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Experimental Investigation on Performance and Emission Characteristics of a DI Diesel Engine Fuelled With Rice Bran Oil Methyl Ester And Methanol as an additive

K Prasada Rao, K Santarao*, P Govinda Rao

Department of Mechanical Engineering, GMR Institute of Technology, Rajam, India

Abstract: The rapid depletion of petroleum fuels and their ever increasing costs and concern for vehicular emissions have led to an intensive search for alternative fuels. Bio-diesel is an attractive alternative fuel which is renewable, non-toxic, reduces carbon monoxide and hydrocarbon emission due to higher content of oxygen. At present, biodiesel is commercially produced from the refined edible vegetable oils such as rice bran oil (RBO), sunflower oil, palm oil and oil, etc. by trans-esterification process. The various parameters that have been considered for the research in this direction with edible oil has yielded encouraging results with rice bran oil which is edible and has been considered as an alternative fuel. Along with this, biodiesel has high cetane number which is a measure of fuel's ignition quality. It replaces the exhaust odor of petroleum diesel with more pleasant smell of popcorn or French fries. RBO is the best biodiesel to use in the internal combustion engine and gives the better result when compared with the others. The lower blends of biodiesel increase the brake thermal efficiency and reduce the fuel consumption. The exhaust gas emissions are reduced with increase in biodiesel concentration. The experimental results proved that rice bran oil can be substituted for diesel without any engine modification as a fuel.

Introduction

Energy is an essential input for economic growth, social development, human welfare and improving the quality of life. Since their exploration, the fossil fuels continued as the major conventional energy source. With increasing trend of modernization and industrialization, the world energy demand is also growing at a faster rate. Apart from their indigenous production, majority of developing countries import crude oil to cope up with their increasing energy demand. Thus, a major chunk of their hard earned export earnings is spent for purchase of petroleum products. India is also a net energy importer and almost 80% of the country's export earnings are directly spent for purchase of petroleum products. There had been sharp increase in the consumption pattern of petroleum products in India. The transport and agriculture sectors are the major users of the conventional liquid fuels.

Due to recent energy crises and dwindling reserves of crude oil, the demand for alternate liquid fuels particularly the diesel is increasing. Bio-fuels are being given serious consideration as potential sources of energy in the future, particularly in developing countries like India. With our present known petroleum reserves and the going rate of their consumption, it is feared that they are not going to last long.

Although the present reserves seem vast, the accelerating consumption will create a challenge before the world that a new type of fuel should replace the conventional fuels. The new reserves appear to grow arithmetically while the consumption is growing geometrically. Under this situation, when consumption overtakes discovery, the world will be leading to an industrial disaster.

Many countries today solely dependent on imports to meet their fuel oil requirements and many more will be added in future as the limited reserves of petroleum deposits get exhausted. The situation is very grave in developing countries like India which imports 70% of the required fuel, spending 30% of her total foreign exchange earnings on oil imports. This situation has created a problem to increase the price of these oils more than two folds in last 5 years. As time passes, these trends will be aggravated further causing greater scarcity and hardships.

Apart from the problem of fast vanishing reserves and irreplaceable nature of petroleum fuels, another important aspect of their use is the extent and nature of environment pollution caused by their combustion in vehicular engines. Petroleum fuelled vehicles significant amount of pollutants like CO, HC, NO_X, soot, lead components and aldehydes.

Oxides of nitrogen and unburned hydrocarbons from the exhaust cause environment fouling by forming photo-chemical smog. Their interaction involves formation of certain formaldehyde, peroxide, Peroxyl nitrate which causes eye and skin irritation, plant damage and reduced visibility. In order to reduce these NO_x emissions and to improve combustion, methanol additive is added to conventional diesel.

In view of these problems of fast dwindling reserves of irreplaceable petroleum fuels and the hazards of environmental pollution caused by the combustion, attempts must be made to develop the technology of alternate clean burning synthetic fuels. These fuels should be such that they have attributes of perennial renewal, they perform well in engine, and their potential for environmental pollution should be quite low.

Diesel fuels have an important role in the industrial economy of any country. Because of the depletion of petroleum reserves, increasing fuel prices and uncertainties concerning petroleum availability, stringent emission standards and global warming caused by carbon dioxide (CO_2) emissions, development of alternative energy sources and fuels has become increasingly important day by day. Vegetable oils have comparable energy density (10 per cent lower) and a cetane number almost similar to diesel. The idea of using vegetable oils as fuel for diesel engine is not new. When Rudolf Diesel first invented the diesel engine, he demonstrated it at the 1900 world exhibition in Paris, employing peanut oil and said that the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become in course of time as important as petroleum and the coal tar products of the present time[1].

Climate changes occurring due to increased Carbon Dioxide (CO_2) emissions and global warming; increasing air pollution and depletion of fossil fuels are the major problems in the present century. The present researchers have been focused on the biofuels as environment friendly energy source to reduce dependence on fossil fuels and to reduce air pollution. The biofuels can play an important role towards the transition to a lower carbon economy and also combine the benefits of low green house emissions with the reduction of oil import. The role biofuels can play within these economies becomes clearer when their relatively developed agricultural sector is taken into account[2].

Biodiesel has received wide attention as a replacement for diesel fuel because it emits less pollution, renewable, environmental friendly and easily produced in rural areas[3, 4]. It is also commonly accepted that diesel engine emission can be reduced effectively using oxygen content alternative fuels, or potentially the addition of oxygen within the diesel fuel. Therefore, much research has focused on screening of oxygenated fuel additives, including alcohols, esters and ethers to reduce emissions[5, 6].

A previous review published by[7] could not reflect the new research achievements this decade, and the new review finished by[8] did not include knowledge about engine durability and about 20% literatures before 2000 year was cited to clarify the effect of biodiesel on engine performances and emissions. But the other newer one, written by[9], seems unconvincing for professional (especially about the review on the long-term biodiesel engine test) and uneasy for nonprofessional to read.

It was observed from the literature[10, 11] that the use of biodiesel in diesel engine results in a slight reduction in brake power and a slight increase in fuel consumption. However, the lubricant properties of the biodiesel are better than diesel, which can help to increase the engine life. Also the exhaust emission of the biodiesel is lower than the neat diesel operation due to the presence of oxygen in the molecular structure of the biodiesel.

The drawbacks of biodiesel are higher nitric oxide emissions and poor oxidation stability than petroleum-based diesel fuel. This oxidation can cause the fuel to become acidic and to form insoluble gums and sediments that can plug fuel filters[12].

Several studies show a decrease in carbon dioxide emission due to blending diesel with biodiesel[13, 14]. The formation of mono nitrogen oxides can lead either to an increase or decrease due to blending [15, 16]. These papers show that in general pre 1997 diesel engines have an increase in NO_x emissions with increased biodiesel percentage due to problems with the injection timings, which is after all designed in accordance with the fuels viscosity[17].

There is no significant effect of Mo and Mg as the additives into B60 biodiesel blend on engine torque and power tested on a single cylinder, 4-stroke, AC, DI diesel engine[18]. The positive effect of a blend of 10% chicken fat biodiesel and diesel fuel with an additive 12 mol Mg, improved the performance of biodiesel in flash point, viscosity and pour point[19]. B20X with 1% 4-nonyl phenoxy acetic acid (NPAA) additive produced higher brake power over the entire speed range in comparison to B20 and B0 (diesel), and the maximum brake power obtained at 2500 rpm is 12.28 kW from B20X followed by 11.93 kW (B0) and 11.8 kW (B20). They contributed to the increase of fuel conversion efficiency by improving fuel ignition and combustion quality due to the effect of fuel additive in B20 blend[20].

In this work, an attempt is made to improve performance and to reduce exhaust emissions by using Rice Bran Methyl Ester as base fuel and additive Methanol in DI diesel engine.

Experimentation

Biodiesel production by trans-esterification method:

The process of trans-esterification method of preperation of bio-diesel is explained in Fig.1:

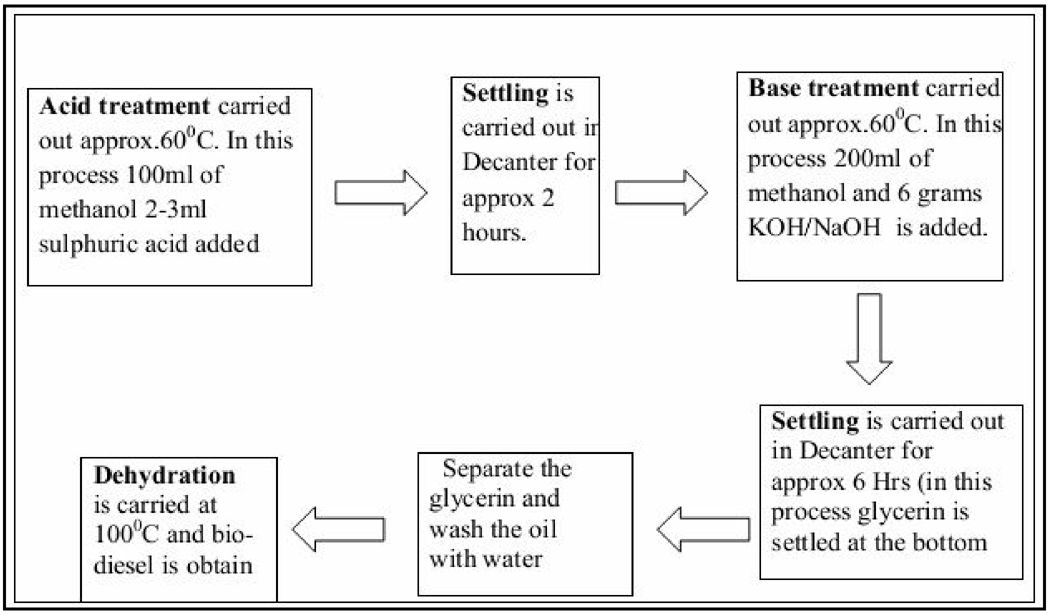

Fig.1 Block diagram for Trans-esterification process

Table-1: Specifications of DI diesel engine

Type of engine	**DI diesel engine**
Make	Kirloskar-AV1
No. of cylinders	One
Brake power	5HP
RPM	1500rpm (constant)
Bore	80 mm
Stroke	110 mm
Loading type	Mechanical
Brake drum diameter	0.315 mm
Orifice diameter	20 mm

Results and discussions

Experimentation is conducted on Direct Injection Diesel engine and engine specifications are mentioned in Table-1. The maximum power of the engine is 5 hp at a constant speed of 1500 rpm.

The engine is operated at 1500rpm at full load approximately 3.88 kW at a spring balance load of 16 kg (equivalent to 3.88 kW) which can be taken up at strategic loads of 4-8-12-16 kg each. Totally, the 16 kg load has been divided into five loads progressively increasing 4-8-12-16 kg each. All the fuel samples have been tested for performance and emissions of the Engine. In an attempt to improve the performance of the engine with neat biodiesel application, methanol is used an additive to control the combustion temperatures. Blends of Rice bran oil methyl ester and methanol have been used to verify the engine performance.

The chosen blends are 1%, 3%, and 5% of methanol with Rice bran oil methyl ester. It is observed homogenous blends with all these percentages of alcohol.

Effect of equivalence ratio on BSFC:

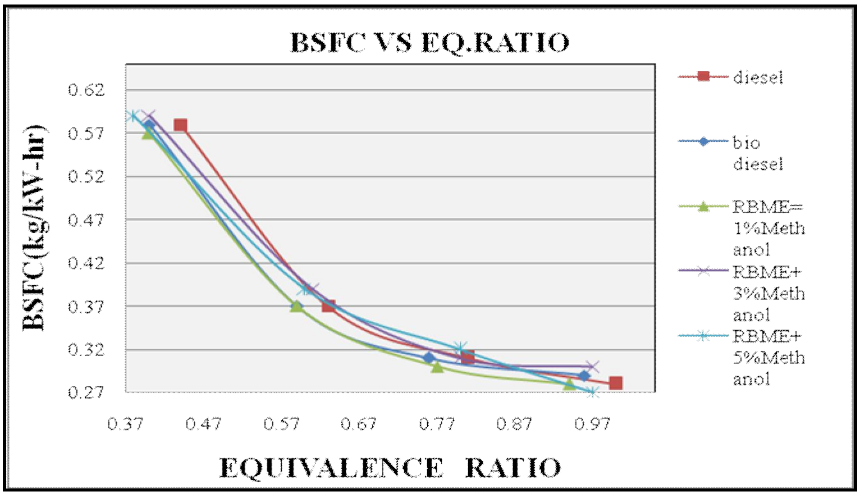

Fig. 2 Equivalence Ratio Vs BSFC

The variation of Brake Specific Fuel Consumption with Equivalence Ratio is shown in Fig.2.The equivalence ratio is observed to be within limits for the part load operation of the engine at 1500 rpm. A smoother trend of the curve is observed for the additive blend of 1% (Green line).The equivalence ratio for the 1% of additive blend is observed on higher side i.e. 0.94 nevertheless the performance can be better when compared to other samples.

Effect of brake power on BSFC:

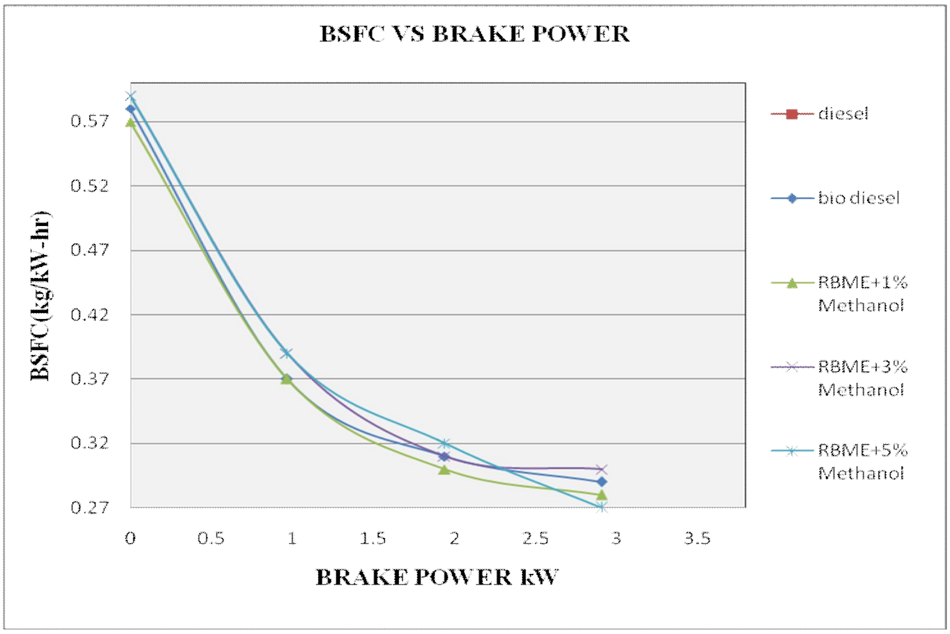

Fig.3 BSFC Vs Brake Power

The variation of BSFC with Brake Power (kW) is shown in Fig.3. The brake power is observed for the part load operation of the engine i.e; 2.91kW. A smooth curve is observed for RBME + 1% Methanol. It means that at 2.91 kW load, the fuel consumption is low compared to other fuel samples.

Effect of equivalence ratio on Brake Thermal Efficiency:

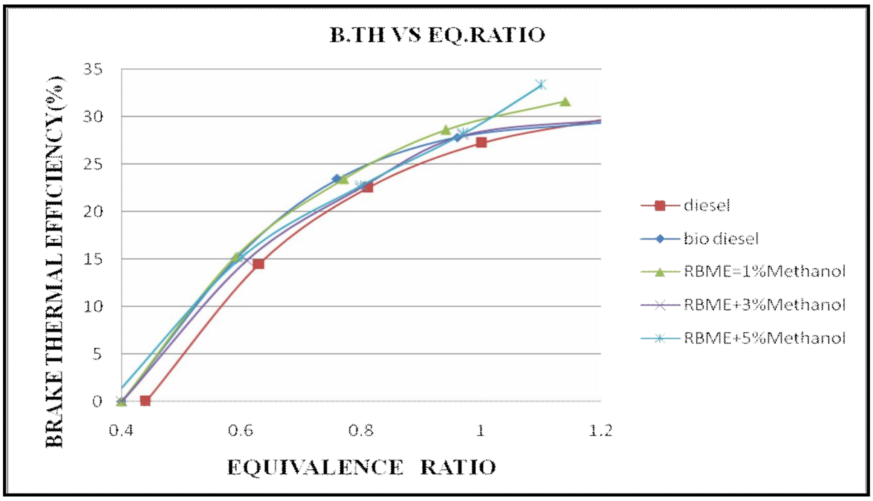

Fig. 4 Break Thermal Efficiency VS Equivalence Ratio

The variation of Brake Thermal Efficiency with Equivalence Ratio is shown in Fig.4. A smooth trend of the curve is observed for RBME + 1% Methanol. This means maximum Brake Thermal Efficiency i.e 31.6% is obtained with RBME + 1% Methanol at equivalence ratio 1.14 when compared to other fuel samples.

Effect of Brake Power On Brake Thermal Efficiency:

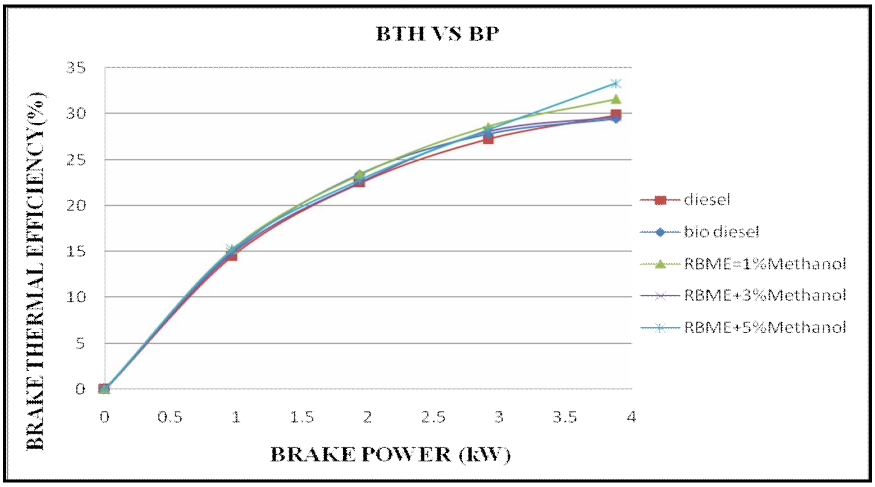

Fig. 5 Break Thermal Efficiency Vs Break Power

The variation of Brake Thermal Efficiency with Brake Power is shown in Fig.5. A smooth trend of the curve is observed for RBME + 1% Methanol. This means maximum Brake Thermal Efficiency i.e; 31.6% is obtained with RBME + 1% Methanol at full load condition i.e; 3.88 kW when compared to other fuel samples.

Effect of Engine Load On Exhaust Gas Temperature:

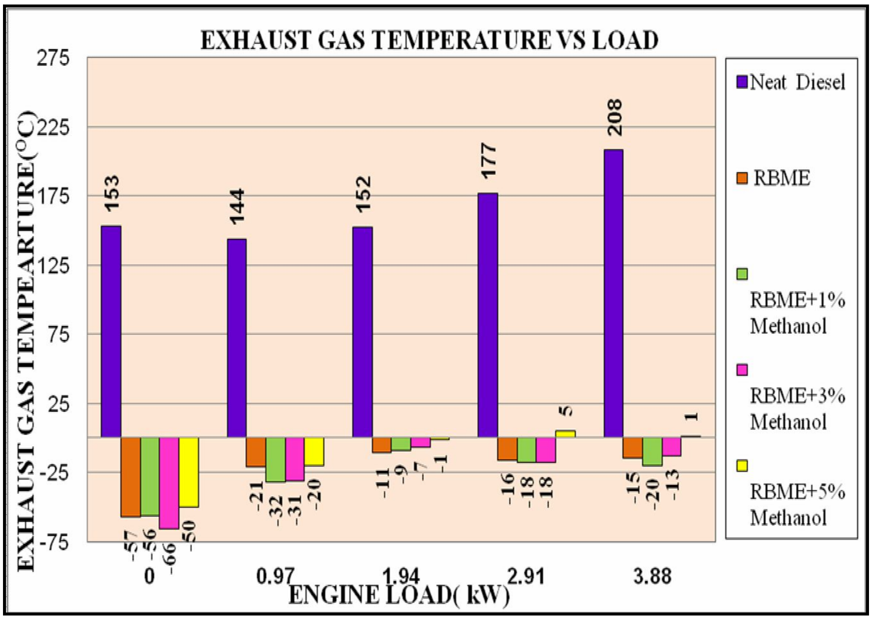

Fig. 6 Exhaust Gas Temperature Vs Load

The variation of Exhaust gas temperature with Engine load is shown in Fig.6. At full load of the engine, Exhaust gas temperature is decreased by 9.6% in the case of RBME + 1% Methanol and this decrement is with respect to the diesel fuel. This observation of lower exhaust gas temperature is the representation of lower combustion temperatures.

Effect of Engine Load On Smoke:

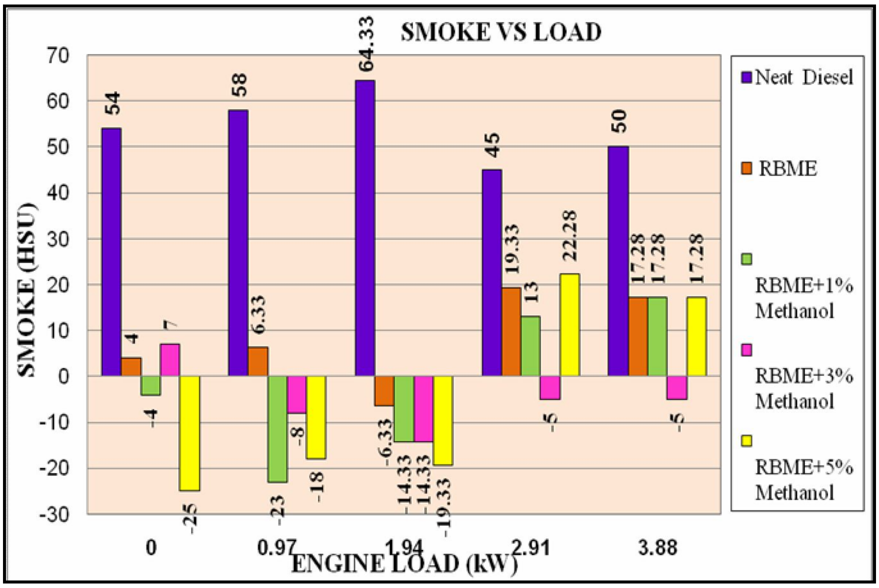

Fig.7 Smoke Vs Load

The variation of smoke in Hatridge units with Engine load in kW is shown in Fig.7. At full load of the engine, smoke levels are decreased by 18%, in the case of RBME +3% Methanol and this decrement is with respect to the diesel fuel. At half load of the engine, smoke levels are decreased by22.3%, in the case of RBME + 1% Methanol. The decrease in smoke level in exhaust with respect to the neat diesel fuel operation is appreciable. This is an indication of better combustion.

Effect of Engine Load On Oxygen Emissions:

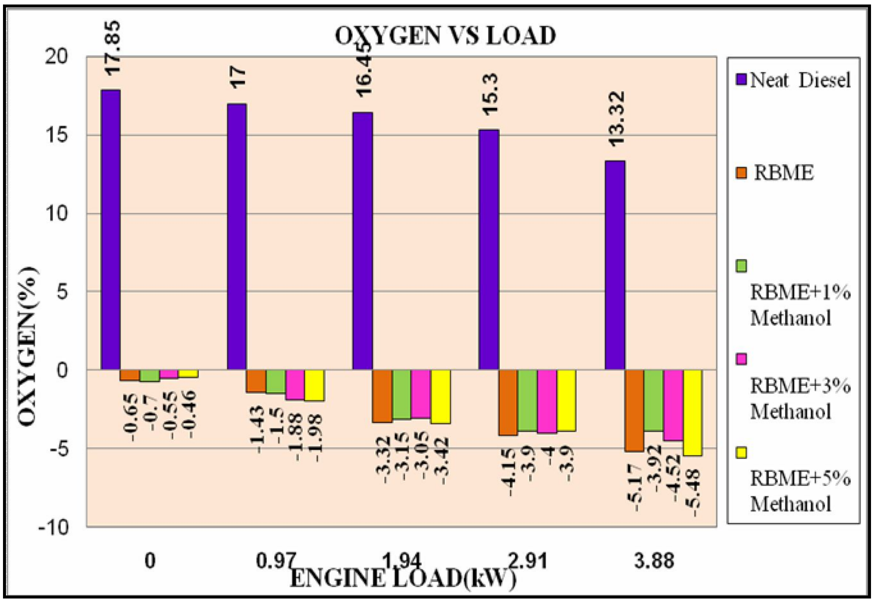

Fig.8 Oxygen Vs Load

The variation of oxygen emissions with Engine load in kW is shown in Fig.8. It can be observed that oxygen emissions are decreased by 29.42% in the case of RBME + 1% Methanol and this decrement is with respect to diesel fuel.

Effect of Engine Load On Carbon Dioxide emissions:

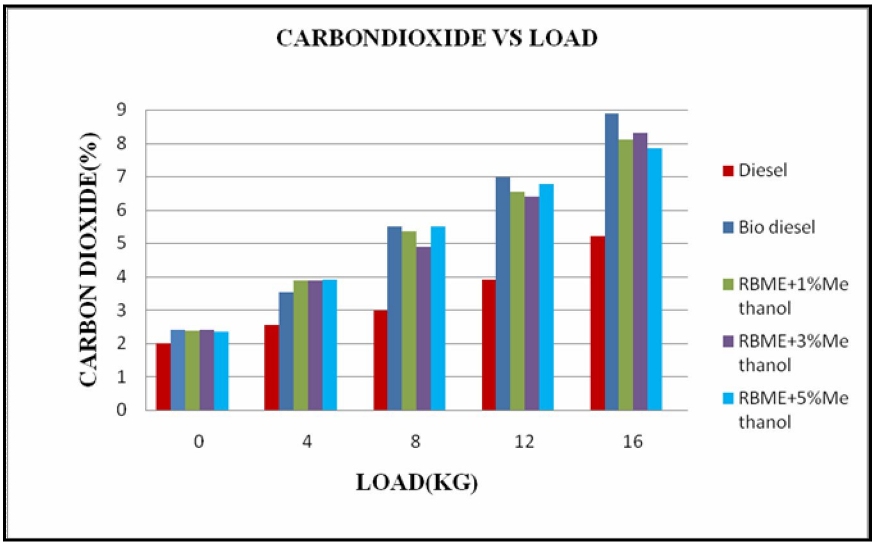

Fig.9 Carbondioxide Vs Load

The variation of Carbondioxide emissions with engine load in kg is shown in Fig.9. It can be observed that Carbondioxide emissions are increasedby 55.17% in the case of RBME + 1% Methanol and this increment is with respect to diesel fuel. Increase of carbon dioxide emissions indicates combustion improvement.

Hence, surveying all the results, RBME + 1% Methanolis the most feasible sample for the application in the DI engine as a replacement to the conventional diesel without any changes in the engine parameters.

Conclusions

In this paper, Diesel, Rice Bran Methyl ester (RBME) and RBME with methanol additive are used as fuels in DI Diesel engine. The performance and emissions are measured to evaluate the suitable methanol percentage which gives maximum benefits. The conclusions are as follows:

- Flash and fire points of biodiesel are quite high compared to diesel making it safer to store and transport.
- The Brake Specific Fuel Consumption is increased by 3.57% when using RBME due to higher viscosity. However with the addition of methanol additive, BSFC is slightly reduced at full load conditions (i.e; 3.88 KW).
- The Brake Thermal Efficiency of RBME and its blends with methanol additive is higher than that of conventional diesel at all load conditions. Brake Thermal Efficiency is increased by 5.83% for RBME + 1% Methanol and by 11.6% for RBME + 5% Methanol at full load conditions.
- There is a significant decrease in exhaust gas temperatures of RBME and its blends with methanol additive compared to conventional diesel at all load conditions. Exhaust gas temperature is decreased by 9.6% for RBME + 1% Methanol at full load conditions.
- Carbon dioxide (CO_2) emissions are increased by 55.17% forRBME + 1% Methanol at all the load conditions because of which improvement in combustion is observed.
- Oxygen (O_2) emissions are decreased by 29.42% for RBME + 1% Methanol at full load conditions.
- At full load conditions, RBME+3% methanol has the lower smoke density than all the other fuels.
- From the above analysis, RBME + 1% Methanol shows optimum performance when compared to RBME, RBME + 3% Methanol and RBME + 5% Methanol. It is observed that 1% additive with biodiesel can be used as substitute to diesel fuel.

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