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PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE WITH MUSTARD OIL-DIESEL BLENDS AS FUEL

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ABSTRACT

This paper investigates the performance and emission characteristics of a diesel engine with mustard oil and its diesel blends. The mustard oil-diesel blends M5 (5% Mustard oil and 95% diesel), M10 (10% Mustard oil and 90% diesel), M15 (15% Mustard oil and 85% diesel), and M20 (20% Mustard oil and 80% diesel) was prepared to test in diesel engines. The present experimental results were obtained on the performance and the emissions of CO, HC and NOx in diesle engine. Comparison of mustard blends (M5, M10, M15 and M20) with engine diesel was done. The results showed that the brake thermal efficiency was decreased as the blend increased, and the brake specific fuel consumption was slightly higher than the diesel fuel. The CO and HC emissions are higher than diesel. However, NOx emissions of the blends were found to be decreased significantly compared to diesel as blend ratio increased. Smoke emission was found to be increased slightly when compared to diesel.

Key words: Diesel engine, Mustard oil, Diesel blend.

INTRODUCTION

The energy demand increases day by day in India due to increase in population as well as increase in modernization of the world. Today India is much dependent on petrochemical reserve (*i.e.* coal, gasoline, crude oil etc.) to satisfy our energy demand. In our country we have a very limited crude oil reserve. So to satisfy our demand we are fully dependent on crude oil import from foreign countries. Among various gasoline fuels, diesel fuel is most widely used as it proves higher energy density (*i.e.* more energy can be extracted from diesel as compared with the same volume of gasoline fuel) than other gasoline. Therefore diesel engines have versatile uses in heavy-duty transportation, power generation and also in agricultural sectors. That's why the consumption of diesel is much

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higher than other gasoline. As the underground crude oil reserve is non-renewable, so its reserve is decreasing rapidly due to gradual increase in its consumption. This phenomenon drives us to search for an alternative and renewable substitute of diesel fuel[1].

The use of vegetable oils as an alternative fuel for diesel engines dates back to around a century. Due to rapid decline of crude oil reserve and increase in price, the use of vegetable oils is again prompted in many countries. Depending upon soil condition and climate, different nations are looking for different vegetable oils- for example, soybean oil in U.S.A., rapeseed and sunflower oil in Europe, palm oil in Malaysia and Problems associated with using straight vegetable oil (SVO) in diesel engine can be classified in two groups, namely: operational and durability problems. Operational problems are related to starting ability, ignition, combustion and performance. Durability problems are related to deposit formation, carbonization of injection tip, ring sticking and lubrication oil dilution [2,3]. Various researchers have shown that the use of vegetable oil and their derivatives is competitive compared to mineral diesel [4,5]. Many researchers have tried to use biodiesel derived from mahua oil as fuel for diesel engine. In most of the countries including India, biodiesel is expensive than the diesel and also biodiesel is not available commercially in the market. Most of the work reported in the literature involves only the laboratory studies [6-8]. Pramanik *et al*. [9] have studied the performance and emissions of a diesel engine with Jatropha methyl ester at various blends. It has been reported that 50% of Jatropha oil blends can be substituted for diesel fuel in a C.I. engine. It has been reported that the Jatropha oil exhibited higher specific fuel consumption and lower exhaust gas temperatures compared with diesel fuel. Etherification is one of the methods to convert the vegetable oil into its methyl ester, known as biodiesel. Several researchers have used biodiesel as an alternate fuel in the existing CI engines without any modifications [9,10]. The objectives of this experimental study are to assess the performance and emission characteristics of a diesel engine with Mustard oil diesel blends and compared with diesel fuel.

EXPERIMENTAL

Materials and methods

Mustard plant and production of mustard oil

Mustard (Brassica juncea) oil is obtained from the seeds of Brassica family, including canola (rapeseed) and turnip, has high levels of omega-3 (6-11%) and are a common, cheap, mass-produced source of plant-base omega-3 fatty acids. Flax (linseed) oil has 55% plant-based omega-3 but is uncommon as a table or cooking oil. Mustard oil was procured from an oil mill. The oil was filtered to remove the impurities. The viscosity of mustard oil was found to be approximately 7 times higher than that of diesel fuel.

Fig. 1: Photographic view of mustard oil

Table 1: Properties of diesel, mahua, mustard biodiesel

Properties	Diesel	Mustard oil
Density	830	953
Specific gravity	0.83	0.953
Kinematic viscosity	4.05	24.67
Calorific value	43000	32430
Flash point	56	185
Fire point	63	225
Cetane Number	48	37

Table 2: Properties of Diesel and mustard oil blends

Properties/Blend	M5	M10	M15	M20
Density (kg m^{-3})	836	842	848	854
Specific gravity	0.836	0.842	0.848	0.854
Calorific value (kJ/kg)	42471	41943	41414	40886
Cetane Number	47.2	46.9	46.4	45.8

Experimental setup and procedure

The engine test was conducted on a four stroke, single cylinder, water-cooled direct injection, Kirloskar Engine diesel engine. The specifications of the test engine are given in Table 2. The schematic of the experimental set up is shown in Fig. 1. A three hole injector nozzle was located at the center of the combustion chamber with high pressure fuel pump and has an operating pressure of 180 bar. The engine was coupled to an electrical dynamometer and loaded by electrical resistance to apply different engine brake loads. AVL DI 444 exhaust gas analyzer was used for this experiment is to measure the exhaust emissions like CO, HC, NO. The measuring method is based on the principle of light absorption in the infrared region, known as "non-dispersive infra red absorption”. The broadband infrared radiation produced by the light source passes through a chamber filled with gas, generally methane or carbon dioxide. Smoke opacity was measured by AVL 437C model. The measurement is based on the principle of light absorption by particle. Photo electronic smoke detection is based on the principle of optical detection. It is also known as the "scattered" light principle.

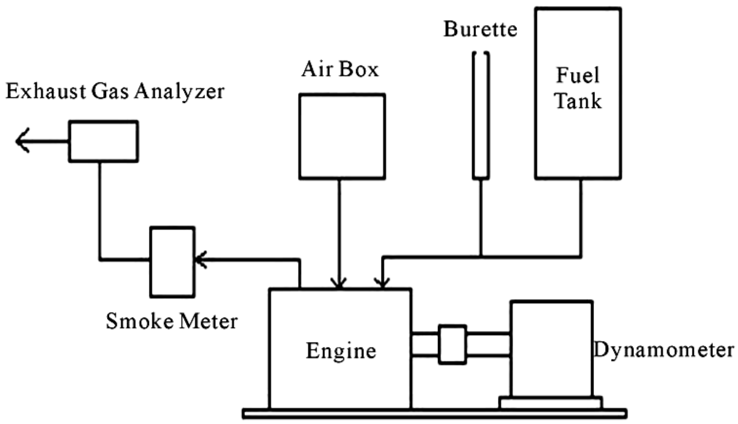

Fig. 2: Schematic view of experimental setup

Table 4: Specification details of Kirloskar TV1 engine

Type	**Vertical, single cylinder 4 stroke**
Number of cylinders	01
Rated power (kW)	3.7
Bore (mm)/Stroke (mm)	80/110
Compression ratio	16.5:1
Speed (rpm)	1500
Type of cooling	Water cooling
Injection pressure	180bar
Injection timing	23^{o} bTDC

To estimate the performance parameters, operating parameters such as engine speed, power output, and fuel consumption were measured. Significant engine performance parameters such as Brake specific fuel consumption (BSFC) and Brake thermal efficiency (BTE) for the test fuels were calculated. Emission parameters such as CO, HC, NO and smoke opacity were observed for various fuel blends. Initially, experimental tests were conducted with neat diesel, In the next phase, the engine was operated diesel-mustard oil blend ratio of 95:05 (M5), 90:10 (M10), 85:15 (M15) and 80:20 (M20).

RESULTS AND DISCUSSION

Brake thermal efficiency

The variations of BTE at different loads and various fuel blends are shown in Fig. 3. The BTE for diesel is higher than that of all other mustard oil diesel -blends at all loads. It is observed that the BTE is decreases with increase in mustard oil diesel blends at full load. The BTE for M5 blend is higher than other blends M10, M15 and M20 blends. The reason for this higher viscosity, lower calorific value of the blends and low cetane number of fuel blends. The BTE of M5, M10, M15 and M20 are 26.6%, 25.5%, 24.2% and 23.2% respectively, whereas for diesel is 28.1% at full load. At 75% of the load all the fuel blends have higher brake thermal efficiency than full load conditions.

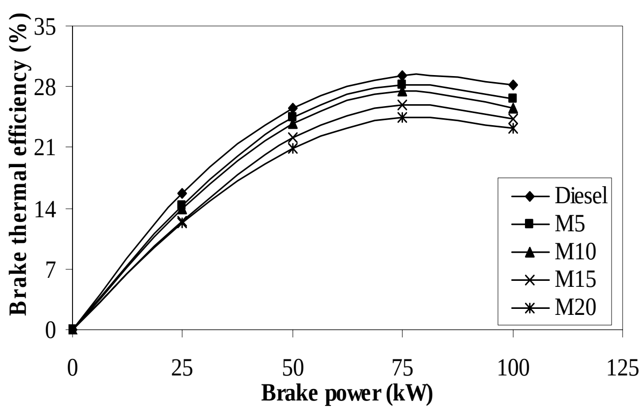

Fig. 3: Brake thermal efficiency Vs brake power

Brake specific fuel consumption

The variation in BSFC for the test fuels with respect to brake power is shown in Fig. 4 for diesel and various mustard oil-diesel blends. The BSFC of all fest fuels are decreases with increase in loads. At 75% of the load mustard oil diesel blends have lower specific fuel consumptions. The BSFC of all mustard oil-diesel blends are higher than diesel fuel at full load. This may be due to poor atomization and vaporisation of high viscosity, low cetane number and lower calorific value of the blends. The BSFC of M5, M10, M15 and M20 are 0.32 kg/kWh, 0.346 kg/kWh, 0.362 kg/kWh and 0.387 kg/kWh respectively, whereas for diesel is 0.306 kg/kWh.

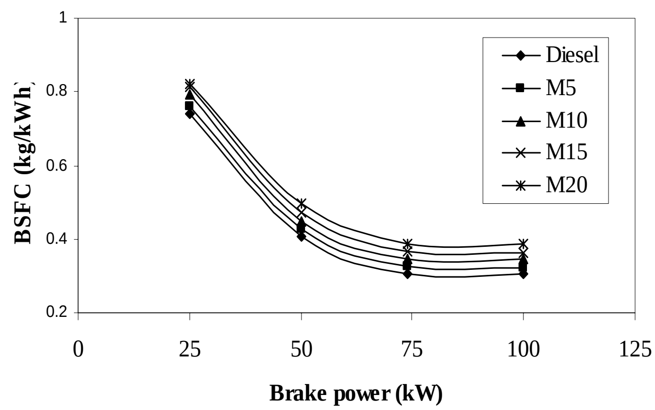

Fig. 4: Brake specific fuel consumption Vs Brake power

Exhaustgas tyemperature

Fig. 10 shows the variation between exhaustgas temperature and brake power for different fuels. It is seen that the exhaust gas temperature increases with increase in load for all test fuels. At higher % load condition, M20 shows higher exhaust gas temperature than other fuel blends. The exhaust gas temperature of M5, M10, M15 and M20 are 345^{o}C, 358^{o}C, 368^{o}C and 382^{o}C, respectively, whereas for diesel is 338^{o}C at full load.

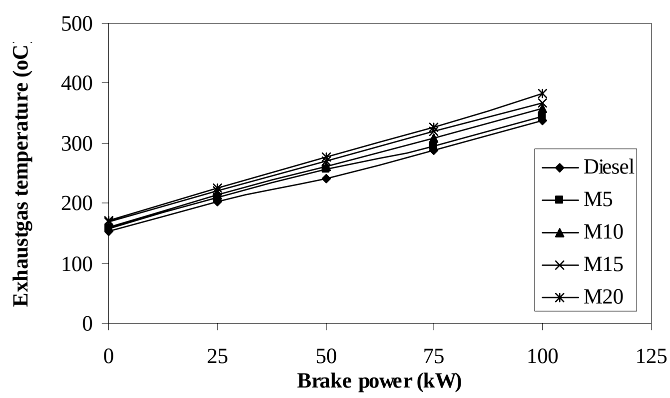

Fig. 5: Exhaustgas temperature Vs brake power

This may be due to slow burning of high viscous mustard oil blends, resulting in higher exhaust gas temperature.

Carbon monoxide emission (CO)

The variation of CO emission with brake power for diesel and different blends of mustard oil is shown in Fig. 6. It is observed that the CO emissions increase with increase in load for all the test fuels. The CO emissions for M5, M10, M15 and M20 are 0.17% Vol, 0.24% Vol, 0.32% Vol and 0.39% Vol, respectively, whereas for diesel is 0.11% Vol at full load. Mustard oil-diese blends have higher CO emissions due to poor atomization and vaporization due to its high viscosity and have less time to undergo complete combustion.

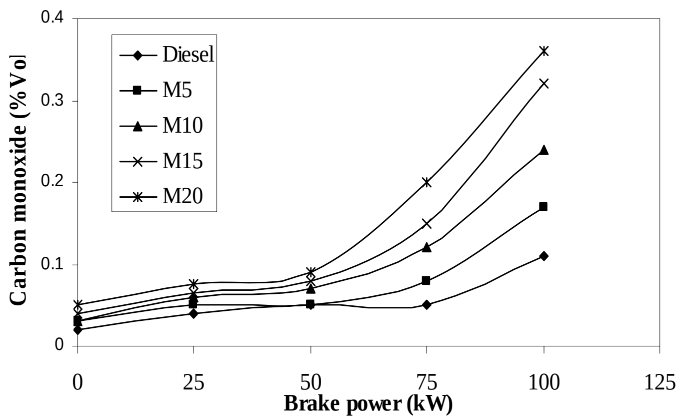

Fig. 6: Carbon monoxide emission Vs brake power

Hydrocarbon emission (HC)

The Fig. 7 shows the variation of hydrocarbon emission with respect to brake power for diesel and different blends of mustard oil. It can be seen that the HC emission for all the mustard oil- diesel blends are higher than that of diesel for medium and higher loads. This may be due to incomplete combustion of vegetable oil blends due its high viscosity and poor atomization of the blends. The HC emission for M5, M10, M15 and M20 are 0.17% Vol, 0.24% Vol, 0.32% Vol and 0.360% Vol, respectively, whereas for diesel is 0.11% Vol at full load

Nitrogen oxides emissions (NO)

The variations of nitrogen oxide emissions with brake power for diesel and different mustard oil blends is shown in Fig. 8. The NOx emission is a function of lean fuel with higher temperature, high peak combustion temperature and spray characteristics. A fuel with high HRR at rapid combustion and lower HRR at mixing controlled combustion will causes of NOx emission. NOx emission increases with increase in load for all test fuels. The NO emission for M5, M10, M15 and M20 blend is 9.6%, 21%, 29% and 37, respectively lower than neat diesel at full load. The decrease in NO emission due to slower burning of high viscosity of mustard oil diesel blends, resulting in lower peak combustion temperature.

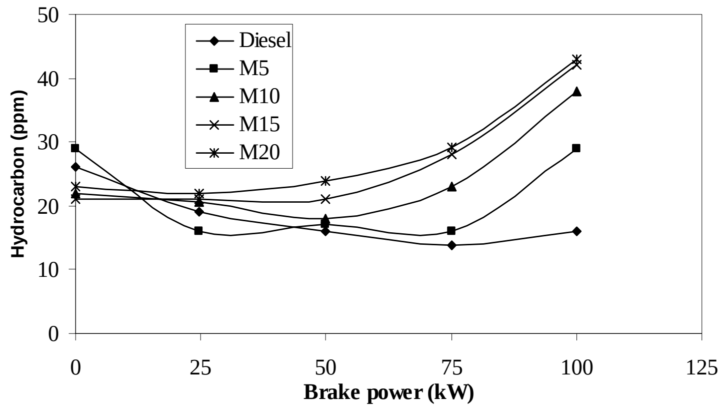

Fig. 7: Hydrocarbon emission Vs brake power

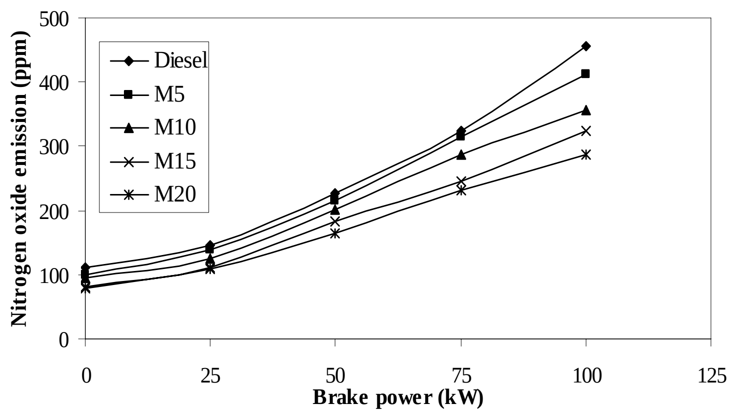

Fig. 8: Nitrogen oxide emission Vs brake power

Smoke opacity

The variation of smoke opacity with brake power for all the test fuels is shown in Fig. 9. The smoke is produced due to incomplete combustion of fuel. It can be seen that at higher load, the smoke intensity for blended fuels are higher comparing to neat diesel. The smoke opacity of M5, M10, M15 and M20 are 4 BSU, 4.3 BSU, 4.5 BSU and 4.9 BSU respectively, whereas for diesel is 3.6 BSU at full load. This may be due to poor atomization and of high viscosity and low volatility of mustard oil blends, resulting in higher smoke emission at full load.

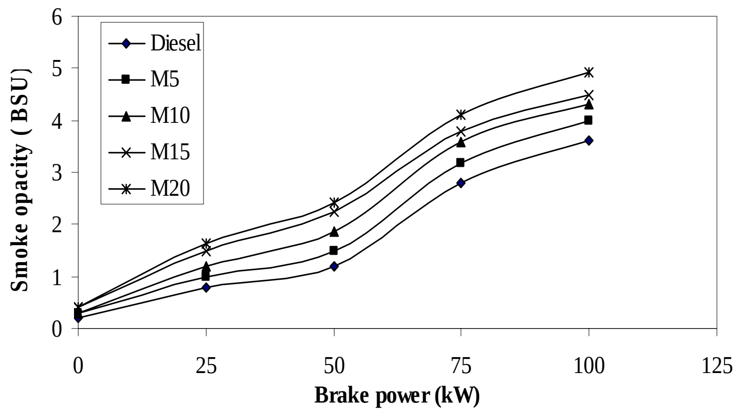

Fig. 9: Smoke opacity Vs brake power

CONCLUSION

In the present investigations the Mustard oil –diesel blends were prepared by blending methods by vol/vol. Fuel properties were determined for the mustard oil diesel blends. Performance and emission characteristics were investigated on diesel engine by smoke analyzer and gas analyzer. The results of the experimental study were concluded as follows: The brake thermal efficiency of all mustard oil diesel blends was slightly higher than diesel due to high viscosity, and low calorific value of the fuel. Brake specific fuel consumption of the blends were determined to be higher for all blends at full load. The exhaust temperature was increased with B20. B40 and B60 biodiesel mixture reduced the temperature as the blend ratio increased. The CO and HC emissions of all blends were higher than diesel. The smoke emissions were found to be slightly higher than diesel fuel. When compared to diesel, NOx emissions of all the blends of mustard oil were found to be increased. As the blend ratio increased, the NOx emissions were also increased respectively.

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