Experimental Study of Performance and Emission Behavior of a Direct Injection Diesel Engine

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Abstract: Exhaust emission coming from IC engines affects not only the environment but also the human health. This serious issue has got attention by the government as well as from the researchers throughout the world. In this regard it is necessary to find out alternative to not only fossil fuel but also environment cooperative fuel. In this regard, investigations were carried out by using Jatropha biodiesel and its blend with used transformer oil which was discarded after use. The test was carried ot in a single cylinder diesel engine and different terms such as performance and emissions of diesel engine were found out and compared with diesel operation. It was noticed that engine can be run by using these kinds of fuels. By using these fuels not only we are solving waste disposal problem but also replacing diesel fuel and environment friendly fuel. The used transformer oils were blended with Jatropha biodiesel in different proportions and test were done.

***Index Terms* - Performance; Diesel Engine; Jatropha Oil; Biodiesel.**

I. INTRODUCTION

Fast depletion of fossil fuels and increasing number of vehicle population, and their detrimental effect on the environment results in urgent need of alternative fuels for meeting the sustainable energy demand with minimum environmental impact [1]. Therefore, there is a necessity to find suitable alternative fuels for diesel engines that are cheaper and eco-friendly. Figure 1.1 depicts that the main sources of energy as per 2018 are still coal, oil and natural gas. But, a significant amount of share is of energy from Biofuels and waste which directly tells the shift in the mindset of people to move towards more eco-friendly fuel and towards renewable energy. Also, it depicts the tremendous amount of research and effort put in by the scientists and researchers to make this dream of sustainable development and cleaner and greener fuel possible. 155,505 Terawatt-hour (TWh) was the approximate primary energy supply of the world in 2012 [3-5].

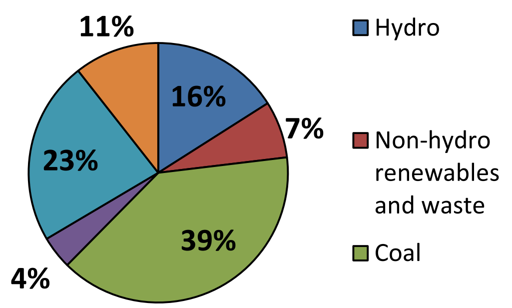

Figure 1.1: Total Primary Energy Supply (TPES) by fuel in 2018 [4].

Biomass is a very good source for deriving different kind of alternative fuels. Biomass is available in the form of agriculture residue, vegetable seeds, animal waste, crop residue, food waste, industrial waste, municipal waste etc [2]. Biomass is an organic matter and is renewable over time. There are two methods commonly adopted to derive alternative fuels from biomass sources which are; (i) Biochemical method (ii) Thermo-chemical method. In biochemical method, fermentation and anaerobic digestion are used to convert some of the biomass wastes into alcohol and biogas respectively. Biomass sources such as crop residue, cow dung, pig manure, spent wash etc. are converted into biogas through anaerobic digestion. If the biomass source is properly converted into an alternative fuel especially for diesel engine, then the demand for diesel fuel will be considerably reduced [3-5].

Fig. 2 Energy Scenario

Energy consumption is growing exponentially due to rapid progress in the population, industrialization and increase in number of automotive vehicle. Nowadays, the petroleum fuels play a vital role in the mobility, industrial sectors, and agricultural sectors. Meanwhile, the availability of petroleum resources is limited in nature, available in restricted area and they are getting depleted day by day [6-10 Furthermore, problems related to the environment are the most important consequences of consumption of more petroleum fuels. The issue of energy security and environment issues made countries and researchers to look for alternate means of renewable as well as environment-friendly fuels. The most promising and economically viable alternative fuels which can be a replacement of petroleum fuels are biofuels [11-13]. Various sectors are looking for alternative fuels because of the energy crisis and the fear of society for depleting earth's non-renewable resources. Among various researchers from all over the world started proposing various methods to use vegetable oils in internal combustion engines. These methods include pyrolysis, micro-emulsification, direct blending with diesel, transesterification. etc. [14-19].

Many investigations have been done on the utilization of biodiesel derived from different feed stock in diesel engine [20-22. From those work it can be pointed out that the selection of biodiesel is very important. The biodiesel derived from non-edible feed stock is always a better choice due to food security issue because use of edible oil as feed stock of biodiesel will affect this issue critically. The different non-edible feed stock used for production of biodiesel is Jatropha curcas, karanja, tobacco seed, rice bran, mahua, neem, rubber Plant, castor, linseed, and microalgae [23-24], etc. In this chapter application of biodiesel derived by Jatropha oil is described. The bio-diesel thus produced is blended with waste transformer oil at different volume proportions and tested in diesel engines.

II. Fuel Preparation

In the present study fuel was produced by transesterification process. In this process Jatropha oil reacts with alcohol in the presence of suitable catalyst. The process yields biodiesel. In this research work discarded transformer oil (DTO) was blended with Jatropha biodiesel to use in diesel engine. The designations of the test fuels and their compositions used in this study are given below.

Fuel	JME (by volume)	WTO (by volume)	Diesel (by volume)
diesel	-	-	100%
JME	100%	-	-
B10	90%	10%	-
B20	80%	20%	-
B30	70%	30%	-
B40	60%	40%	-

III. Engine Test

The test was carried out on a single cylinder, four stroke, naturally aspirated, air cooled, DI diesel engine which has a maximum power out of 4.4 kW. The test engine specifications are provided in Table 1.

Table 1 Engine specifications

Manufacturer	Kirloskar
Model	TAF 1
Engine type	Single cylinder, four stroke, constant speed, air cooled, direct injection, CI engine
Rated power (kW)	4.4
Speed (rpm)	1500 (constant)
Bore (mm)	87.5
Stroke (mm)	110
Piston type	Bowl-in-piston
Displacement volume (cm^3)	661
Compression ratio	17.5
Nozzle Opening pressure (bar)	200
Start of fuel injection	23 °CA bTDC (for diesel)
Start of fuel injection	24.5 °CA bTDC (for JMETPO20)
Dynamometer	Eddy current
Injection type	Pump-line-nozzle injection system
Nozzle type	Multi hole
No. of holes	3

IV. Results and Discussion

This section discusses the results of the performance and emission parameters obtained from the test engine run on diesel, JME and different JME-WTO blends.

4.1BTE

The brake thermal efficiency gives information regarding how efficient the energy in the fuel was converted in to power output [25]. Figure 1 discusses about the efficiency of present engine when different test fuels were used. At full load the diesel gave highest brake thermal efficiency compared to all the test fuels used in the present study. This can be pertained to the higher calorific value of the diesel fuel compared among all test fuel used. The poor atomization of test fuels due to the higher viscosity may also be one of the causes for lower brake thermal efficiency than that of diesel. Among blends B20 produces highest brake thermal efficiency.

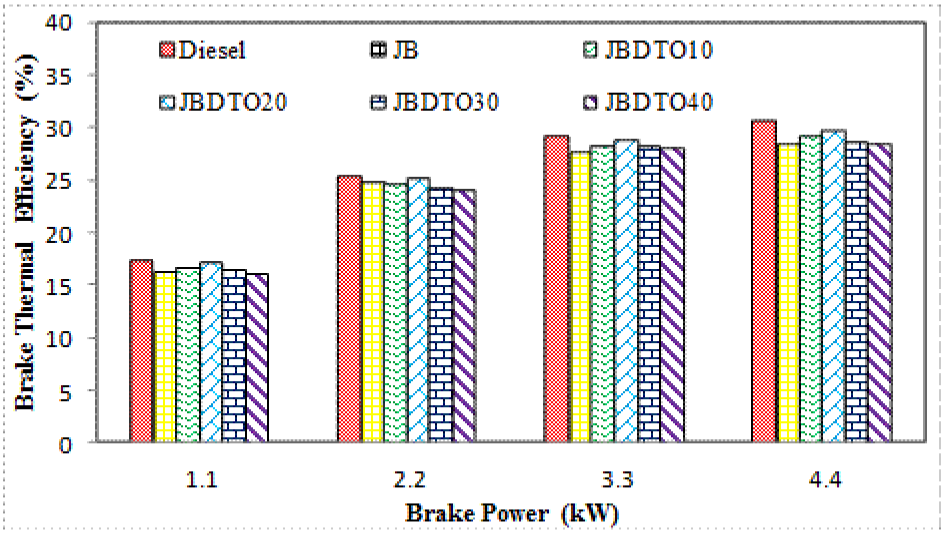

Fig.1 Variation of brake thermal efficiency with brake power

3.2 CO Emission

The trend for CO emission is shown in Fig. 2. The formation of CO occurs due to incomplete combustion of fuel. If sufficient amount of oxygen will not be available then CO emission will form. But availability of sufficient oxygen generates CO2 [26]. The value of CO emission at full load for the diesel, JME, B10, B10, B15 and B20 blend was found to be 0.044, 0.035, 0.037, 0.04, 0.046 and 0.052%. The CO emission for the JME, B10 and B20 is marginally lower than those of diesel fuel. The reason for this can be say due to oxygen of JB. This may be due presence of aromatic content which results in incomplete combustion, and may lead to higher CO emission [27].

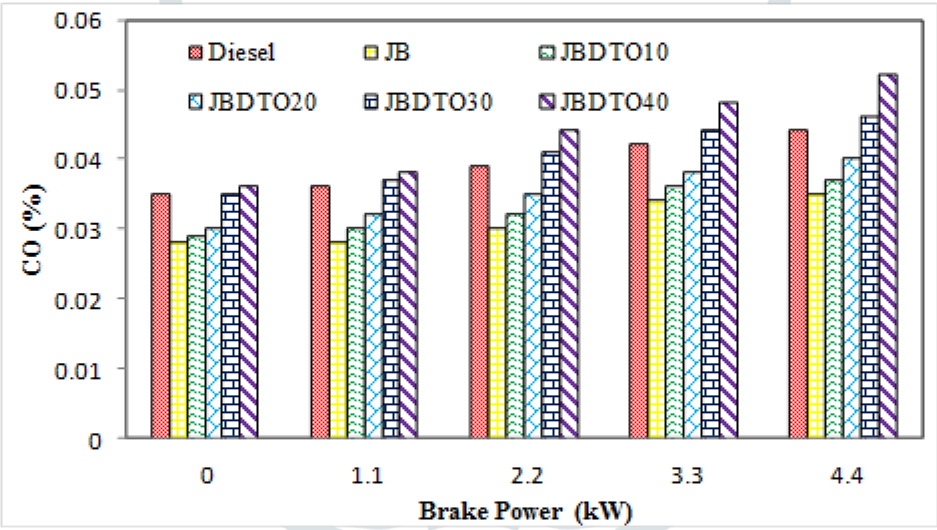

Fig.2 Variation of carbon monoxide emission with brake power

3.3 HC Emission

The variation of hydrocarbon (HC) emission for diesel, JME and different test fuel blends is shown in Fig. 3. It is observed that hydrocarbon emission increases with the increase in percentage of WTO in the JME-WTO blends. The HC emission is lowest for JME and it was about 18 ppm at full load operation. This can be due to oxygen molecule present in biodiesel [28]. The highest value of HC emission was obtained with B20 blend and was noticed to be 31 ppm. But the addition of the tire derived liquid percentage results in higher HC emission. This is due to the fact that WTO has higher aromatic content, and hence may result in incomplete combustion and more HC emission for B15 and B20 compared to the other test fuels used in this study. The HC values for diesel, JME, B10, B20, B30 and B40 are 23, 18, 19, 21,25 and 31 ppm are at full load.

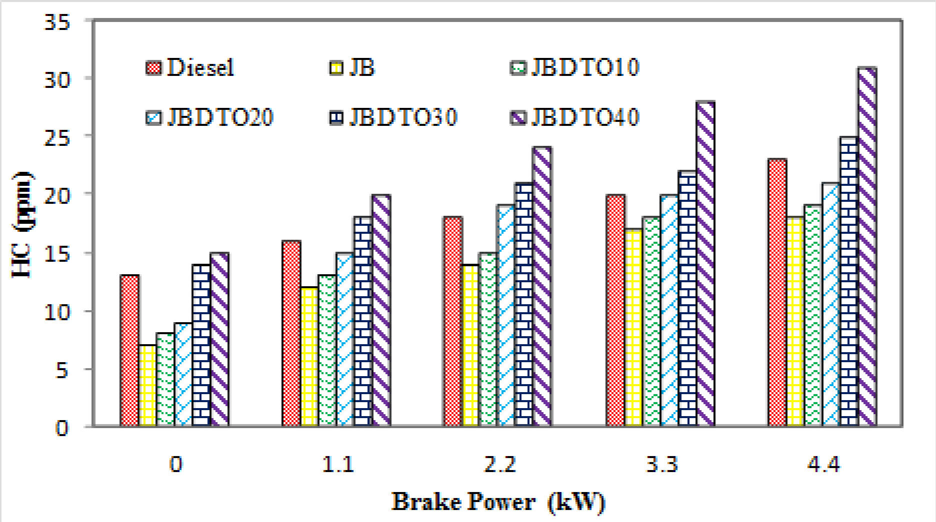

Fig.3 Variation of the unburnt hydrocarbon emission with brake power

3.4 No Emission

The results of nitric oxide (NO) emission foe fuels used in this study are presented in Fig.4. It can be seen that the NO emission concentration increased with the load for all the test fuels. It is observed that load increase results in higher NO emission [29-30]. The NO emission form engine exhaust is highly dependent on oxygen concentration and combustion temperature. The JME has about 11% oxygen molecule which is the major cause of higher NO emission for this fuel compared to all other test fuel used in this study. While increasing the WTO percentage in the blend, the NO emission decreases, because of lower heat release rates than that of JME. The values of NO emission for diesel, JME, B10, B20, B30, and B40 are by about 452, 614, 589, 564, 549, and 532 ppm respectively, at full load operation.

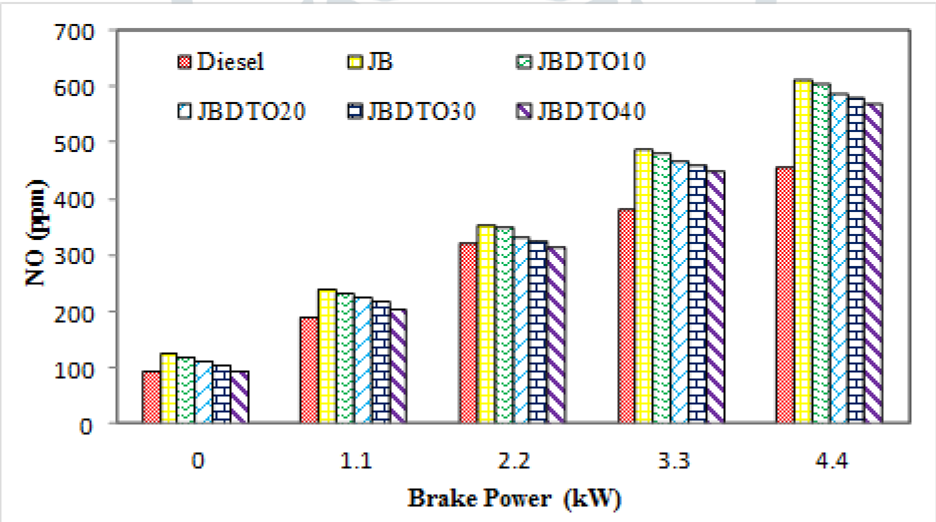

Fig.4 Variation of the nitric oxide emission with brake power

IV Conclusions

A single cylinder, diesel engine was operated successfully using JME-WTO blends. The following conclusions are made based on the experimental results.

- The BTE of the engine was highest for the diesel and among different blend B10 gave higher brake thermal efficiency. At full load, the BTE is almost the same, i.e., 29.9% and 30.8% for B20 and diesel respectively, at full load.
- The CO and HC emissions were lower by about 9%, 19% respectively for B20, compared to diesel at full load.
- Nitric oxide emission was higher by about 21% for B20 in comparison with diesel at full load.
- Overall we can say that B20 blend can be used in diesel engine.

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