Performance Analysis of Twin Cylinder Water Cooled Diesel Engine By Using Distilled Tyre Pyrolysis Oil

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Abstract*- Due to the scarcity of conventional fuels, the crude oil the price was going up day to day and there will be no more conventional fuels in future and also increasing the environmental pollution by the usage of crude oils there is a need for the search of alternative fuel sources for the automobile applications. There are many alternate fuels we already existing like bio-diesel, bio-mass, alcoholic fuels, hydrogen, non-fossil methane and non-fossil gases (like LPG, CNG) and other bio-mass sources which were useful for different applications, out of these bio-diesels are one of the prominent alternative fuel for diesel engines. Generally bio-diesel is the renewable fuel which is derived by chemically reacting with the sources of bio diesel like vegetable oils, animal oils, plastics, and waste automobile tyres etc. The chemical reaction requires a catalyst usually a strong acid or base such as sulfuric acid, sodium or potassium hydroxide, and produces a new chemical compounds called methyl or ethyl esters of the vegetable crude oil which is called as bio-diesel.2.Therefore in the present investigation the oil taken 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 4-stroke single cylinder water cooled direct injection 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 blending with diesel in different proportions such as T5, T10, T20 and T30 to find out the performance parameters and emissions. The performance and emission parameters obtained by the above tests are compared with the baseline data obtained earlier by using diesel. After finding the optimum blend in the third stage the test to be conducted again on the engine to find out the performance and emission parameters by adding isopropyl alcohol to the optimum blend. The main purpose of adding the isopropyl alcohol is to know ignition and brake thermal efficiency .Finally the performance parameters obtained by the above tests are compared with the optimum blend.*

I. INTRODUCTION

Alternative Fuel:

Alternative fuels, known as non-conventional or advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels. Conventional fuels include: fossil fuels (petroleum, coal, propane and natural gas), as well as nuclear materials such as uranium and thorium, as well as artificial radioisotope fuels that are made in nuclear reactors, and store their energy.Some well-known alternative 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.

Biodiesel:

Bio-diesel is not your regular vegetable oil and is not safe to swallow. However, biodiesel is considered biodegradable, so it is considered to be much less harmful to the environment if spilled. Biodiesel also has been shown to produce lower tailpipe emissions than regular fuel. The best thing about biodiesel is that it is made from plants and animals, which are renewable resources. Biodiesel is an alternative fuel for diesel, every year in states 280 million tyres are being dumped in the landfills, which became an unacceptable solution hence the tyre pyrolysis oil is produced which can used in a useful way. Not only in states all over the world there is an increase in waste tyres, so scrap tyres are used in the form of pyrolysis tyre oil is used as a blend in diesel oil, which increases the efficiency of the engine. The purpose of this study was to compare used tyre pyrolysis oil blends with conventional diesel fuel when fueled in a diesel engine. The test fuel was 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 were also evaluated for raw oil, refined oil before and after distillation. The fuel was then blended with diesel and used in an internal combustion engine. Blends of 10%, 20%, and 30% by volume were investigated. This performance data were collected for study 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. We believe that significant improvement in the economics can be accomplished by upgrading the primary pyrolysis products, like the tyre oil.

Tyre disposal method:

The scrap tyre disposal process can be broadly divided into physical and chemical methods. One of the methods is to use the scrap tyre for landfill although this method should not be employed any more due to the intrinsic environmental limitation. Other physical method is to make the scrap tyre into granules and recycle them for carpets, tiles and road pavement materials. However, the treatment and disposal option for spent tyres most commonly used is land filling which represents a problem may result in accidental fires with high pollution emissions. In addition, tyres can be a breeding ground for insects and home for vermin. The current disposal methods of land filling of tyres are clearly a waste of a valuable resource, because a typical car tyre equals to 10 lit of fuel oil. Consequently, alternative treatment and disposal routes for tyres are urgently being sought. The alternative process is pyrolysis, a chemical method. In which, the thermal decomposition is used.

Biodiesel produced from different vegetable oils and animal fat oils (soyabean, rapeseed and sunflower, jathropa, karanji, neem, cottonseed, palm, castored, fish based oil, waste chicken fat based oil and animal tallow for example), seems very interesting for several reasons. It can replace diesel oil in boilers and internal combustion engines without major adjustments; only a small decrease in performances is reported; almost zero emissions of sulfates; a small net contribution of carbon dioxide (CO_2) when the whole life-cycle is considered emission of pollutants comparable with that of diesel oil. Criteria pollutants are reduced with biodiesel use. Tests show the use of biodiesel in diesel engines results in substantial reductions of unburned hydrocarbons, carbon monoxide and particulate matter. The exhaust emissions of total hydrocarbons (a contributing factor in the localized formation of smog and ozone) are on average 67 percent lower for biodiesel than diesel fuel. The exhaust emissions of carbon monoxide (a poisonous gas) from biodiesel are on average 48 percent lower than carbon monoxide emissions from diesel. Breathing particulate has been shown to be a human health hazard. The exhaust emissions of particulate matter from biodiesel are about 47 percent lower than overall particulate matter emissions from diesel. Emissions of nitrogen oxides stay the same or are slightly increased. However, some companies have successfully developed additives to reduce NOx emissions in biodiesel blends.

2.4 Methods for the production of bio-diesel:

In general, vegetable oil contains of triglycerides and monoglycerides and fatty acids. In general, to reduce the free fatty acids and viscosity of vegetable oil by using the fallowing processes.

1. Dilution or Blending process
2. Pyrolysis or Cracking process
3. Micro-emulsification process
4. Transesterification process

Transesterification

Transesterification is otherwise known as alcoholisms. It is the reaction of fat or oil with alcohol to form esters and glycerin. A catalyst is used to improve the reaction rate yield. Among these methods transesterification process is the best process to produce the cleaner and environmentally safe form of vegetable oils.

II.LITERATURE REVIEW

S. Murugan, used Tyre pyrolysis oil and blended with diesel fuel at different ratios. Those different blends were used as in a diesel engine and then evaluate the performance parameters like brake thermal efficiency, brake specific fuel consumption (BSFC), exhaust gas temperature and the emissions measured were carbon monoxide (CO), smoke density, hydrocarbon (HC), and oxides of nitrogen (NO_x).The oil to getting from the waste automobile tyres by using pyrolysis process. The oil which obtained by the pyrolysis process will mix with the diesel in different proportions to get different blends like B10, B30, B50. And those different blends were used as fuel in a diesel engine. And then evaluate the performance and emission characteristics of a single cylinder four stroke, air cooled, constant speed (1500rpm), direct injection diesel engine.

M. Mani, used waste plastic oil. And then evaluate the performance parameters like brake thermal efficiency, brake specific fuel consumption (BSFC), exhaust gas temperature and the emissions measured were carbon monoxide (CO), smoke density, hydrocarbon (HC), and oxides of nitrogen (NO_x).The oil to getting from the weaste plastics by using pyrolysis process. The oil which obtained by the pyrolysis process will used as fuel in a diesel engine. And then evaluate the performance and emission characteristics of a single cylinder four stroke, air cooled, constant speed(1500rpm), direct injection diesel engine.

Ali Keskin , used cotton oil soapstock and blended with diesel fuel at different ratios. Those different blends were used as in a diesel engine. And then evaluate the performance parameters like brake thermal efficiency, brake specific energy consumption (BSEC) and the emissions measured were carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), and oxides of nitrogen (NO_x).vegetable oils and animal oils are have high viscosity so, methyl esters are using to decreasing the viscosity by the transesterification process. To get the properties of those oils closer to the diesel. The oil which obtained by the transesterification process will mix with the diesel in different proportions to get different blends like B20, B40, B60. And those different blends were used as fuel in a diesel engine. And then evaluate the performance and emission characteristics of a vertical, single cylinder four stroke, water cooled, direct injection, constant speed (1500rpm), compression ignition diesel engine.

Jagannath Balasaheb Hirkude, used waste fried oil and blended with diesel fuel at different ratios. Those different blends were used as in a diesel engine. And then evaluate the performance parameters like brake thermal efficiency, brake specific energy consumption (BSEC) and the emissions measured were carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), and oxides of nitrogen (NO_x).vegetable oils and animal oils are have high viscosity so, methyl esters are using to decreasing the viscosity by the transesterification process. To get the properties of those oils closer to the diesel. The oil which obtained by the transesterification process will mix with the diesel in different proportions to get different blends like B50, B70, B90. And those different blends were used as fuel in a diesel engine. And then evaluate the performance and emission characteristics of a vertical, single cylinder four stroke, water cooled, direct injection, constant speed (1500rpm), compression ignition diesel engine.

Sharanappa Godiganur, used mahua oil and blended with diesel fuel at different ratios. Those different blends were used as in a diesel engine. And then evaluate the performance parameters like brake thermal efficiency, brake specific energy consumption (BSEC) and the emissions measured were carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), and oxides of nitrogen (NO_x).vegetable oils and animal oils are have high viscosity so, methyl esters are using to decreasing the viscosity by the transesterification process. To get the properties of those oils closer to the diesel. The oil which obtained by the transesterification process will mix with the diesel in different proportions to get different blends like B20, B40, B60. And those different blends were used as fuel in a diesel engine. And then evaluate the performance and emission characteristics of a Cummins 6BTA 5.9 G2- 1, 158 HP rated power, turbocharged, direct injection, water cooled diesel engine.

III. TYRE OIL PRODUCTION

3.1 Definition of pyrolysis:

Pyrolysis, in general, is the thermal degradation in the absence of oxygen agent. Relatively low temperature is employed (500^0C -800^0C). Three products are usually produced: gas, pyrolysis oil and char, the relative proportions of which depends up on pyrolysis method, characteristics of biomass and the reaction parameters.

3.2 Pyrolysis process:

Chipped tyres are heated in a stationary bed of the pyrolysis reactor up to 600^0C in the absence of oxygen. During thermal cracking the polymer chains of rubber are cracked to form monomers or shorter chains. The primary products obtained are pyrolysis gas, oil and char.

The basic phenomenon that takes place during pyrolysis is:

- Heat transfer from heat source leading to an increase in temperature inside the fuel.
- Initiation of pyrolysis reactions due to this increased temperature leading to the release of volatiles and formation of char
- Out flow of volatiles, resulting in heat transfer between hot volatiles and cooler un pyrolyzed fuel.
- Condensation of some of volatiles in cooler parts of fuel to produce tar.
- Autocatalytic secondary pyrolysis reactions.

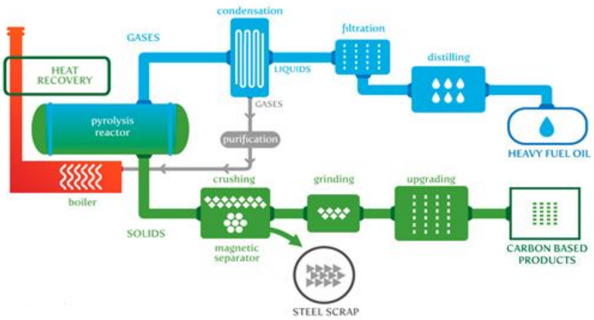

Fig. 3.1`Experimental set up for Pyrolysis Process

The main products of pyrolysis are oil, gas that contains H_2, CH_4 and carbon black. The raw oil has broad fuel properties similar to commercial grade furnace oil. The raw oil may be combusted directly or added to petroleum derived fuels after refining. The raw oil contains impurities and moisture, which can find direct applications in oil fired stoves and burners. The moisture is removed by heating. Treating with conc.H_2SO_4 reduces the percentage of sulphur in the fuel. On distillation with fuller's earth as adsorbent, a product with good combustible properties, free from impurities similar is diesel is obtained.

3.3 Preparation of blends:

The obtained tyre oil is blended for conducting the performance test, the tyre pyrolysis oil is mixed in proper proportions as shown

Table 3.1 Blending Percentage of Fuel

Notation	Fuel Quantity (ml)	Bio-Diesel Quantity(ml)	Diesel Quantity (ml)
T5	700	35	665
T10	700	70	630
T20	700	140	560
T30	700	210	490

3.4 Experimental setup:

3.4.1 Engine description:

The 4-stroke diesel engine is shown in Fig. 4.1. It is a 4 stroke, vertical, single cylinder, water cooled, constant speed diesel engine which is coupled to rope brake drum arrangement to absorb the power produced. The engine crank started. Necessary dead weights and spring balance are included to apply load on brake drum. Suitable cooling water arrangement for the brake drum is provide. A measuring system for fuel consumption consisting of a fuel tank, burette, and a 3- way cock mounted on stand and stop watch are provided. Air intake is measured using an air tank fitted with an orifice meter and a water U- tube differential manometer. Also digital temperature indicator with selector switch for temperature measurement and a digital rpm indicator for speed measurement are provided on the panel board. A governor is provided to maintain the constant speed.

Fig.3.2 Four- Stroke Twin cylinder Diesel Engine

IV. RESULTS AND DISCUSSION

The experiments are conducted on the four stroke twin cylinder water cooled diesel engine at constant speed (1500 rpm) with varying loads with diesel and different blends of tyre oil like T5, T10, T20, T30, T19.8D79.2ISPA1 and T19.6D78.4ISPA2. Various performance parameters such as brake thermal efficiency, mechanical efficiency, indicated thermal efficiency, volumetric efficiency, brake specific fuel consumption, indicated specific fuel consumption and air – fuel ratio are discussed below.

4.1. Brake Thermal Efficiency:

The variation of brake thermal efficiency with load is shown in Fig. 6.1. From the plot it is observed that as load increases brake thermal efficiency is also increases for diesel as well as the blends of tyre oil. At full load condition, the brake thermal efficiencies are obtained 41.31%, 41.91%, 43.20%, 45.46% and 43.97% for the fuels diesel,T5, T10, T20 and T30 respectively. Among the four blends of tyre oil the maximum BTE is 45.46% which is obtained for T20. The BTE of tyre oil is increases up to 3.13% as compared with diesel at full load condition. The increment in brake thermal efficiency is due to the better combustion because of high calorific value and less viscosity of the tyre oil.

4.2 Mechanical Efficiency:

The variation of mechanical efficiency with load is shown in Fig. 6.2. From the plot it is observed as load increases mechanical efficiency is also increases for diesel as well as the blends of tyre oil. At full load condition the mechanical efficiencies obtained are 63.11%, 71.99%, 71.81% , 72.08% and 72.17% for the fuels of diesel and T5, T10, T20 and T30 respectively. From the above results is observed that there is considerable change in mechanical efficiency using blends of tyre oil.

4.3 Volumetric Efficiency:

The variation of volumetric efficiency with load is shown in Fig. 6.3. From the plot it is observed as load increases volumetric efficiency is also increases for diesel as well as the blends of tyre oil. At full load condition the volumetric efficiencies obtained are 69.75%, 67.15%, 67.33% ,67.29% and 67.30% for the diesel and T5, T10, T20 and T30 respectively. The reduction of volumetric efficiency is considerable for using blends of tyre oil. The decrement in volumetric efficiency is may due to take the less amount of intake air due to high exhaust temperature.

4.4 Brake Specific Fuel Consumption:

The variation of brake specific fuel consumption with load is shown in Fig. 6.4. The plot it is reveals that as the load increases the fuel consumption decreases. At full load condition the BSFC obtained are 0.204 kg/kW-hr, 0.202 kg/kW-hr, 0.196 kg/kW-hr ,0.186 kg/kW-hr and 0.192 kg/kW-hr for fuels of diesel, T5, T10, T20 and T30 respectively. The minimum fuel consumption is for T20 is 0.186 kg/kW-hr as to that of diesel is 0.192 kg/kW-hr. The BSFC of tyre oil blend T20 is decreases up to 3.12% as compared with diesel at full load condition. The tyre oil blends shows minimum BSFC value than diesel due to the tyre oil calorific value is high as compared to diesel fuel.

4.5 Discussion:

A twin cylinder compression ignition engine was operated successfully using blends of tyre oil like T5, T10, T20 and T30 as an alternative fuel and the performance and emissions are compared with diesel fuel. The following conclusions are drawn based on the experimental results.

- At full load condition the BSFC obtained are 0.204 kg/kW-hr, 0.202 kg/kW-hr, 0.196 kg/kW-hr ,0.186 kg/kW-hr and 0.192 kg/kW-hr for fuels of diesel, T5, T10, T20 and T30 respectively. The minimum fuel consumption is for T20 is 0.186 kg/kW-hr as to that of diesel is 0.192 kg/kW-hr. The BSFC of tyre oil blend T20 is decreases up to 3.12% as compared with diesel at full load condition.
- At full load condition, the brake thermal efficiencies are obtained 41.31%, 41.91%, 43.20%, 45.46% and 43.97% for the fuels diesel,T5, T10, T20 and T30 respectively. Among the four blends of tyre oil the maximum BTE is 45.46% which is obtained for T20. The BTE of tyre oil is increases up to 3.13% as compared with diesel at full load condition.

From the above analysis the blend T20 shows the better performance comparedto other blends(T5, T10 & T20) in the sense of performance parameters like brake thermal efficiency, brake specific fuel consumption. Hence due to the better performance T20 is taken as optimum blend.

Further the experiment is conducted on same engine with the optimum blend by adding ignition improver isopropyl alcohol in the quantity of 7ml and 14ml and all performance parameters like brake thermal efficiency, brake specific fuel consumption are evaluated.

4.6 Graphs of above mentioned performance parameters with respect to load:

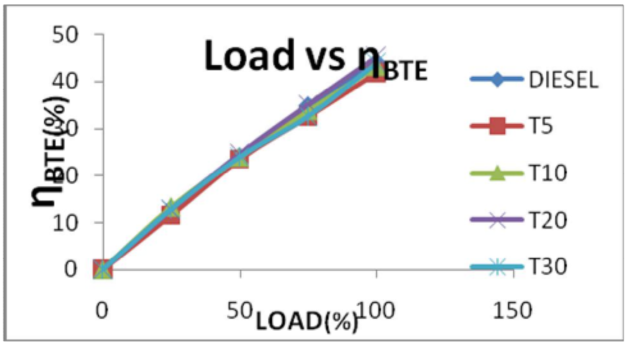

Fig. 4.1 Load Vs Brake Thermal Efficiency

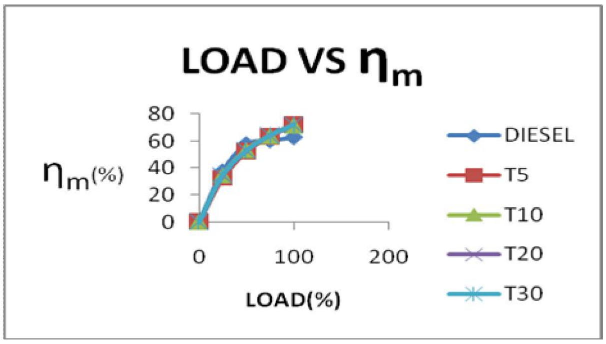

Fig. 4.2 Load Vs Mechanical Efficiency

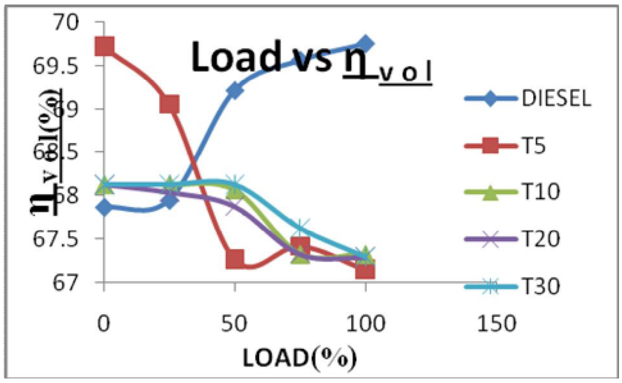

Fig. 4.3 Load Vs Volumetric Efficiency

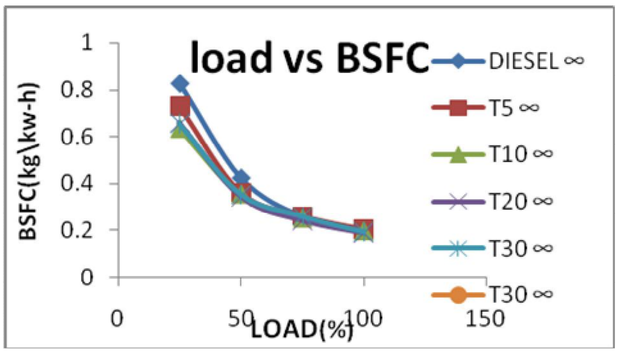

Fig. 4.4 Load Vs Brake Specific Fuel Consumption

4.7 Experimental results of optimum blend with Ignition improver:

After getting the optimum blend the test to be conducted again on the engine to find out the performance and emission parameters by adding isopropyl alcohol to the optimum blend. The main purpose of the isopropyl alcohol is to improve ignition and thermal efficiency along with reduction in emission parameters. Finally the performance and emission parameters obtained by the above tests are to be compared with the optimum blend.

4.7.1 Brake Thermal Efficiency:

The variation of brake thermal efficiency with load is shown in Fig. 6.6 From the plot it is observed as the BP increases there is considerable increase in the BTE. The BTE of diesel at full load is 41.31% while the blends of T20 is 45.46%, T19.8D79.2ISPA1 is 46.23%, T19.6D78.4ISPA2 is 46.00%, among the three the maximum BTE is 46.23% which is obtained for T19.8D79.2ISPA1. The BTE of tyre oil is increases up to 1.693% as compared with optimum blend at full load condition. The increment in brake thermal efficiency due to better combustion because of adding ignition improver it effects to decrease the viscosity due to high volatility.

4.7.2 Mechanical efficiency:

The variation of mechanical efficiency with load is shown in Fig. 6.7. From the plot it is observed as load increases mechanical efficiency is also increases for diesel as well as the blends of tyre oil. At full load condition the mechanical efficiencies obtained are 63.11%, 72.08%, 71.69% and 71.95% for the fuels of diesel and T20, T19.8D79.2ISPA1 and T19.6D78.4ISPA2 respectively. From the above results is observed that there is considerable change in mechanical efficiency using blends of tyre oil.

4.7.3 Volumetric Efficiency:

The variation of volumetric efficiency with load is shown in Fig. 6.8. From the plot it is observed as load increases volumetric efficiency is also increases for diesel as well as the blends of tyre oil. At full load condition the volumetric efficiencies obtained are 69.75%, 67.29%, 67.29% and 67.88% for the diesel and T20, T19.8D79.2ISPA1 and T19.6D78.4ISPA2 respectively. The reduction of volumetric efficiency is considerable for using blends of tyre oil. The decrement in volumetric efficiency is may due to take the less amount of intake air due to high exhaust temperature.

4.7.4 Brake Specific Fuel Consumption:

The variation of brake specific fuel consumption with load is shown in Fig. 6.9. The plot is reveals that as the load increases the fuel consumption decreases. At full load condition the BSFC obtained are 0.204 kg/kW-hr, 0.1863 kg/kW-hr, 0.1832 kg/kW-hr and 0.1841 kg/kW-hr for fuels of diesel, T20, T19.8D79.2ISPA1 and T19.6D78.4ISPA2 respectively. The BSFC of after adding ignition improver of tyre oil is decreases up to 1.98% as compared with optimum blend (T20) at full load condition. The tyre oil blends shows minimum BSFC value than diesel due to the tyre oil calorific value is high as compared to diesel fuel.

4.7.5 Discussion:

From all the above results of ignition improvers (T19.8D79.2ISPA1 and T19.6D78.4ISPA2) and the best blend (T20) it can be concluded that the blend T20 added with ignition improver of isopropyl alcohol of 7ml is shown the best performance in the sense,

- The BTE of diesel at full load is 41.31% while the blends of T20 is 45.46%, T19.8D79.2ISPA1 is 46.23%, T19.6D78.4ISPA2 is 46.00%, among the three the maximum BTE is 46.23% which is obtained for T19.8D79.2ISPA1. The BTE of tyre oil is increases up to 1.693% as compared with optimum blend at full load condition.
- At full load condition the BSFC obtained are 0.204 kg/kW-hr, 0.1863 kg/kW-hr, 0.1832 kg/kW-hr and 0.1841 kg/kW-hr for fuels of diesel, T20, T19.8D79.2ISPA1 and T19.6D78.4ISPA2 respectively. The BSFC of after adding ignition improver of tyre oil is decreases up to 1.98% as compared with optimum blend (T20) at full load condition.

4.8 Graphs of above mentioned performance parameters with respect to load:

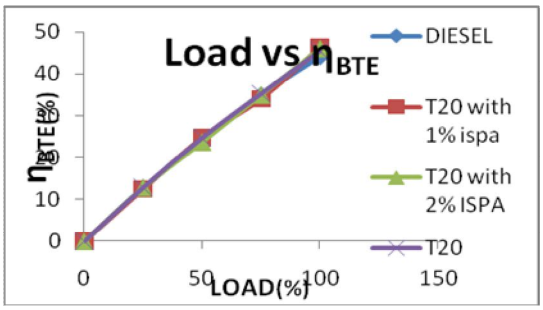

Fig. 4.5 Load Vs Brake Thermal Efficiency

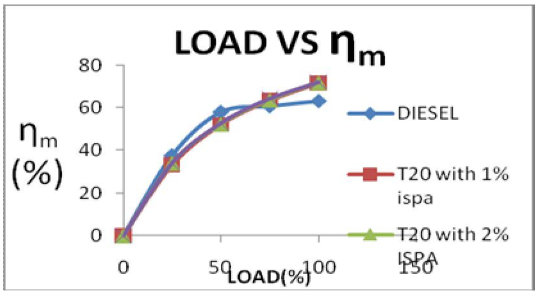

Fig. 4.6 Load Vs Mechanical Efficiency

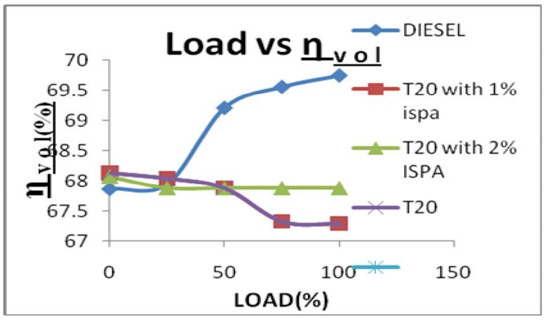

Fig. 4.7 Load Vs Volumetric Efficiency

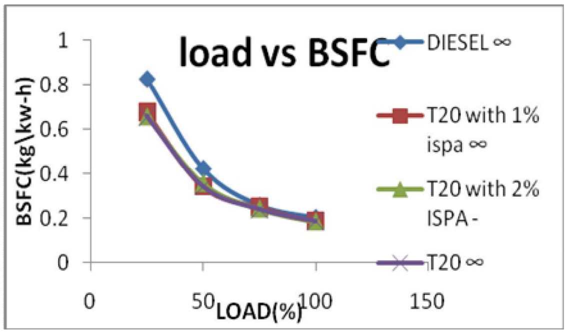

Fig.4.8 Load Vs Brake Specific Fuel Consumption

V. CONCLUSION

The experimental tests are conducted on 4-stroke, twin cylinder, water cooled and direct injection diesel engine by using tyre pyrolysis oil blends of T5, T10, T20 and T30, pure diesel at constant speed of 1500 rpm. From the first set of results it can be conclude that the blend T20 has given the better performance in the sense of brake thermal efficiency, specific fuel consumption. No engine seizing, injector blocking was found during the entire operation while the engine running with different blends of tyre pyrolysis oil and diesel. So T20 can be used as alternative fuel and we can save 20% of diesel that we are importing and increase the economy. In the second stage again the test is conducted on the engine by taking the blend T20 along with the addition of ignition improver isopropyl alcohol in the quantity of 7ml (T19.8D79.2ISPA1) and 14ml (T19.6D78.4ISPA2) at the same operating conditions. Among these two compositions the one T19.8D79.2ISPA1 has given the better performance in the following parameters.

1. Brake thermal efficiency is observed as the load increases there is considerable increase in the BTE. The BTE of diesel at full load is 44.08% while the blends of T20 is 45.46%, T19.8D79.2ISPA1 is 46.23%, T19.6D78.4ISPA2 is 46.00%, among the three the maximum BTE is 46.23% which is obtained for T19.8D79.2ISPA1. The BTE of tyre oil is increases up to 1.693% as compared with optimum blend at full load condition.
2. At full load condition the BSFC obtained are 0.1923 kg/kW-hr, 0.1863 kg/kW-hr, 0.1832 kg/kW-hr and 0.1841 kg/kW-hr for fuels of diesel, T20, T19.8D79.2ISPA1 and T19.6D78.4ISPA2 respectively. The BSFC of after adding ignition improver of tyre oil is decreases up to 1.98% as compared with optimum blend (T20) at full load condition
3. From all the above discussion it can be concluded that the tyre oil can be used as an alternative fuel in the diesel engines with the addition of ignition improver is isopropyl alcohol operating without any modifications of engine.

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