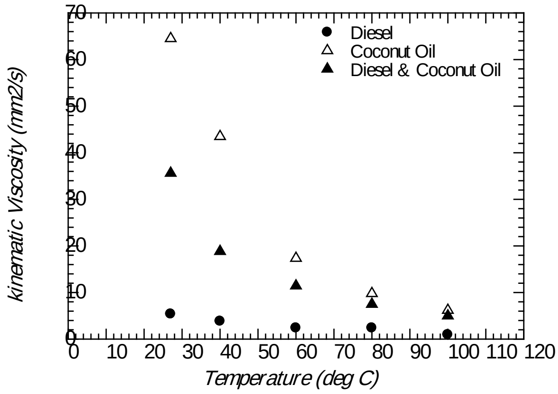


Fig. 2(b): Effect of temperatures on the viscosities of Coconut oil and Diesel.

In Figs. 3(a) and 3(b), variations of fuel density with temperature are shown. It is found that the densities of WVO and coconut oil are higher than that of diesel at room temperature. When WVO and coconut oil is blended with diesel and heated up to 100^{o}C, its density becomes close to diesel fuel. However the percentage changes in density values are not as significant as that of viscosity. The highest change in this case is about 7%.

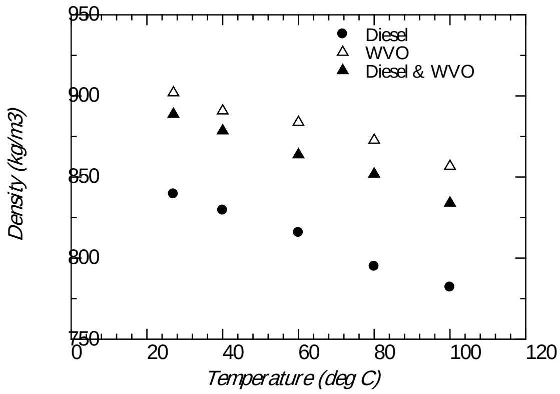


Fig. 3(a): Variations of densities of WVO and diesel with different temperatures.

Lower heating value (LHV) of coconut oil is 36.54 MJ/Kg and WVO is 37.75 MJ/Kg is lower than diesel's LHV 42.97 MJ/Kg which is evaluated by ASTM D 240 method. In the experiment cetane number (CN) of coconut oil and waste vegetable oil is found to be 60 and 61 as compared to diesel's CN 45 – 55 by ASTM test methods using IQT: D6890 and D7170.

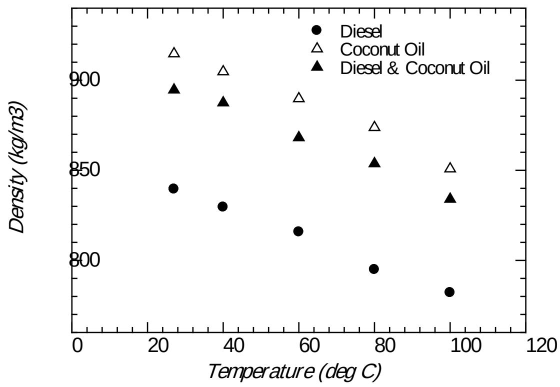


Fig. 3(b): Variations of densities of coconut oil with diesel at different temperatures.

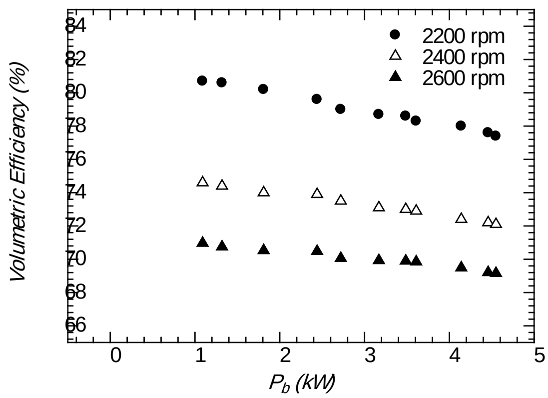


Fig.4: Variation of volumetric efficiencies as a function of brake power output at three different speeds running on diesel fuel.

Figure 4 shows the variations of volumetric efficiency, with engine power. With increase in load, volumetric efficiency decreases, since the temperature of combustion chamber walls are increased. In a diesel engine the cylinder and combustion chamber walls are hot, and confines the hot residual gas within the cylinder at the end of the exhaust stroke. When the residual flows into the inlet manifold, the inlet valve and port are heated. The entering fresh charge is also heated, not only by the walls, but also by the hot inlet valve and port. Thus volumetric efficiency is decreased. At lower speed volumetric efficiency is greater than at higher speed because of the fact that at higher engine speeds, the flow into the engine during the intake process a part of inlet becomes choked. Once this occurs, further increases in speed do not increase the flow rate significantly and so volumetric efficiency decreases [4].

In Fig. 5 fuel consumption rates of diesel fuel are presented at three different speeds at different loads. It is seen that fuel consumption rate increases with the increase in load. In diesel engine the absolute value of total friction work varies with load, and increases as speed increases. The friction work is the pumping work in the engine, to overcome the resistance to relative motion of all the moving parts of the engine, and to drive the engine accessories. To overcome these friction works for the same fuel and same power, the fuel consumption rate is higher for higher speeds [4].

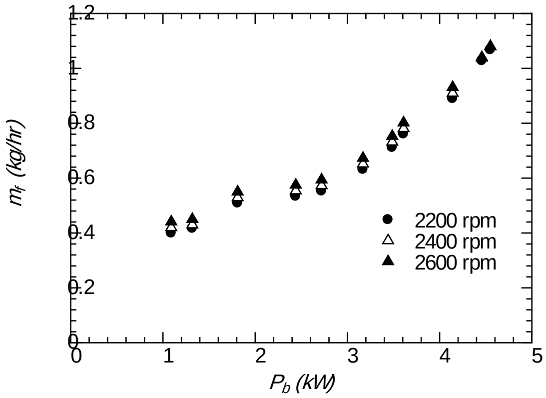


Fig.5. Variation of mass flow rate of fuel as a function of brake power output at three different speeds running on diesel fuel

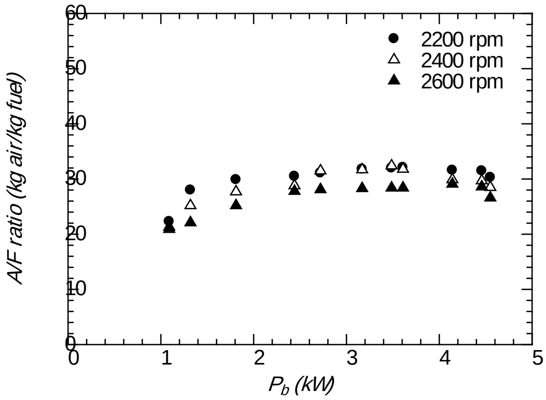


Fig.6. Variation of air-fuel ratio as a function of brake power output at three different speeds running on diesel fuel

In Fig. 6 variation of air fuel ratio is plotted against engine brake power. It is observed that the overall *A/F* ratio is in the range of 15.7-53 at rated speed. With change in load the quantity of fuel is changed, which changes the air fuel ratio. Whatever may be the overall *A/F* ratio in a diesel engine due to the injection of fuel, there is a heterogeneous mixture with *A/F* ratio varying widely in different areas within the chamber. Relative *A/F* ratio may be defined as λ . At low load λ >1 i.e for fuel lean mixture and at high load λ <1, i.e. for fuel rich mixture. In a diesel engine *A/F* ratio for stoichiometric mixture is 14.5 [4]. However, *A/F* ratio in a diesel engine can't approach the chemically correct mixture without the appearance of smoke. The engine should never be operated at the point of maximum power, because extreme smoking and fouling of the engine would occur. Many engines will smoke even at *A/F* ratio of 30:1. In the diesel engine, injection must occur near the point where pressure rise is desirable and therefore little time is available for the fuel to find air. For this reason, the injection pump is equipped with a quantity stop that prevents injection of fuel beyond that of light smoke in diesel engine. Thus the points of maximum power and maximum economy in the diesel engine are shifted toward relatively high air fuel ratios than the chemically correct ratio [5].

Variations of brake specific fuel consumption, *bsfc,* with brake power, P_b at different speed is shown in Fig. 7. It is seen that *bsfc* values all follow a hooked curve. At lower load, *bsfc* is higher because *A/F* ratio is high, its value decrease with the increase of brake power until the rated output of the engine is reached. Minimum value of *bsfc* is reached at each engine speed when all the fuel in the cylinder is most effectively consumed. After the rated output, *bsfc* slightly increases again because air fuel mixture is richer due to scarcity of air. This parameter *bsfc* is preferred, rather than thermal efficiency, because all quantities are measured in standard and accepted physical units: time, horsepower and mass [5].

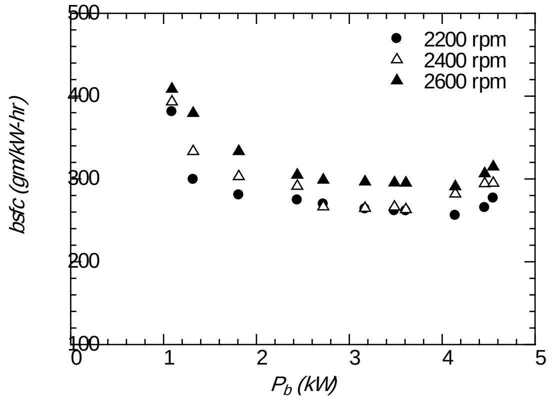


Fig.7. Variation of brake specific fuel consumption as a function of brake power output at three different speeds running on diesel fuel

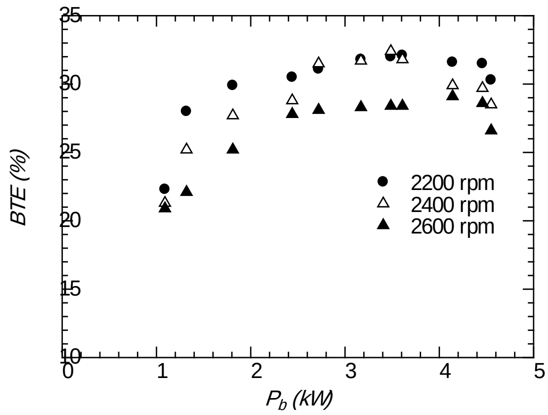


Fig. 8 Variation of brake thermal efficiency as a function of brake power output at three different speeds running on diesel fuel

In Fig. 8 brake thermal efficiency *BTE* is plotted against the same conditions mentioned above. The *bsfc* and *BTE* are inversely related to each other. So at lower brake power *BTE* is lower and it increases significantly up to the rated power and after this point it decreases slightly. For calculating *BTE* of a fuel higher heating value of the fuel should be used, because higher heating value at constant pressure represents the maximum amount of heat that can be transferred from steady flow machine. However, the heat that can be attained by condensing the water formed by combustion is (practically) not attainable, because exhaust gases invariably are discharged at high temperatures. For this reason, efficiency calculations are based upon the lower heating value of the fuel [5]. Brake mean effective pressure *bmep* is a true indication of the relative performance of different engines. There is a good reason for this; all engines tend to be made from similar materials. Since material stress in an engine depends on a first approximation only on the *bmep* and mean piston speed, it follows that for the same stress limit imposed by the material, all engines should have the same *bmep* and mean piston speed. As a result, *bmep* is used here, to compare performance parameters of engine as it is roughly comparable for different engines. From now on the performance terms are evaluated as a function of *bmep*.

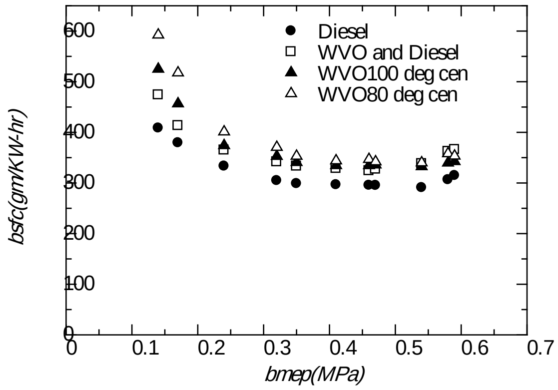


Fig.9. Comparison of brake specific fuel consumption levels as a function of brake mean effective pressure at 2600 rpm

The comparison of brake specific fuel consumption is plotted as a function of *bmep* for two different preheat temperatures 80° and 100°C for pure WVO and 100°C preheat temperature for 80% WVO and 20% diesel blend and are compared with that of diesel fuel in Fig. 9. It was observed that *bsfc* of all fuels tend to decrease with increasing load. The WVO diesel blends yielded a *bsfc* closely matching that of diesel oil. Though the preheated WVO at 80° and 100°C temperatures maintained a similar trend to that of diesel, the value of *bsfc* of heated WVO was higher than that of diesel in the entire load range of the engine. This is due to the combined effect of viscosity and lower heating value of WVO. High viscosity and poor volatility of the WVO results in poor atomization and mixture formation and increase fuel consumption to maintain the power. However preheated WVO shows improvement in energy consumption at higher load. In addition to that lower heating value of the WVO leads to more fuel delivery for the same load condition. Same trend is observed for coconut oil from Fig.10.

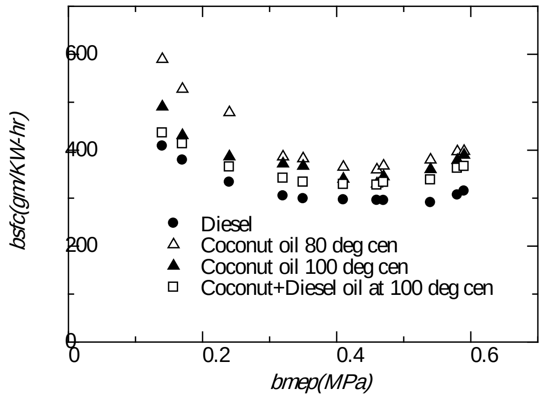


Fig.10. Comparison of brake specific fuel consumption levels as a function of brake mean effective pressure at 2600 rpm

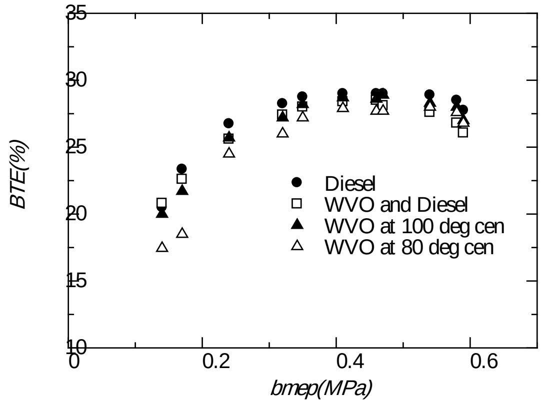


Fig.11. Comparison of brake thermal efficiencies as a function of brake mean effective pressure at 2600 rpm

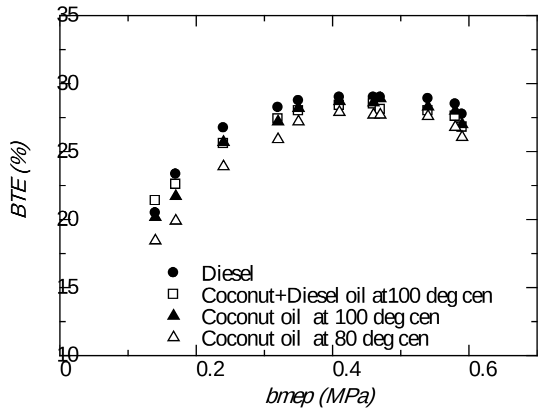


Fig.12. Comparison of brake thermal efficiencies as a function of brake mean effective pressure at 2600 rpm

In Figs. 11 and 12, a variation of brake thermal efficiency *BTE*, is shown for the above mentioned conditions. In Figure 11 reveals that with increasing *bmep*, of WVO at 80°C and 100°C temperatures and blends of WVO and diesel is increased. In case of blend closely matches with that of diesel oil. Same trend is observed for coconut oil from the Fig. 12. It is noticed that the use of oxygen-rich alternative fuels promote a better mixture formation and combustion, thus improving the thermal efficiency.

The improvement in brake thermal efficiency *BTE* can be attributed to the enhanced oxygen content which improves combustion especially during the phase of diffusion combustion, and to the higher lubricity of alternative fuels which reduces the friction loss.

4. Conclusion

The major inferences that can be drawn from the present study are summarized below:

1. The most significant difference between diesel oil, WVO and coconut oil is the latter's much higher viscosity and higher density. When WVO and coconut oil is heated up to 80-100^{o}C, then viscosity and density of WVO and coconut oil becomes close to that of diesel.

2. From engine performance test it is found that with increase in load, volumetric efficiency decreases. It is seen that fuel consumption rate increases with the increase in load.

3. Though the preheated WVO and coconut oil at 80° and 100^{o}C temperatures maintain a similar trend of *bsfc* to that of diesel, the value of *bsfc* of heated WVO and coconut oil is higher than that of diesel in the entire load range of the engine. Because high viscosity and poor volatility of the WVO and coconut oil results in poor atomization and mixture formation thereby increasing the fuel consumption to maintain power.

5. REFERENCES

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8. NOMENCLATURE

Symbol	Meaning	Unit
P_b	Brake power	kW
m_a	Mass flow rate of air	kg/hr
m_f	Mass flow rate of fuel	kg/hr
bsfc	Brake specific fuel consumption	gm/kW-hr
bmep	Brake mean effective pressure	MPa
BTE	Brake thermal efficiency	%
A/F ratio	Air fuel ratio	kg of air/kg of fuel