Experimental Investigations on Diesel Engine Fueled with Tyre Pyrolysis Oil and Diesel Blends

Rajesh.Abburi
Dept.of Mech. Engineering
BVC Engineering College
Odalarevu, A.P, India

B. Srinivas
Dept. of Mech. Engineering
BVC Engineering College
Odalarevu, A.P, India

K. Srinivasa Rao
Dept. of Mech. Engineering
Sai Spurthi Inst. of Tech.
Sathupally, A.P, India

Abstract

The prices of conventional fuels are increasing day by day due to technological constraints, gap in the demand and supply and scarcity of conventional fuels. Environmental pollution is also increasing by the usage of crude oils and hence there is a need for exploration of alternative fuel sources for automobile applications. Bio-diesel is a renewable fuel which is derived chemically by reacting with the sources of bio diesel. In the present investigation the alternative fuel used is the tyre pyrolysis oil, which was obtained by the pyrolysis of the waste automobile tyres. In the initial stage the tests are conducted on the computerized 4-stroke single cylinder water cooled DI-CI diesel engine by using diesel and base line data is generated. Further in the second stage experimental investigations are carried out on the same engine with same operating parameters by using the tyre pyrolysis oil blended with diesel in different proportions such as T10, T20 and T30 to find out the performance parameters and emissions. Among the three blends T20 has shown better performance in terms of engine performance and emission control, there by T20 is taken as the optimum blend. Finally the performance and emission parameters obtained by the above test are compared with the base line data obtained earlier by using diesel.

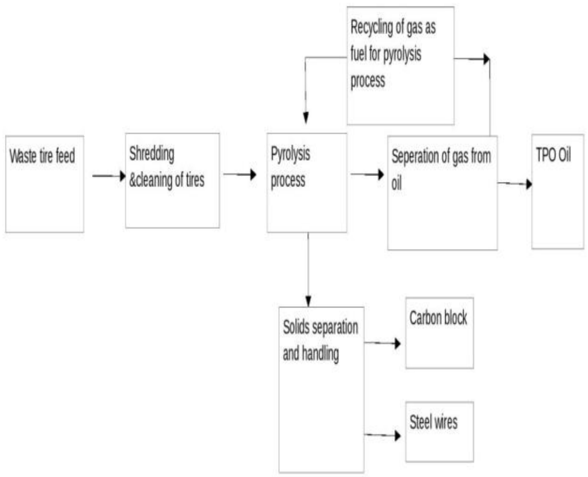
Keywords
Diesel-Biodiesel blends, tyre Pyrolysis process, performance and Emissions.

1.Introduction

Conventional fuels include: fossil fuels (petroleum, coal, propane and natural gas), nuclear isotopes such as uranium, thorium as well as artificial radio-isotopes that are produced in nuclear reactors, and store their Energy. Some well-known alternative fuels include: biodiesel, bio-alcohol (methanol, ethanol and butanol), chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas and other biomass sources. However, biodiesel is considered to be biodegradable, hence it is considered to be very less harmful to the environment, if spilled.

Biodiesel is an alternative fuel for diesel. In United States, every year around 280 million tyres in waste form are being dumped in the landfills, hence these tyres are used to produce pyrolysis oil to use them in a useful way. Not only in United States, all over the world there is an increase in waste tyres, so scrap tyres are used to produce tyre pyrolysis oil and is used as a blend in diesel oil, which increases the efficiency of the engine. The test fuel is characterized based on the density, viscosity, boiling point, calorific value, sulphur content, flash point, carbon residue, ash and water content. The thermo-physical and chemical characteristics are also evaluated for raw oil and refined oil before and after distillation. The fuel is then blended with diesel and used in an internal combustion engine. Blends of 10%, 20%, and 30% by volume are investigated. This performance data is collected for steady state operation at different load conditions. It has been found from the performance that the usage of oil as blends with diesel in direct injection CI engines has shown similar performance and reduced emission as that of same CI engine operated in pure diesel. It is believed that significant improvement in the economics can be accomplished by upgrading the primary pyrolysis products, like the tyre oil. Pyrolysis is the process of conversion of one substance into another by means of heat or with the aid of catalyst, caused by the application of thermal energy in the absence of air or oxygen. The pyrolyzate had lower viscosity, flash point and pour point than diesel fuel and equivalent calorific values.

PREPARATION OF TYRE PYROLYSIS OIL



Initially an automobile tyre is cut into a number of pieces and the bead, steel wires and fabrics are removed. Thick rubber at the periphery of the tyre is alone made into small chips. The tyre chips are washed, dried and fed into a mild steel pyrolysis reactor unit. The pyrolysis reactor used is a full insulated cylindrical chamber of inner diameter 110 mm and outer diameter 115 mm and height 300 mm. Vacuum is created in the pyrolysis reactor and then externally heated by means of 1.5 kW heaters. The process is carried out between 450°C and 650°C in the reactor for 2 hours and 30 minutes. The products of pyrolysis in the form of vapour are sent to a water cooled condenser and the condensed liquid is collected as a fuel. The non condensable gases were let out to atmosphere. The TPO collected is crude in nature. For an output of 1 kg of TPO about 2.09 kg of waste tyres feedstock is required. The product yields from the process are Tyre Pyrolysis Oil (50 %), Pyro gas (40 %) and char (l0 %). The heat energy required to convert the waste tyres into the products is around 7.8 MJ/kg. The residence time of the pyrolysis process was 90 minutes. TPO was filtered by fabric filter and again filtered by micron filter to remove impurities, dust, low and high volatile fractions of hydrocarbons.

Table 1. Properties of Tyre Pyrolysis Oil

S.No	Oil	Kinematic Viscosity(centi strokes)	Dynamic viscosity(centi poise)
1	Diesel	0.328	0.278
2	Tyre pyrolysis oil	2.297	2.16

2. Experimental set up and procedure

The performance tests are carried out on a single cylinder, four stroke naturally aspirated, and water-cooled kirloskar computerized diesel engine test rig. Diesel engine is directly coupled to an eddy current dynamometer. The engine and dynamometer are interfaced to a control panel, which is connected to a computer. This computerized test rig is used for recording the test parameters such as fuel flow rate, temperature, air flow rate, and load for calculating the engine performance such as mean effective pressure, power, brake specific fuel consumption, brake thermal efficiency, and emissions like HC, CO, NOx and smoke. The exhaust gas temperature, inlet and outlet water temperatures are measured through the data acquisition system and are fed to the computer. The exhaust gas is made to pass through the probe of Crypton computerized exhaust gas analyzer for the measurement of HC, CO, NOx and later passed through the probe of smoke meter of Bosch type for the measurement of smoke opacity. The whole set of experiments are conducted at the engine speed of 1500 rpm and compression ratio of 16.5:1. After setting the engine speed and load to required values the following observations and subsequent calculations are made.

Fig. Diesel Engine Test Rig.

Table 2. Specifications of the Test Engine

Specifications of the Test Engine	
Particulars	**Specifications**
Make	Kirloskar
Rated Power	3.7 kw
Bore	80 mm
Stroke Length	110 mm
Swept volume	562 cc
Compression ratio	16.5:1

2.2 Test Fuels

For experimental investigations, biodiesel derived from tyre pyrolysis oil is mixed with diesel in varying proportions 10%, 20% and 30% by volume respectively to all the blends.

3. Results and Discussion

3.1. Performance analysis

The experiments are conducted on the four stroke single cylinder water cooled diesel engine at constant speed (1500 rpm) with varying loads. Various performance parameters such as brake thermal efficiency, mechanical efficiency, indicated thermal efficiency, volumetric efficiency, brake specific fuel consumption and indicated specific fuel consumption are evaluated and discussed below.

3.1.1 Brake Thermal Efficiency

The variation of brake thermal efficiency with brake power is shown in Fig. 3.1.1. From the plot it is observed that the load increases brake thermal efficiency is increases. This was due to reduction in heat loss, increase in power with increase in load and effective combustion due to the fine spray formed in the combustion. At full load condition the brake thermal efficiencies obtained are 32.82%, 32.23%, 32.97% and 31.34% for the fuels of diesel, T10, T20 and T30 respectively. Among the three blends of tyre oil the maximum BTE is 32.97% which is obtained for T20. Hence this blend was selected as optimum blend for future investigations.

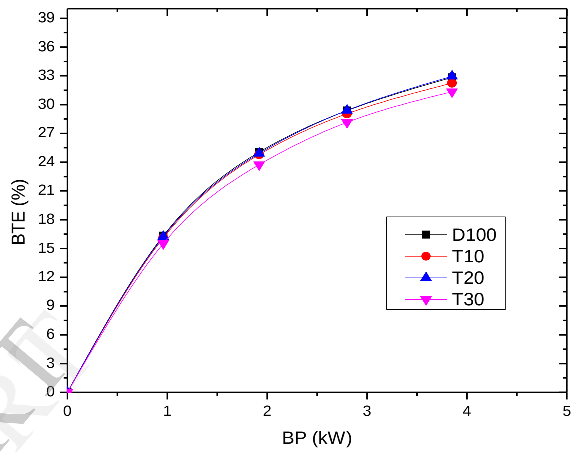


Fig.3.1.1.Brake Power versus BTE

3.1.2 Mechanical Efficiency

The variation of mechanical efficiency with brake power is shown in Fig. 3.1.2. From the plot it is observed as load increases mechanical efficiency is also increases because of tyre oil is lowest frictional powers compared to diesel. At full load condition the mechanical efficiencies obtained are 63.11%, 61.04%, 63.11% and 64.16% for the fuels: diesel, T10, T20 and T30 respectively. Among the three blends of tyre oil the maximum mechanical efficiency is 64.16% which is obtained for T30. Hence this blend was selected as optimum blend for future investigations.

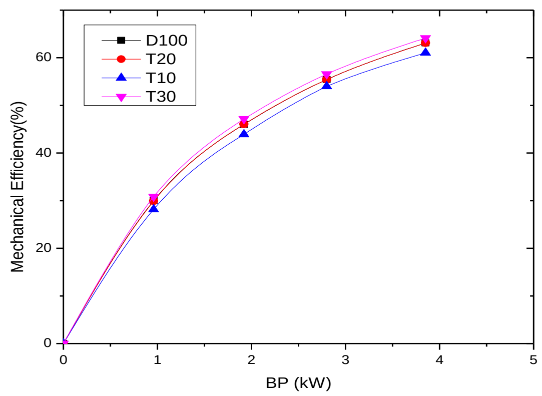


Fig.3.1.2 Brake Power versus Mechanical Efficiency

3.1.3 Volumetric Efficiency

The variation of volumetric efficiency with brake power is shown in Fig.3.1.3. From the plot it is observed as load increases volumetric efficiency is decreases. The decrement in the volumetric efficiency is due to the decrease in the amount of intake air due to high temperature in the cylinder. At full load condition the volumetric efficiencies obtained are 80.87%, 79.38%, 80.88% and 78.97% for the fuel of diesel, T10, T20 and T30 respectively. Among the three blends of tyre oil decrease in volumetric efficiency is 78.97% which is obtained for T30. Hence this blend was selected as optimum blend for future investigations.

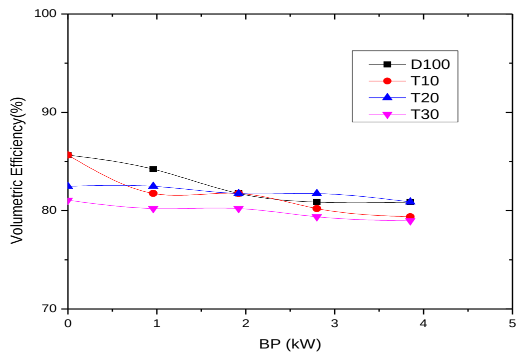


Fig.3.1.3 Brake Power versus Volumetric Efficiency

3.1.4 Brake Specific Fuel Consumption

The variation of brake specific fuel consumption with brake power is shown in Fig. 3.1.4. The plot reveals that as the load increases the fuel consumption decreases. At full load condition the BSFC obtained are 0.26 kg/kW-hr, 0.262 kg/kW-hr, 0.256 kg/kW-hr and 0.269 kg/kW-hr for fuels of diesel, T10, T20 and T30 respectively. The minimum fuel consumption is for T20 which is 0.256 kg/kW-hr as compared to that of diesel which is 0.26 kg/kW-hr. The BSFC of tyre oil blend T20 is decreases up to 1.53% as compared with diesel at full load condition. The tyre oil blends shows minimum BSFC than diesel as the tyre oil's calorific value is high as compared to diesel fuel.

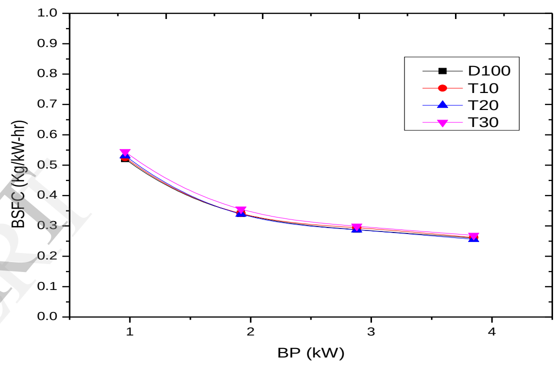


Fig.3.1.4. Brake Power versus BSFC

3.1.5 Indicated Specific Fuel Consumption

The variation of indicated specific fuel consumption with brake power is shown in Fig. 3.1.5. From the plot it is observed that the indicated specific fuel consumption is slightly higher than the diesel for the blends of tyre pyrolysis oil. This improvement in ISFC was perhaps due to better combustion of the fuel, which may be attributed to the presence of oxygen in the blend. At full load condition the ISFC obtained are 0.163 kg/kW-hr, 0.160 kg/kW-hr, 0.161 kg/kW-hr and 0.173 kg/kW-hr for the diesel, T10, T20 and T30. Among the three blends of tyre oil increase in ISFC is

0.173 kg/kW-hr which is obtained for T30. Hence this blend was selected as optimum blend for future investigations.

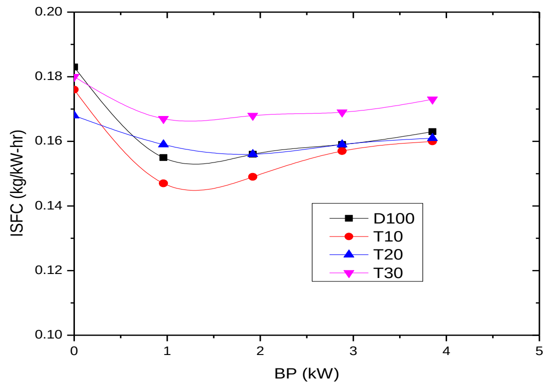


Fig.3.1.5 Brake Power versus ISFC

3.2. Emission analysis

The experiments are conducted on the four stroke single cylinder water cooled diesel engine at constant speed (1500 rpm) with varying loads. Various emission parameters like smoke density, unburned hydrocarbons, carbon monoxide, carbon dioxide and nitrogen are discussed below.

3.2.1 Smoke Density

The Smoke is nothing but solid soot particles suspended in exhaust gas. Fig.3.2.1. shows the variation of smoke level with brake power at various loads for different blends like T10, T20 and T30. At full load condition the smoke density obtained are 79.6 HSU, 82.55 HSU, 76.72 HSU and 75.59 HSU for the fuels of diesel, T10, T20 and T30. It is observed that smoke density is decreases for tyre oil blends at full load conditions as compared to diesel except T10 blend. The reason for the reduced smoke is the availability of premixed and homogeneous charge inside the engine well before the commencement of combustion, higher combustion temperature, extended duration of combustion and rapid flame propagation are the other reasons for reduced smoke. This may be due to better and optimum fuel air mixture for T20 and T30.

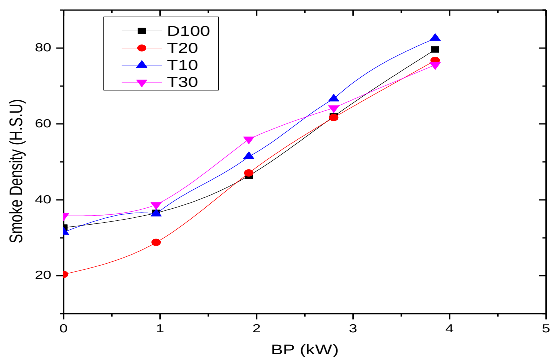


Fig.3.2.1 Brake Power versus smoke density

3.2.2. Carbon Monoxide (CO) Emission

The variation of CO emission with brake power is shown in Fig.3.2.2. from the plot it is observed that the engine emits more CO for diesel as compared to TPO blends under all loading conditions. At full load condition the CO emission obtained are 0.07%, 0.08%, 0.06% and 0.08% for the fuels of diesel, T10, T20 and T30 respectively. The CO concentration is decreases for the blends of T20 and it has been increased for T10 and T30 blends. At lower tyre oil concentration, the oxygen present in T20 aids for complete combustion. However as the tyre oil concentration increases, the negative effect due to viscosity and small increase in specific gravity suppresses the complete combustion process, which produces more amount of CO.

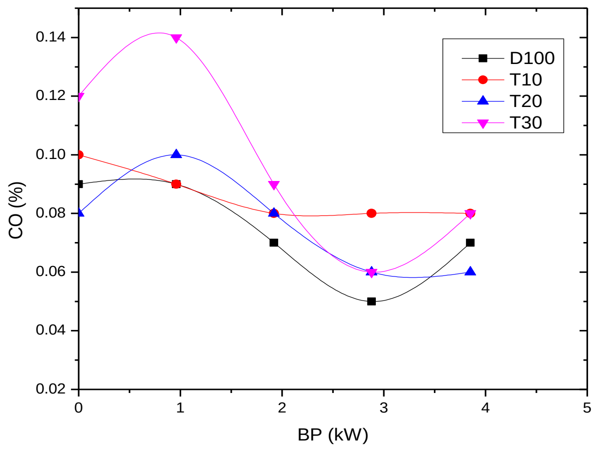


Fig.3.2.2 Brake Power versus CO

3.2.3. Carbon Dioxide ($C0_2$)

The variation of carbon dioxide with brake power is shown in fig.3.2.3. The plot is revels that different specified blends are indicated. At full load condition the CO2 emission obtained are 8.27%, 7.85%, 10.16% and 10.28% for the fuels of diesel, T10, T20 and T30 respectively. The CO2 emission for TPO except T10 blend, increasing trend with respect to load. The reason could be the high amount oxygen in the specified fuel blends which is converting CO emission into CO_2 emission content.

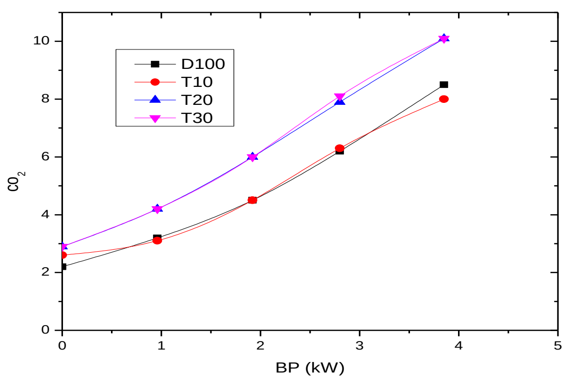


Fig.3.2.3. Brake Power versus CO_2

3.2.4. Unburned Hydrocarbon Emission

The variation of HC emission with brake power is shown in Fig.3.2.4. The plot it is observed that the load increases the HC emission decreases. At full load condition the unburned hydrocarbons are obtained 58ppm, 42ppm, 24ppm and 27ppm for the fuels of diesel, T10, T20 and T30 respectively. As the cetane number of ester based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low HC emission. Also the intrinsic oxygen contained by the biodiesel was responsible for the reduction in HC emission.

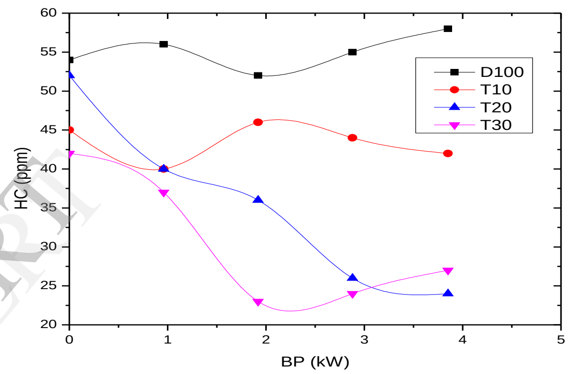


Fig.3.2.4. Brake Power versus HC

3.2.5 Oxides of Nitrogen (NOx) Emission

The variation of NO_X emission with brake power is shown in Fig.3.2.5. From the plot it is observed that for different blends is indicated. The NO_X emission for all the fuels tested followed an increasing trend with respect to load. At full load condition the NOx emission obtained are 1236ppm, 1084ppm, 1134ppm and 1074ppm for the fuels of diesel, T10, T20 and T30 respectively. The reason could be the higher average gas temperature, residence time at higher load conditions. A reduction in the emission for all the blends as compared to diesel was noted. With increase in the tyre oil content of the fuel, corresponding reduction in NOx emission was noted and the reduction was remarkable for T10, T20 and T30.

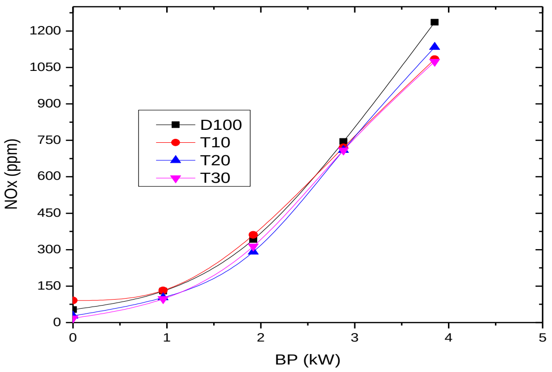


Fig.3.2.5. Brake Power versus NO_x Emissions

Conclusion

From the above analysis the blend T20 shows the better performance compare to other blends (T10 and T30) in the sense of better performance parameters like break thermal efficiency, break specific fuel consumption and decreased emission parameters like smoke density, unburned hydrocarbons, carbon monoxide, oxides of nitrogen. Hence due to the better performance T20 is taken as optimum blend and can be used as substitute for diesel.

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Nomenclature

B.P	Brake Power
BSFC	Brake Specific Fuel Consumption
BTH	Brake Thermal Efficiency
CO	Carbon Monoxide
HC	Unburned Hydro Carbons
NOx	Oxides Of Nitrogen
ppm	parts per million

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