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Performance analysis of direct injection diesel engine using tyre pyrolytic oil blends

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Abstract

Due to the increased industrialization and urbanization effects the demands of petroleum products have shown a sharp rise. But as these are non-renewable resources, many attempts have been made by researchers to find an alternate fuel. In this context pyrolysis of scrap tyres seems to be a viable option for production of Tyre Pyrolitic Oil [TPO] as a fuel in IC engines, thereby solving the problem of waste tyre disposal. In the present study, TPO blended with diesel under various proportions was tested in a single cylinder, four stroke, water cooled, direct injection engine to evaluate the performance and smoke parameters. Five TPO blends namely B30, B40, B50, B60 and B70 were obtained and tested as fuel in the engine. The performance and smoke parameters were analyzed and compared with those of diesel operations. The results of the investigation indicate that the brake thermal efficiency of the engine fueled with blends decreased marginally compared to that of diesel fuel. And the smoke emissions were found for the TPO blends in comparison with diesel fuel. The comparison results were inferred to suggest an optimum blend which was further subjected to speed variation test and varying injection pressure test to find out the optimum running condition. The results of the test carried out and performance curves plotted are presented in this paper. The investigations lead to a sustainable solution to our energy needs.

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Introduction

The steep increase in the demand of petroleum products due to the increasing industrialization and motorization of the world is indeed the root cause of the fossil fuel crisis prevailing across the globe. This fossil fuel reserves are limited in amount, also nonrenewable in nature. Growing economies like India, China etc. import about 80% of total demand of crude oil from OPEC nations as they occupy the major fossil fuel resources of the world. The global initiatives to find an alternate fuel for petrol and diesel opened the way for bio-fuel research (Habibullah *et al.*, 2014, Kale, 2014, Magín Lapuerta, 2015, Auti and Rathod, 2021). A lot of studies and researches happened over recent years and many excelled in deriving bio-fuels from vegetable oils, animal fats and algae.

Waste to energy is the recent trend in selection of bio-fuels where fuels are derived from suitable waste materials. Disposal of solid waste become a prime concern of modern world. Waste automobile tyres are one of the solid wastes that are disposed in large quantities every year throughout the world. About 1.4 billion new tyres are sold worldwide each year and subsequently just as many falls into the category of end-of-life tyres. On average, a brand-new car tyre weighs 11kg and 9kg when it is scrapped. Similarly, heavy tyres such as truck and bus tyres, weigh 54kg and 45kg respectively. These heavy quantities of waste tyres can be efficiently disposed using pyrolysis technique to obtain Tyre Pyrolytic Oil. In this pyrolysis process, long chain polymers are thermally broken down at high temperatures (300-900) into small molecules in the absence of oxygen. The recovered TPO a mixture of paraffin, olefins and aromatic compounds is a dark brown liquid. It has properties similar to that of diesel fuel (Glkılıc and Aydin, 2011).

Researchers have successfully used TPO and its blends to run CI engines. Researchers have also characterized the fuel to understand the constituents present in it. Plastic Pyrolytic Oil (PPO) and Tyre Pyrolytic Oil are the two bio-fuels used widely. Wonkhorsun and Chindaprasert, 2013 studied the performance of TPO and PPO on unmodified engine and found that PPO is less acceptable as a bio-fuel compared to TPO. Bhatt and Patel, 2012 have studied the suitability of TPO as a fuel to be used in IC engines. According to their research about 190 million tonnes of tyres are produced each year in India alone. They analyzed the properties of TPO and concluded that it can be used as a fuel for industrial furnaces and boilers in power plants due to their high calorific value, low ash and Sulphur content. But TPO has higher density, kinematic viscosity and lower cetane value compared to that of diesel. This limits its use as a fuel in IC engines. They proposed to use TPO blended with diesel fuel in various proportions by volume keeping the blend quality under permissible limits. One of the major problems of TPO is its Sulphur content. Before it can be used as a fuel the Sulphur content has to be minimized. Rok Vihar *et al.*, 2015 have conducted experiments on the combustion and emission characteristics of TPO on a six cylinder four stroke turbocharged 6.87 L MAN Diesel engine and concluded that TPO has combustion characteristic compared to that of diesel. They also found that TPO has higher levels of emission. They suggested that SO_2 emission can be reduced by removing Sulphur content from TPO. Cumali and Huseyin, 2011 reported different methods of desulphurization. They found that Pyrolysis done at 500°C yielded low Sulphur TPO. Their research revealed, treating TPO with CaO, $Ca(OH)_2$ derivatives, formic acid – H_2O_2 or acetic acid – H_2O_2 was effective for desulphurization of TPO. It is found that slow distillation of TPO was found effective in desulphurization of TPO.

Williams *et al*, 1998 studied the compounds present in TPO along with its combustion in a ceramic lined furnace. Their investigation revealed that TPO has PAH in high concentrations. They found high SO_2 and NO_X emissions. To avoid PAH, they proposed combustion under excess oxygen conditions. Sharma and Murugan, 2013 have created an oxygen rich environment by blending TPO with an oxygenated fuel i.e. Jatropha Methyl Ester. They reported NO_x and SO_2 emissions comparable to that of diesel when used in an IC engine. Murugan *et al.*, 2008 found that TPO when blended with diesel showed anomalous combustion and performance characteristics. They reported that TPO when blended with diesel in ratio of 30 - 40% by volume gives better combustion and performance than all other blends.

Improved efficiencies were obtained for various TPO-biodiesel blends on different IC engines. A study carried out by Mohammed Younus *et al.*, 2013 on an air cooled four stroke single cylinder engine found that TPO-Ethanol blends at different ratios gave better efficiency, less fuel consumption and less emission compared to diesel. Performance analysis of a four stroke diesel engine using jetropha methyl ester-TPO blend by Abishek shows efficiencies comparable to that of diesel. The JME-TPO blend gave high SFC and exhaust gas temperature, less emission compared to that of diesel (Abhishek Sharma and Bijay Dhakal, 2013).

Rajesh Abburi *et al.*, 2014 tested the viscosity of TPO and compared with diesel and found that TPO has higher viscosity than Diesel, a performance test is conducted on a single cylinder four stroke naturally aspirated water cooled engine and found that 20% TPO blended with diesel have high BTE and 30% TPO blended with diesel have higher mechanical efficiency. Emission analysis is also conducted on different blends T10, T20, T30 and found that biodiesel have less emission, but there is an increased rate of NO_x emission. Stefano Frigo *et al.*, 2014 tested TPO-Diesel fuel blend in single cylinder diesel engine and found that TPO upto 20% can be used in diesel engines along with diesel engine without any engine modification. Murugan *et al.*, 2008 in their research work tested that CI engines can run up to 90% distilled TPO blend, above which the engine fails becomes dysfunctional. They carried out distillation less than 200°C which the kerosene ranges. Findings of their research showed higher smoke, HC emissions but lower NO_x emissions compared to that of diesel when used to run a DI diesel engine. In addition, the engine output power and torque decreased while the brake specific fuel consumption increased with the increasing tyre derived fuel content in the diesel blends. Kiran Kumar *et al*, 2015 have conducted a load test on single cylinder DI diesel engine using 20% TPO blended with diesel and got performance characteristics similar to diesel. Murugan *et al.* 2008 carried out a study to evaluate the performance and emission characteristics of a single cylinder Direct Injection diesel engine fueled by 10, 30 and 50 percent blends of TPO with diesel fuel (DF). Results showed that the brake thermal efficiency of the engine fueled by TPO-DF blends decreased with increase in blend concentration and higher than Diesel. NO_x, HC, CO and smoke emissions were found to be higher at higher loads due to high aromatic content and longer ignition delay. Another study found that, as the percentage of the TPO increases in blend, the aromatic content and carbon/ hydrogen ratio also increases and this results in higher smoke with increasing TPO in the blends (Kennedy and Rathinaraj, 2007). Shahir *et al.*, 2020 have worked on TPO and diesel blends in different proportions by volume. Based on the investigations they observed that pyrolysis helps in dealing with disposal of generated waste tyres from end of life vehicles.

From the above literatures it is understood that TPO is a promising alternate fuel with less emission and diesel like CI engine characteristics. In recent years, there have been commercial tyre pyrolysis plants installed around the world, especially in countries such as China, India, Canada, France, Italy where tyre derived fuels are produced for industrial furnaces. With adequate research in potential use of TPO blends in CI engines these plants can be turned into alternate fuel suppliers (Sanjay Patil and Akarte, 2012). Only a limited number of studies have been previously performed to investigate the effect of TPO-Diesel blends on engine performance and emission as an alternative fuel for diesel engines. This paper discusses about the performance analysis of DI diesel engines using TPO and various blends with diesel and compares the results with standard diesel.

Researchers have explored the feasibility of using tyre pyrolytic oil (TPO) in engines. We need to identify the optimum parameters of getting the TPO and the methodology of using it in engines for having minimum emissions. But the identification of the best diesel TPO blends and need of using that best blend in an engine with varying the engine parameters like injection pressure and engine speed has been rarely explored by researchers. The present research focuses on these specific unexplored aspects related with the performance of alternate fuels in engines.

Thus the novelty in our research lies in the following aspects:
(1) Impact of tyre pyrolytic oil (TPO) obtained from the reactor at a specific distillate stream temperature (180^oC - 225^oC, reactor operating parameter) and making it suitable for using it in an engine by analysing the viscosity of the TPO blends at various temperatures and making it same as diesel, suitable for using it in diesel engines.

(2) Explore its impact on the performance parameters of the engine by varying the following parameters for identifying the best TPO blend with diesel. Initially the best blend needs to be identified by conducting the load test for diesel and with various blends. The performance parameters thus obtained are to be by compared with the readings obtained that of diesel.
Performance parameters- Brake thermal efficiency, brake specific fuel consumption, mechanical efficiency-(3 Nos)
Emission Parameters- Smoke density, Smoke opacity-(2 Nos)
Variation of Load- Percentage loads 0, 20, 40, 60, 80, 100 (5Nos)
Fuel types used/Blending with diesel -Pure diesel, Blends- B30, B40, B50, B60 and B70-(6Nos)

(3) The best blend identified need to be tested for following injection pressures and speeds up to the full load condition
Variation of Fuel Injection pressure- 220, 240, and 260bar (3 Nos)
Variation of Engine speed- 1450rpm, 1800rpm, 2100rpm (3 Nos)
The best TPO diesel blend with best performance /operating parameters for an engine at its best injection pressure and operating speed can be identified which will give minimum emissions. Thus the aim of this research is to identify the best fuel for a diesel engine and its best operating conditions for sustainable development.

Materials and methods

Pyrolysis Process

For the present investigation TPO was collected from a commercial Pyrolysis plant. The schematic illustration of plant is given in Fig.1. Pyrolysis is the thermo-chemical decomposition of organic material at elevated temperature in the absence of oxygen. The waste tyres are fed into the 8 Tonnes capacity rotating retort; where it is heated upto 450^oC in the absence of air. This anaerobic thermal digestion of rubber leads to break down of hydrocarbon bonds in rubber leading formation of vapours with new hydrocarbon structures. This group of vapours has condensable and non-condensable components. They are lead to a condenser where the condensable components form liquids and non-condensable part remains as gases. Condensed liquids are combustible and are stored separately. It is called Tyre Pyrolitic Oil.

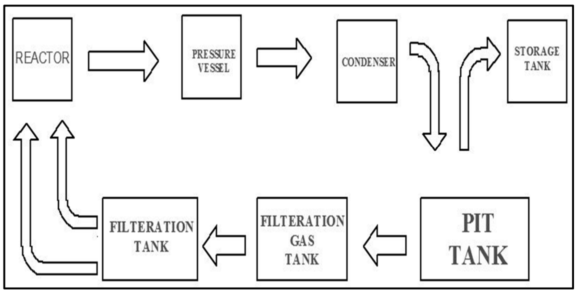

Fig. 1. Layout of Tyre Pyrolytic Plant.

The gases, mainly consisting of methane, hydrogen and carbon monoxide with traces of propane and ethane are lead to a temporary storage balloon from where they are ploughed back to the retort for heating the feed stock. The TPO thus obtained after this process subjected to fractional distillation and various cuts are taken based on boiling point. Layout of Distillation unit is shown in Fig. 2. For the present investigation we have collected TPO sample of distillate stream 180^oC - 225^oC. The properties of the fuel are listed in Table 1.

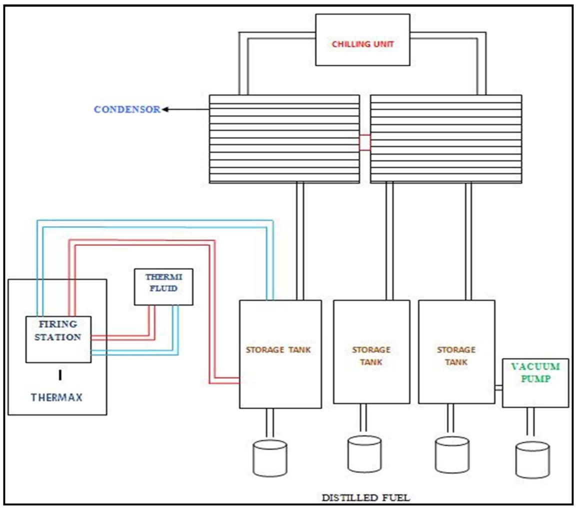

Fig. 2. Layout of Distillation Unit.

Table 1. Properties of TPO sample.

SL	Parameters	Results
1	Density	0.8245 gm/cc
2	Viscosity @ 30° C	4.1 cSt
3	Viscosity @ 80°C	2.246 cSt
4	Gross Calorific Value	10577 kcal/kg
5	Flash Point	< 37°C
6	Sulphur as S	0.08%
7	Ash Content	0.01%
8	Copper strip Corrosion	1
9	Water Content	0.04%
10	Specific Gravity	0.84

Comparison of Fuel Properties

Table 2 gives the comparison of the physical properties of Diesel and TPO blends at 30°C. Viscosity and density values are obtained using Redwood Viscometer no 2 and Digital weighing machine. Calorific Values are obtained using Bomb Calorimeter. The sample B60 denotes 60% of TPO blended with 40% of diesel.

Table 2. Physical properties of Diesel and TPO blends.

Properties	Diesel	B30	B40	B50	B60	B70
Viscosity (cSt)	2.24	2.46	2.77	2.816	3.03	3.19
Density (g/cc)	0.82	0.82	0.82	0.82	0.82	0.84
Calorific value (kJ/kg)	44100	44151.96	44169.28	44186.6	44203.92	44221.24

By analyzing the above properties the TPO blends B40, B50, B60 and B70 needs to be preheated before introducing into the engine in order to make their viscosity comparable with that of diesel. Among different blends P1B30 and P1B40 do not require preheating. But samples P1B60 and P1B50 must be preheated to temperature range of 40°C-50°C to obtain viscosity values similar to that of diesel. Whereas the sample P1B70 needs to be heated a range of 60°C-70°C. Thus preheating of blends has an important role in the engine performance.

Experimental Setup

Experiments have been conducted in a single cylinder, four stroke, water cooled, Direct Injection, diesel engine, with a developing power of 11.03 kW at 2200 rpm. Fig. 3 shows the schematic diagram of the experimental set up, and Table 3 gives the technical specifications of the engine used in this study.

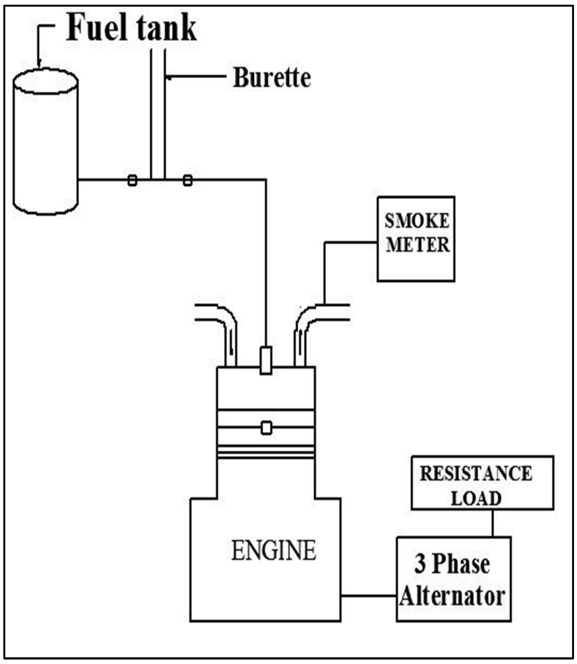

Fig. 3. Experimental Setup.

Experiments were initially started with diesel and after the engine's warm up condition, it was switched over to different Diesel-TPO blends. For conducting load test a constant speed of 2200 rpm was maintained and fuel consumption and brake power were recorded for different loading conditions for pure diesel fuel followed by TPO blends. A burette was used for measuring the total fuel consumption.

An AVL 437C smoke meter was used to measure the smoke emission.

Table 3. Engine Test Rig Specification.

Engine model	CZS1100N
Type	Single cylinder, four stroke, Horizontal type, Direct injection
Rated Power	11.03 kW
Rated Speed	2200 rpm
Cylinder bore × Piston Stroke	100 × 115
Piston Displacement	0.903
Compression Ratio	17.5
Specific Fuel Consumption	246.2 g/h kW
Advance Angle of Fuel delivery	20 ± 1°
Valve Clearance	Intake Valve :0.35 ± 0.05mm Exhaust Valve:0.45 ± 0.05mm
Overall dimension	864 × 411 × 639mm
Net Weight	155kg
Smoke meter	AVL 437C
Alternator	3ϕ , 15 kVA @ 1500 rpm
Injector	Hole-Type Nozzle

Load test was carried out with each sample of diesel – TPO blends in different proportions such as B30, B40, B50, B60 and B70. Before introducing the samples directly into the engine they are subjected to preheating using a heating apparatus. A resistance loading system was employed to load the engine, powered by a 3-phase Alternator (15kVA, 1500rpm), connected to the engine by means of a V-belt drive. The pulleys are designed in such a way that the alternator will run at its rated speed when the engine attains its rated speed. For each load, the engine was run to reach the steady state of test condition before collecting data. Once the experiment was complete, then the test fuel was drained, from the fuel line. The engine was further run with diesel to remove the strains of TPO blend. After this the engine was tested with the next blend. By analyzing the test results an optimum blend was selected and it was subjected to further tests by varying the injection pressure and engine speed.

Results and Discussions

Performance Parameters

The performance parameters, of the engine such as brake thermal efficiency, brake specific fuel consumption (BSFC), mechanical efficiency and smoke opacity, smoke density of the TPO blends are compared with those of diesel and discussed below.

Load Test

Load test is conducted by measuring the various performance parameters of the engine by varying the percentage load from 0, 20,40,60,80 and 100 corresponding to each type of fuel like Pure Diesel, Diesel TPO Blends- B30, B40, B50, B60 and B70. Corresponding load is applied on the engine and the engine is allowed to run at its rated speed and after stabilizing, the time taken for the fuel consumption for a specific quantity, smoke opacity, smoke density are noted. The test is repeated for different loads and the results are tabulated. These results are utilised for calculating the various performance parameters like, Brake thermal efficiency (BTE), Brake specific fuel consumption (BSFC), Mechanical Efficiency.

Brake Thermal Efficiency (BTE)

Fig. 4 portrays the variation of the brake thermal efficiency with brake power for diesel and TPO blends.

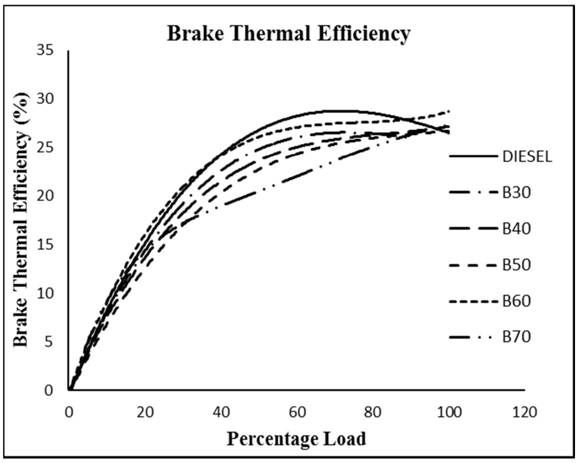

Fig. 4. Variation of brake thermal efficiency with Brake Power.

The brake thermal efficiency of the engine increases with an increase in the brake power for diesel and the TPO blends, as expected. The brake thermal efficiency for diesel at full load is 27.07%. The brake thermal efficiencies for B30, B40, B50, B60 and B70 are 26.06%, 26.79%, 27.59%, 28.34%, and 27.81% respectively, at full load. It was found that the brake thermal efficiency of B60 was 28.34% which is higher than other blends. B30 have the least BTE with 26.06%. It is seen that the brake thermal efficiency increases with the percentage load. It may be due to the reason that as engine load increases power also increases due to the reduction in heat losses. The atomization may be poor due to higher viscosity, this also reduces fuel vaporization. As the TPO blends are having slightly higher viscosity compared to diesel the brake thermal efficiency (BTE) may decrease due to this reason.

At part loads, BTE is less than that at full load condition. At higher partial load, fuel droplets get enough time to complete the combustion process resulting in complete conversion of chemical energy of fuel to mechanical energy, leading to higher efficiency. As load increases further fuel injection rate has to increase so as to supply the required amount of energy which reduces the time of combustion for fuel droplets. So complete conversion of chemical energy to mechanical energy do not taking place, leading to lower efficiency.

Brake Specific Fuel Consumption (BSFC)

Fig. 5 portrays the variation of the brake specific fuel consumption with brake power for diesel and TPO blends.

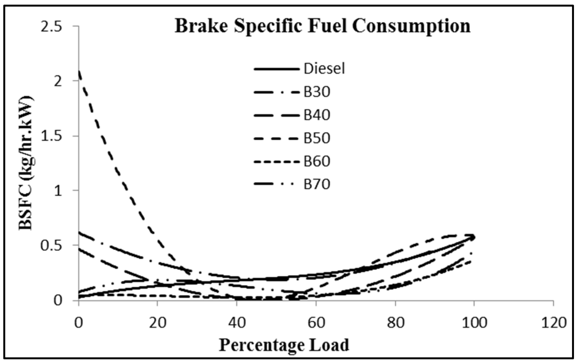

Fig. 5. Variation of BSFC with Brake Power.

The BSFC for diesel is 0.301kg/hrkW at full load condition. The values of BSFC for B30, B40, B50, B60 and B70 are found to be 0.313, 0.304, 0.295, 0.287 and 0.293kg/hrkW respectively at full load. By analyzing the above graphical data, minimum value of BSFC is observed for B60 blend. At high speed, BSFC increases due to increase in friction losses.

The mass of fuel consumption is larger especially during the cold/initial starting condition, but as the engine becomes warmer this trend gradually decreases. This may be due to the larger heat loss due to the lower engine coolant temperature and lower engine lubricating oil temperature which normally leading to increase in frictional losses. The fuel consumption depends on fuel specific gravity, viscosity and calorific value: biodiesel presents a higher specific gravity and a lower heating value than diesel and more amount of fuel is needed to produce the same amount of energy. This reveals that the engine temperature and driving conditions may be affecting the fuel efficiency.

Mechanical Efficiency

Fig. 6 portrays the variation of the mechanical efficiency with brake power for diesel and TPO blends. The reason for increase in mechanical efficiency may be due to the reason that as load increases there may be reduction in frictional losses and heat losses.

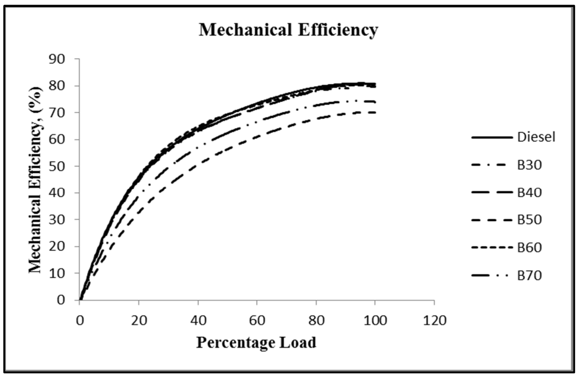

Fig. 6. Variation of mechanical efficiency with Brake Power.

Mechanical efficiency measures the effectiveness of a machine in transforming the energy and power that is input to the device into an output force and movement. As the load increases the mechanical efficiency also shows a gradual increase. By analyzing the graph, maximum value is obtained for B60 (79.42%) which is comparable with diesel (80.89%) fuel.

Smoke Density

Smoke density also known as absorption coefficient is a fundamental means of quantifying the ability of a smoke containing gas sample to obscure light. By convention, smoke density is expressed on a per metre basis (m^{-1}). The smoke density is a function of the number of smoke particles per unit gas volume, the size distribution of the smoke particles, and the light absorption and scattering properties of the particles.

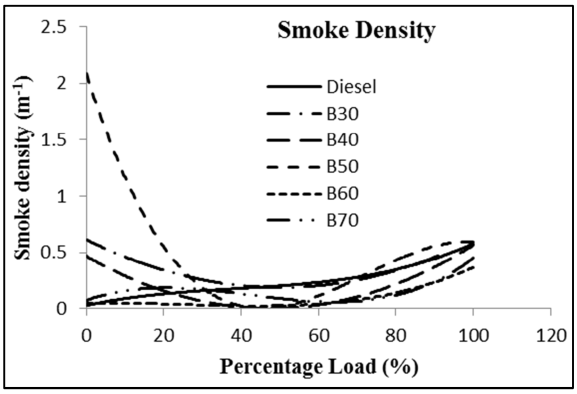

Fig. 7. Variation of smoke density with Brake power.

Fig. 7 shows the variation of smoke density with brake power for the different tested blends. Smoke density for diesel at full load is $0.59m^{-1}$. At full load the smoke density values are $0.45m^{-1}$, $0.53m^{-1}$, $0.66m^{-1}$, $0.36m^{-1}$ and $0.44m^{-1}$ for B30, B40, B50, B60 and B70 respectively. The reduction in smoke on increasing blend concentration is due to the oxygen rich nature of TPO.

Smoke Opacity

The percentage (%) of light transmitted from a source which is prevented from reaching a light detector.

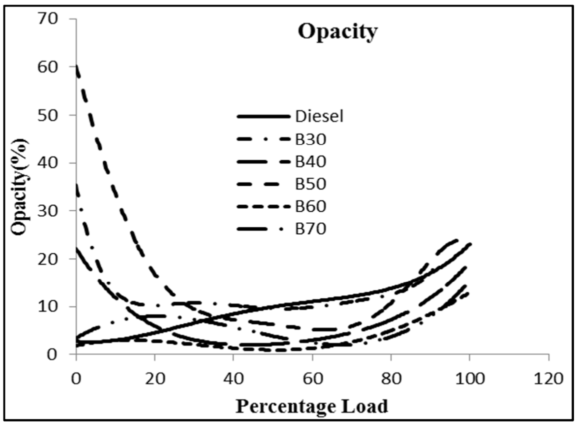

Fig. 8. Variation of smoke opacity with Brake power.

Fig. 8 shows the variation in the smoke opacity with brake power for the different tested blends. Smoke opacity increases with an increase in the brake power for all the tested blends. Smoke opacity for diesel at full load is 22.5%. At full load the smoke opacity values are 18%, 17.6%, 23.4%, 12.9% and 14.9% for B30, B40, B50, B60 and B70 respectively.

The factors affecting smoke opacity or soot formation are the type and nature of the fuel and the air fuel ratio. If sufficient quantity of oxygen is available either in air or in fuel it utilizes it and burns completely and reduces the percentage of smoke opacity. But it it does not happens the soot will normally accumulate and flow through the exhaust pipe. This will be visible as black smoke in the tail pipe. The size of the particulate matter affects the density and thus the visual appearance of the smoke. The factors affecting the black smoke are air fuel ratio, combustion efficiency, atomization of fuel, injector pressure, viscosity of the fuel etc.

It can be observed from the Fig. 8 that smoke opacity for the blends of TPO is comparable with that of diesel for all the loads. In comparison with diesel, the smoke is less for TPO blends at full load because of complete combustion. Load on the engine is also another major factor, in determining smoke opacity, as load increases; the smoke opacity initially decreases as the combustion efficiency increases. But when the engine is overloaded it may increase due to the large variation of air fuel ratio and incomplete combustion. Higher viscosity, lower volatility and poor atomization of the fuel also leads to greater smoke opacity during higher loads.

Speed Variation Test

For obtaining these characteristics, the optimum blend B60 was introduced into the engine, and for each loads added the engine was made to run at different speeds ranging from 1450 rpm to 2100 rpm, upto the full load condition. The observations were tabulated and results were plotted.

Fig. 9 shows the results of the speed variation test conducted at various loads. From the above results, we can say that at lower loads BSFC will be maximum and

BTE values will be minimum. But at higher loads BSFC will be minimum and BTE values will be maximum.

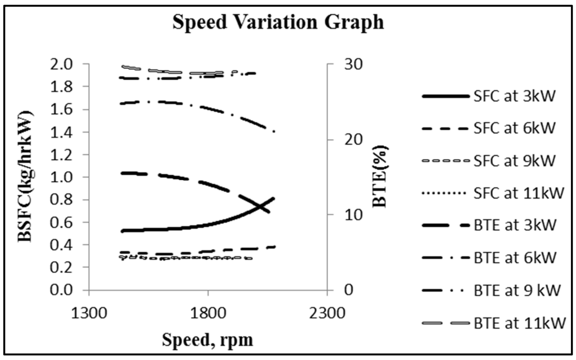

Fig. 9. Variation of BTE and SFC with speed at various loads.

At 3 kW load, the optimum speed range obtained is 1440 rpm to 1500 rpm with SFC varies between 0.5 to 0.6kg/hr kW and BTE varies between 15 to 16%. At 6 kW load, the optimum speed range obtained is between 1580 rpm to 1620 rpm with SFC varies between 0.3 to 0.35kg/hr kW and BTE varies between 22 to 27%. At 9 kW load, the optimum speed range obtained is 1580 rpm to 1620 rpm with SFC varies between 0.25 to 0.3kg/hr kW and BTE varies between 25 to 30%. At 11 kW load, the optimum speed range obtained is 1420 rpm to 1570 rpm with SFC varies between 0.25 to 0.3kg/hr kW and BTE varies between 27 to 29%.

At lower speeds, BSFC will be low and BTE will be maximum. As the speed increases BSFC increases, which reduces the time for combustion and hence the BTE decreases. During full load condition, when the speeds are varied, BSFC values and BTE values does not exhibit a prominent variation. Optimum BSFC may be obtained when the engine is having air fuel ratio reaching its stoichiometric value and the economic speed of the engine can also be identified at a specific load.

Varying Injection Pressure Test

Viscosity of TPO is more than that of diesel at 30°C. Injection of higher viscous fuel results in to larger droplets resulting in poor atomization. As fuel injection pressure is increased, the atomization of the fuel may be better as the size of the fuel particles will come down drastically leading to better combustion. But as it happens the combustion efficiency may increase leading to increase in temperature of exhaust gases. This may also lead to the increase in oxides of nitrogen in the exhaust.

For obtaining these characteristics, the optimum blend B60 was introduced into the engine and tests were carried out for 3 sets of injection pressures (220, 240, and 260bar). For each injection pressure, the engine was made to run from no load to full load conditions and the results obtained were tabulated and curves were plotted as follows (Fig 10, 11)

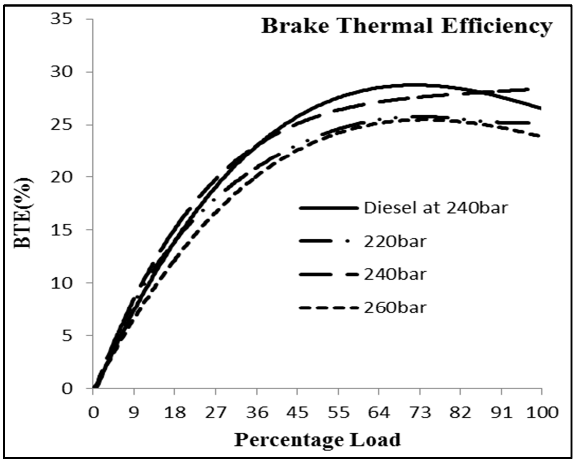

Fig. 10. Variation of brake thermal efficiency for variable injection pressure.

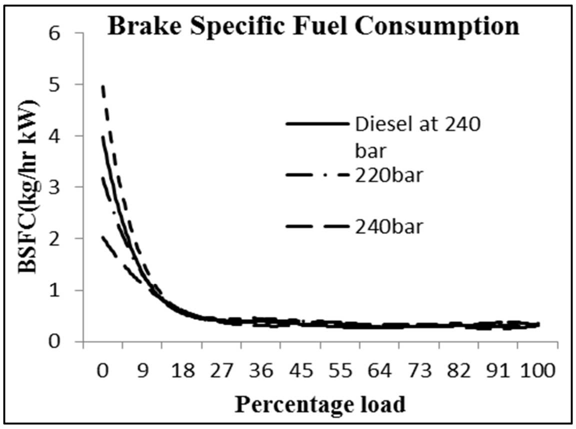

Fig. 11. Variation of Brake Specific Fuel Consumption for variable injection pressure.

The nozzle opening pressure was set by adjusting the spring of the injector. By analyzing the test results, the brake thermal efficiency of the engine with injection pressures 220 bar and 240 bar seems comparable with each other and the maximum is at pressure 240 bar. The brake thermal efficiency of the engine at injection pressure 220 bar and 240 bar at full load conditions are 25.78% and 28.34% respectively. The value of brake specific fuel consumption at injection pressure 240 bar is 0.287kg/hr kW which is the minimum, when compared to other two pressures (220 bar & 260 bar).

The optimum value of brake thermal efficiency (BTE) is obtained for an injector pressure of 240 Bar for the best TPO blend. As the injector pressure is increased there is a reduction in BTE. The factors like lower momentum of fuel droplets through the combustion chamber may be leading to the reduction the BTE.

Conclusion

In the present investigation experiments were conducted in a single cylinder four stroke water cooled Direct Injection diesel engine with B30, B40, B50, B60 and B70. The conclusions of the investigation are summarized as the engine works smoothly with the TPO blends and exhibits similar performance compared to that of diesel. Load test was conducted for the various TPO blends and it was found that B60 blend gives the optimal result for major performance parameters compared to the other TPO blends.

The optimum blend B60 has characterized by the lower BSFC and comparable brake thermal efficiency that of the diesel and other blends. The BSFC for diesel is 0.301kg/hrkW and for B60 is 0.287kg/hrkW at full load condition which is 4.65% lower than diesel. The brake thermal efficiency of B60 blend (28.34%) is comparable with diesel (31.25%) at full load conditions. The optimum blend is then subjected to variable speed test and variable injection pressure test. By analyzing the speed variation test we have obtained economic operating speed of engine for different loads. Varying injection pressure test shows that the pressure 220 bar and 240 bar having comparable efficiency, but the BSFC is lower at 240 bar. Hence by analyzing the results suggested that 240 bar is the optimum injection pressure.

The optimum blend B60 also exhibit the lower smoke density value compared to diesel and other TPO blends. By examining the results smoke density is lowered by 38.9% for B60 as compared to diesel fuel at full load condition. Smoke opacity is also lowered by about 42.66% for B60, compared to diesel at full load condition. The added advantage of promoting the optimum blend B60 as an automotive fuel is that while producing one kilowatt of brake power in one hour, 2.79% of diesel can be saved. Hence the research identified the best TPO blend and how effectively it may be used in and diesel engine by modifying the injector pressure and engine speed so as to optimize the engine performance and reduce the emission.

Abbreviations

PPO- Plastic Pyrolytic Oil

PAH- Polycyclic Aromatic Hydrocarbon

BTE- Brake Thermal Efficiency

BSFC-Brake Specific Fuel Consumption

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