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Eucalyptus Oil-A Promising Biodiesel Fuel for Direct Injection Diesel Engines

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Abstract: This experimental investigation focuses on finding out an alternative fuel for direct injection diesel engines without any modification. Experiments have been conducted on a single cylinder, water cooled diesel engine to carry out the tests on performance and emission characteristics with various blends of eucalyptus oil. Initially properties of chosen oil have been compared with those of other biodiesel fuels which were already tested. The properties of the eucalyptus oil are closer to diesel and comparatively better than other biodiesel fuels. Further tests have been carried out for confirmation. The performance parameters chosen are brake thermal efficiency, specific energy consumption, pressure angle diagram and heat release rate. The emission parameters chosen are unburnt hydrocarbon emission, carbon monoxide emission, carbon dioxide, smoke opacity and Oxides of Nitrogen (NO_x) emission. As the overall experimental results and regulated emission parameters showed appreciable results, eucalyptus oil may be a futuristic biodiesel fuel.

Key words: Eucalyptus oil, brake thermal efficiency, unburnt hydrocarbon emission, oxides of nitrogen emission, modification

INTRODUCTION

Direct injection diesel engines have the two main sources of alternative fuel as per the present investigations. One of them is biodiesel fuel and the other one is hydrogen fuel. But the latter needs intensive research to overcome the limitations so that it could be used in the engine without harming humans and other vehicles as it is an explosive. For a decade, researches went on with various biodiesel fuels and it was proved that biodiesel fuel could be blended with diesel by 20% by its volume with 1 L of diesel. A few biodiesels tested were Jatropha, Karanja, Mahua, Neem, Nerium, Rice bran oil, etc. Almost all the researches gave out a consolidated result of reduced brake thermal efficiency and increased oxides of nitrogen emission. Researches went on with minor modifications in the engine from the manufacturer's settings. Modifications done were varying the injection timing, injection pressure and compression ratio.

Shay (1993) discussed that the inventor of diesel engine Rudolph Diesel himself demonstrated engine with vegetable oil as the fuel. The rapid depletion of fossil fuel is another threat to the researchers which urges them to involve deeply into the research to find out an alternative fuel. An investigation by Sensoz *et al*. (2000) suggested that the scarcity of conventional fossil fuels, growing emissions of combustion generated pollutants and their increasing costs would make biomass sources more attractive. Jaichandar and Annamalai (2013) reported that biodiesel could be said to be carbon neutral as more CO_2 is absorbed by the biodiesel yielding plants than what is added to the atmosphere when used as fuel. Direct usage of vegetable oil posed few problems such as clogging of injection nozzle, poor atomization and cold starting of vehicle.

Murayama *et al*. (1984) mentioned that vegetable oils resulted in an acceptable engine performance and emission levels for short term operation but they caused the carbon deposit to stick with piston ring sticking during extended operation. Hence, biodiesel is extracted from vegetable oil by transesterification process and it is blended with diesel for various proportions. Most of the biodiesel fuels have showed successful results when they are blended by 20% by its volume with diesel.

As per the ASTM International (2009) report when biodiesel is used as a blend for petro diesel up to 20%, no changes are required for existing diesel engines. Bozbas (2008) mentioned that biodiesel prepared from vegetable oil after transesterification reaction shows a similar performance to diesel at all loading conditions and can be used as alternate fuel to diesel without any modifications in the engine design. Kumar *et al*. (2013) stated that transesterification process removes fatty acids in the form of glycerol thereby reducing the viscosity. Hence, biodiesel could be easily blended with diesel and used in diesel engines without any modification. The general report from the biodiesel research gave an outline that the emission of NO_x is more compared to diesel fuel. But other

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emission parameters such as unburnt hydrocarbon, carbon monoxide, carbon dioxide are considerably reduced.

In a research by Balusamy and Marappan (2007), it was found that engine performance and combustion characteristics with methyl ester of thevetia peruviana seed oil were comparable to those of diesel and CO, HC emissions were less. But oxides of nitrogen emission and smoke emission were higher than for diesel. A few researches went on with engine modification also. Modifications carried out were varying the injection timing, injection pressure or compression ratio.

Venkatraman and Devaradjane (2010) concluded that retarding the injection timing led to the reduction in efficiency and also in emission characteristics. Venkatraman and Devaradjane (2010) had also reported that advancing the injection timing led to an increase in brake thermal efficiency and reduction in few emission parameters. Mahesh *et al.* (2012) concluded that there was an increase of brake thermal efficiency with the increase of injection pressure whereas exhaust temperature also increased. This experimental investigation was carried out with eucalyptus oil as the biodiesel fuel without any engine modification.

MATERIALS AND METHODS

A single cylinder Kirloskar branded AV1 Model was used for this experimental investigation. Kirloskar engine was preferred as it is one of the oldest model engines which are used for agricultural pump and it is very sturdy in construction. Researchers prefer this model as the engine modifications such as injection time variation, injection pressure variation could be easily done. Data acquisition system was used for generating the in-cylinder pressure and crank angle diagram. It received the feedback from the pressure transducer fitted on the cylinder head and crank angle decoder assembly from the engine flywheel. Both the feedbacks were sent to the control unit which converts the analog signal into digital signal and sends the data to the computer (Fig. 1).

A Crypton EN290 series gas analyzer was used for measuring unburnt Hydrocarbon (HC), Carbon monoxide (CO), Carbon dioxide (CO_2) and Oxides of Nitrogen (NO_x) emission. AVL smoke meter was used for measuring smoke opacity in terms of Hatridge Smoke Units (HSU). HSU has a smoke measurement in the range of 1-100. Eddy current loading was used for varying the load conditions of the engine. The specifications of the engine are given in the Table 1.

Comparison of properties: The fuel properties of various biodiesel fuels were checked to compare with the properties of eucalyptus oil.

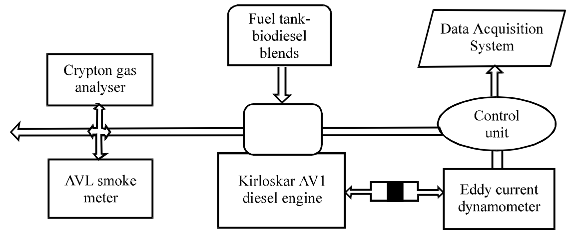

Fig. 1: Experimental setup

Table 1: Engine specifications

Engine specifications	Values
Brand and model	Kirloskar AV1
No of cylinders	1
Type of cooling	Water cooled
Compression ratio	16.5:1
Bore (mm)	80
Stroke (mm)	110
Rated speed (rpm)	1500
Injection pressure (bar)	215.8
Injection time	23°BTDC

Table 2: Comparison of properties of diesel and other biodiesel fuels

Properties	Diesel	Eucalyptus	Jatropha	Pongamia	Mahua
Calorific value (MJ kg^{-1})	43.200	43.500	42.250	42.330	42.060
Specific gravity	0.804	0.876	0.815	0.821	0.816
Kinematic viscosity (cSt)	1.580	1.860	4.840	6.400	4.800
Flash point (°C)	56.000	40.000	92.000	95.000	85.000
Fire point (°C)	64.000	50.000	96.000	98.000	92.000

From Table 2, it is found that the properties of eucalyptus oil are almost closer to diesel. The viscosity of eucalyptus oil is also less than that of other biodiesels and it is slightly higher than that of diesel fuel. Appreciably the calorific value is slightly higher than that of diesel which is a good sign of using it.

RESULTS AND DISCUSSION

In this investigation the performance parameters chosen for the comparison were brake thermal efficiency and specific energy consumption. The combustion parameters were in-cylinder pressure, crank angle graph and heat release rate. The emission parameters were unburnt hydrocarbons, carbon monoxide, carbon dioxide and oxides of nitrogen emission. E20 refers to 20% of eucalyptus oil with diesel fuel and similarly for E30 and E40.

Performance parameters

Brake thermal efficiency: Jaichandar and Annamalai (2013) stated that thermal efficiency is the true indication of the efficiency with which the chemical energy input in the form of fuel is converted into useful work. The calorific value of fuel plays a vital role in improving the brake thermal efficiency as the chemical reaction between

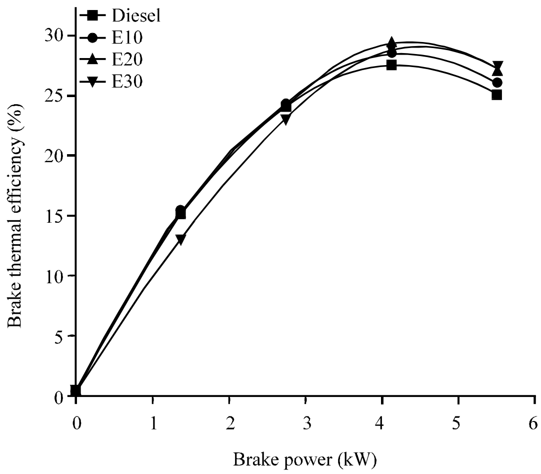

Fig. 2: Brake power vs. brake thermal efficiency

the species of the fuel creates an effect in developing the pressure on the piston. In this investigation, it was found that the maximum efficiency for diesel at three fourth loads was 27.5%. The efficiencies were found to be 28.5, 29.3 and 28.8% with the blends E10, E20 and E30, respectively. The efficiency of biodiesel fuel is higher than that of diesel fuel which may be due its higher calorific value than diesel (Fig. 2).

At the same time, it reduced when the blend E30 was used. The reduced efficiency could have been due to its higher viscosity than that of diesel. The molecular size due to higher viscosity may lead to poor combustion reaction at higher loads. In his research, Anandavelu *et al.* (2013) reported that there was a slight decrease of brake thermal efficiency when higher blends (50%) of eucalyptus oil were used. Kumar *et al.* (2001) stated in his research that, increase in brake thermal efficiency could be due to better vaporization and mixture preparation of eucalyptus oil which led to rapid heat release rate.

In-cylinder pressure and crank angle: In-cylinder pressure developed due to the combustion reaction taking place in the cylinder which could be further related to the chemical reaction due to the presence of species present in the fuel used. Figure 3 shows the graph between in-cylinder pressure and crank angle. It was found that the maximum pressure developed with diesel and E20 biodiesel blends. Higher blends of eucalyptus oil produced less pressure due to its increased viscosity which led to slower reaction due to heavier molecular size. Kumar *et al.* (2001) stated that low cetane number and viscosity of eucalyptus oil to reduce in-cylinder pressure at higher blends.

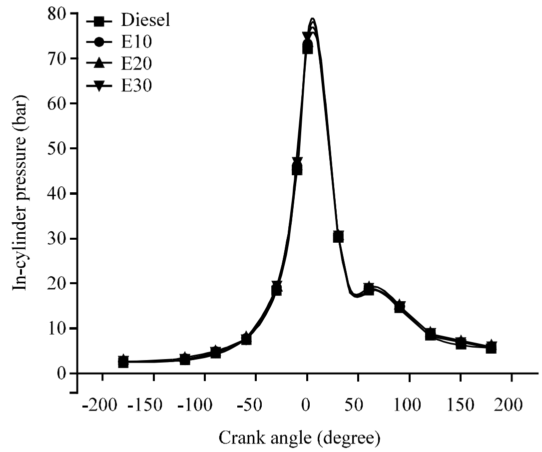

Fig. 3: In-cylinder pressure vs. crank angle

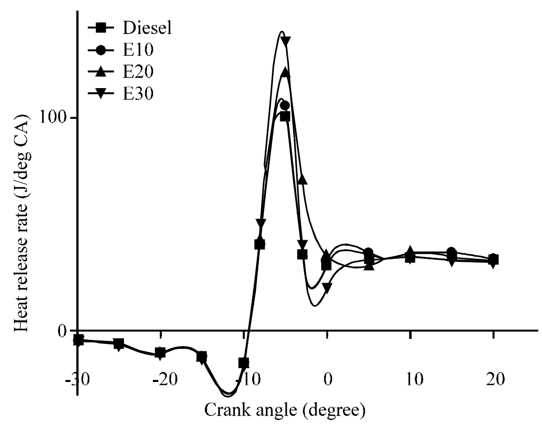

Fig. 4: Heat release rate vs. crank angle

Heat release rate: Figure 4 shows the graph between heat release rate and crank angle. E10 blend shows almost same trend like diesel fuel. It may be due to the calorific value of E10 which is slightly higher than diesel fuel. But due to its viscosity the higher blends of eucalyptus oil may not be able to give the same performance like E10. It is found that higher blends of eucalyptus oil give out more heat release. Kumar *et al.* (2001) reported that the ignition delay period increased with the higher proportion of eucalyptus oil hence higher heat release rate was obtained. Tarabet *et al.* (2012), in his research work explained that the negative heat release in the curve was due to vaporization of the fuel accumulated during the ignition delay.

Emission parameters

Unburnt Hydrocarbon (UBHC) emission: Figure 5 shows the results of the investigation as a trend between brake power and unburnt hydrocarbon emission. Eucalyptus oil has the higher oxygen content than diesel fuel. This

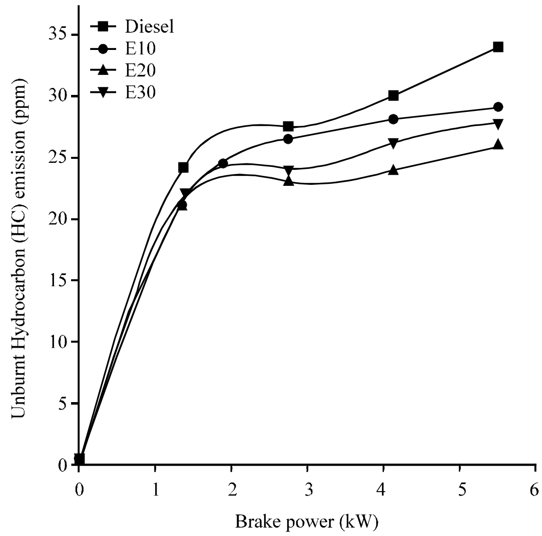

Fig. 5: Brake power vs. UBHC emission

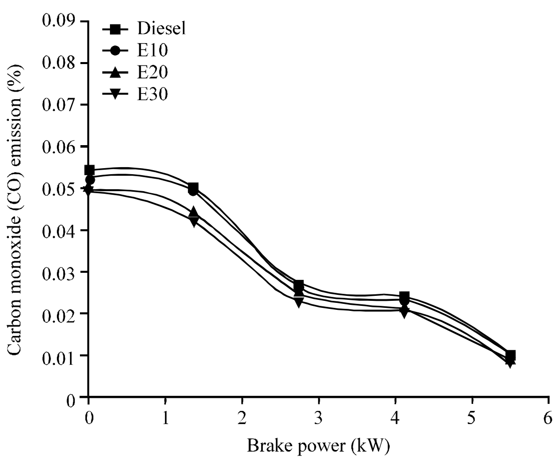

Fig. 6: Brake power vs. CO emission

accelerates the reaction and leads to a complete combustion. Hence, the unburnt hydrocarbon emission was appreciably reduced with eucalyptus oil blends. Tarabet *et al*. (2012) mentioned that the oxygen content improves the combustion quality in the combustion chamber. But diesel fuel has higher hydrocarbon emission than all other blends of eucalyptus oil. This may be due to the less oxygen availability than biodiesel fuel. Duraisamy *et al*. (2011) stated that the reason of hydrocarbon emission might be due to low oxygen availability for combustion.

Carbon monoxide (CO) emission: Figure 6 shows a lower carbon monoxide (CO) emission with eucalyptus oil blends than diesel fuel. It may be due to the higher oxygen content in eucalyptus oil than diesel fuel.

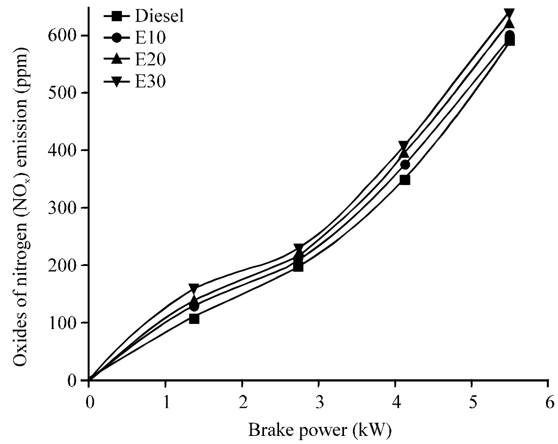

Fig. 7: Brake power vs. NO_x emission

Tarabet *et al*. (2012) stated that the effect on CO emission could be due to dominant premixed lean combustion with excess air. Tarabet *et al*. (2012) also stated that unburned Hydrocarbon (HC) is an important parameter for determining the emission behavior of the engine. The carbon monoxide emission was considerably reduced with eucalyptus oil in all proportion ranges. In this investigation, it was found that CO emission at full load was 0.01% for diesel whereas it reduced to 0.0082% for E30.

Oxides of nitrogen (NO_x) emission: Oxygen content and elevated temperature are the two major components which accelerate the reaction between oxygen and nitrogen. In general almost all biodiesel fuels have higher oxygen content than diesel fuel. Musthafa and Sivapirakasam (2010) in his research stated that an increase in after combustion temperature caused an increase in NO_x emission. Labeckas and Slavinskas (2006) in his research findings stated that the total NO_x emissions as a sum of both harmful pollutants, NO and NO_2, depended actually on the biofuel feedstock, its chemical structure, oxidation rate, thermal stability and iodine number. Figure 7 shows the trend between brake power and oxides of nitrogen emission of the experimental results. The NO_x emission for diesel fuel was found to be 590 ppm whereas the values increased to 600, 620 and 640 ppm for E10, E20 and E30, respectively. This result was almost expected because of the higher oxygen content and higher combustion chamber temperature.

CONCLUSION

The promising results of this investigation ensure that tests on eucalyptus oil could be continued as it shows a calorific value closer to diesel. Brake thermal efficiency of E10 was slightly more than that of diesel. It got reduced by the increase of the biodiesel blend. UBHC and CO emissions were remarkably within the limit but oxides of nitrogen emission were greater. The oxides of nitrogen emission could be reduced by optimizing the injection timing, injection pressure or compression ratio. It could also be considerably reduced by the addition of water directly or with emulsified fuel.

RECOMMENDATIONS

In this investigation, it was found that the heating value of the eucalyptus oil was appreciably closer to diesel and the efficiency value also showed a good sign of using it as a futuristic fuel. Though UBHC and CO emissions were remarkably less, NO_x emission was higher. Instead of proceeding with the investigation with engine modification, emulsified fuel could be tried further to reduce NO_x emission.

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