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Experimental Investigation of Engine Characteristics using Biomedical Waste Pyrolytic Oil at Different Injection Pressures

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Abstract

The main aim of this study is to investigate the effect of injection pressures on emission and performance analysis of biomedical waste pyrolysis oil, plastic waste oil and its blends with diesel using diesel engine. This research describe a comparison of the use of pyrolysis oil i.e plastic pyrolysis oil which is extracted from biomedical wastes and normal diesel oil for different injection pressures in the assessment of engine performance, characteristics, and feasibility analysis. .The parameters like brake thermal efficiency, brake specific fuel consumption, and exhaust emissions like NOx, CO2, CO, and mass fraction burned., were considered for comparing the performance of pyrolysis oil in various proportions and with varying loads at two injection pressure i,e 180 and 200 bar. The initial experiments were done at injection pressure of 180 bars, later the injection pressure was changed to 200 bars. It was observed that the brake thermal efficiency increased as the injection pressure increased from 180 bars to 200 bars. The NOx emission reduced as the injection pressure was increased to the CO emission gradually decreases as the injection pressure increased. It was observed that addition of oxygenates had improved the combustion process and reduced the emissions. The investigation revealed that blending of DEE with plastic oil increases the Cetyane rating which is superior to neat diesel. The economic analysis shows that the pyrolysis oil is able to replace diesel in terms of engine performance and energy output if the price of pyrolysis oil is not greater than 85% of diesel oil.

Keywords- Pyrolysis; waste plastic Pyrolysis Oil; Engine Performance, injection pressure, Feasibility Study Emission

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I. INTRODUCTION

Due to the fossil fuel crisis in past decade, mankind has to focus on developing the alternate energy sources such as biomass, hydropower, geothermal energy, wind energy, solar energy, and nuclear energy. The developing of alternative-fuel technologies are investigated to deliver the replacement of fossil fuel. The focused technologies are bio-ethanol, bio-diesel lipid derived biofuel, waste oil recycling, pyrolysis, gasification, dimethyl ether, and biogas. On the other hand, appropriate waste management strategy is another important aspect of sustainable development since waste problem is concerned in every city.

The waste to energy technology is investigated to process the potential materials in waste which are plastic, biomass and rubber tire to be oil. Pyrolysis process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. Waste plastic and waste tire are investigated in this research as they are the available technology. The advantage of the pyrolysis process is its ability to handle unsort and dirty plastic. The pre-treatment of the material is easy. Tire is needed to be shredded while plastic is needed to be sorted and dried. Pyrolysis is also no toxic or environmental harmful emission unlike incineration. The tire pyrolysis oil and plastic pyrolysis oil have been investigated and found that they both are able to run in diesel engine and the fuel properties of the oils are comparable to diesel oil.

II. LITERATURE REVIEW

M.F.Ali[3] reported that the high yields of liquid fuels in the boiling range 100–480°C and gases were obtained along with a small amount of heavy oils and insoluble material such as gums and coke. The results obtained on the co-processing of polypropylene with coal and petroleum residues are very encouraging as this method appears to be quite feasible to convert plastic materials into liquefied coal products and to upgrade the petroleum residues and waste plastics.

Miskolczi[4] investigated the pyrolysis of real waste plastics (high-density polyethylene and polypropylene) in a pilot scale horizontal tube reactor at 520 °C temperature in the presence and absence of ZSM-5 catalyst. It was found that the yields of gases, gasoline and light oil could be increased in the presence of catalyst. They also concluded that the plastic wastes could be converted into gasoline and light oil with yields of 20–48% and 17–36% respectively depending on the used parameters.

F Murfyk [5] from the recent literature, it is evident that the process of converting waste plastic to reusable oil is a current research topic. Hence in this paper, preparation of blends of diesel with varying proportions of waste plastic oil produced from the thermal pyrolysis and the analysis of viscosity and density of these blends is presented. The feasibility of the waste plastic oils derived from PVC plastics as an alternate fuel for transportation is also checked by conducting performance test on a single cylinder Kirlosker diesel engine equipped with electrical loading at 50% of the engine maximum load i.e., at 3.7 Kw.

S Murugan. [6] Used distilled tire pyrolysis oil (DTPO) as an alternate fuel in a diesel engine without any engine modification. It was observed that engine was able to run up to 90% DTPO. The use of waste plastic oil as an alternate fuel in a diesel engine it's taken for study.

III. BIOMEDICAL WASTE

'Bio-medical waste' means any solid and/or liquid waste including its container and any intermediate product, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research pertaining there to or in the production or testing thereof.

WHO stated that 85% of hospital wastes are actually non-hazardous, around 10% are infectious and around 5% are non-infectious but hazardous wastes. In the USA, about 15% of hospital waste is regulated as infectious waste. In India this could range from 15% to 35% depending on the total amount of waste generated.

Fig. 1: Bio-medical waste

IV. PYROLYSIS

Feedstock material is the main factor to indicate the properties of the pyrolysis oil. Tire pyrolysis and plastic pyrolysis technologies are the available technologies on the market in Thailand. The feedstock pre-process is one of the main factors to assess the possibility of the technology. The waste tires are collected easily from the scavenger and garage as they are bulky and heavy but only shredding process is required to reduce the size. The medical waste plastics are collected from hospitals, nursing homes and such area where the medical waste available. The weakness of the plastic is the character of the plastic, which is mainly from plastic, is small high impurity and bulky. Soring and cleaning is required for plastic process. However, as the purpose of the process is turning waste to energy, the pyrolysis process of tire and plastic is distinguished and compared in this research. Physical and chemical analysis properties of both oils are studied and compared in order to ensure to usage of the oil in diesel engine.

Pyrolysis is the initial process that takes place when organic matter is first heated in the absence of oxygen to produce combustible gases. Pyrolysis by itself does not normally release excessive heat; rather, it requires heat to sustain it. Pyrolysis of organic materials such as biomass at high temperatures (greater than 428° F) decomposes the fuel source into charcoal (carbon and ash) and volatile matter. The latter comprises condensable vapour called pyrolysis oil (also known as bio-oil, bio crude, etc.) at room temperatures and non-condensable (permanent) gases such as carbon monoxide, carbon dioxide, hydrogen and light molecular weight hydrocarbon gases such as methane, collectively called synthesis gas (syngas or producer gas).

V. EXPERIMENTAL SET UP

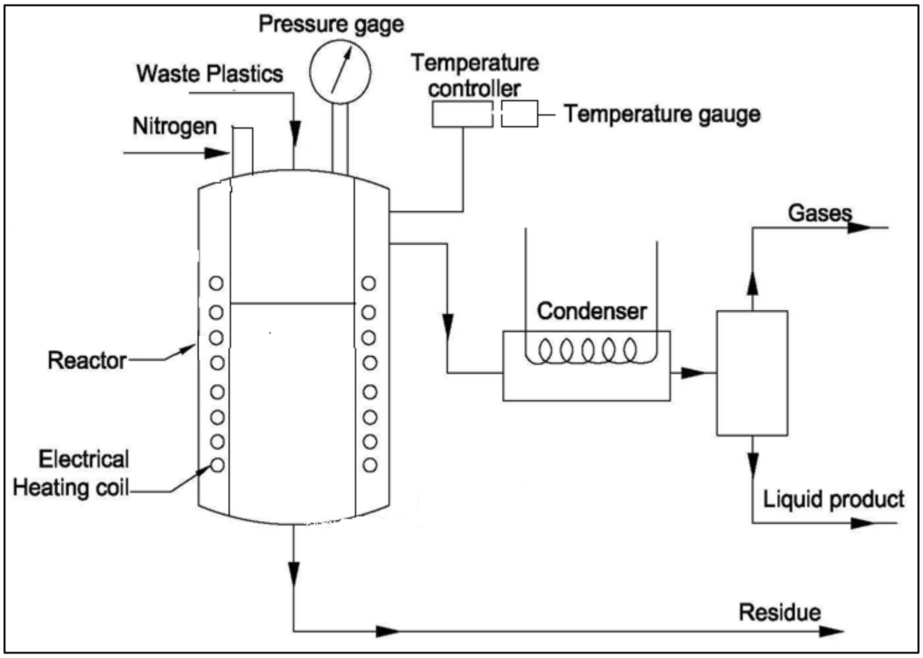

Fig. 2: Experimental Set Up

The Oil extraction plant consist of

- Reactor
- Condenser
- Temperature controller
- Pressure gauge

1) Reactor: The reactor consists of electrical heating coil and bricks around the reactor where the combustion takes place.
2) Condenser: In condenser the change of phase takes place i.e. vapour to liquid.
3) Temperature controller: The temperature controller controls and sets the temperature which is required for reactor to carryout combustion.
4) Pressure Gauge: Pressure gauge indicates the pressure in the reactor.


Fig. 3: The Oil extraction plant

VI. RESULT AND DISCUSSION FOR 180 PRESSURES

A. Performance Characteristics

1) Variation of Brake Thermal Efficiency with Brake Power

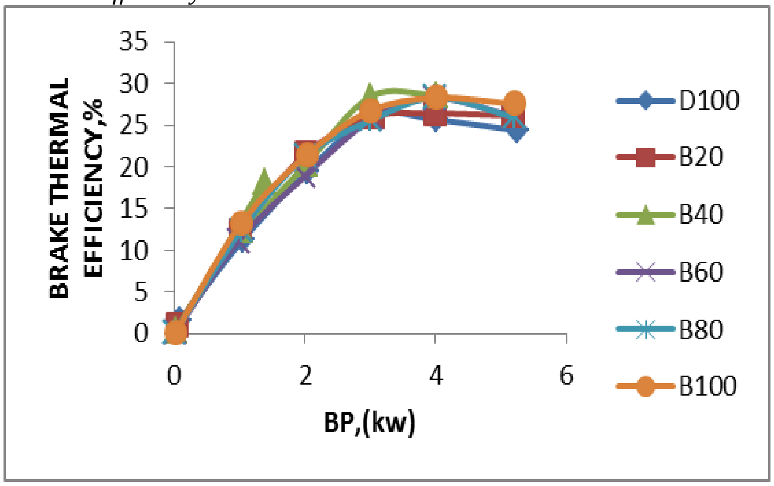

Fig. 4: Variation of brake thermal efficiency with brake power

Fig. focuses on the variation of Brake thermal efficiency with load for various Blend Proportion of plastic pyrolysis oil in diesel fuel. Brake thermal efficiency seems lowest for 80% blend and highest for 40% Blend Proportions. Higher thermal efficiencies of 100%, 20%, 60% Blended fuel than the diesel fuel, 80%, 40% blend is because of less fuel consumption. Similarly, with increase in blend proportions, fuel consumption is consistently decreasing. So, thermal efficiencies are increasing with increase in blend proportion of plastic pyrolysis oil in diesel fuel.

2) Variation of Specific Fuel Consumption with Brake Power

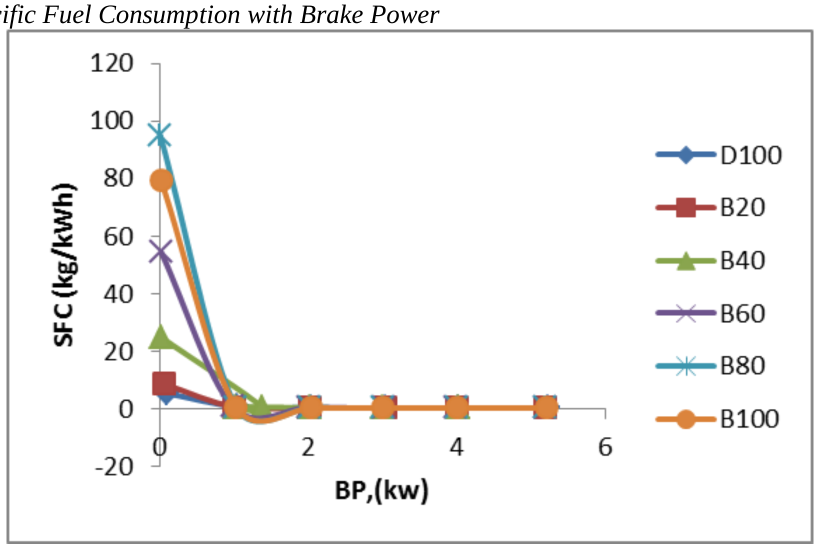

Fig. 5: Variation of Specific fuel consumption with Brake power

Fig. shows the variation in Specific fuel consumption with load for different Blend Proportions. Specific fuel consumption decreases with increase in load. It is very much clear from the graph that Specific fuel consumption is maximum for 80% of blend than any of the Blend Proportion for lower and higher loads. Specific fuel consumption is decreasing with increase in Blend proportion of plastic pyrolysis oil in diesel fuel. This is also because of the same reason for decrease in fuel consumption with increase in blend percentage of plastic pyrolysis oil. Due to higher calorific value of the plastic pyrolysis oil, enough required heat can be produced with lesser amount of fuel. And thus specific fuel consumption consistently decreases with increase in percentage of plastic pyrolysis oil in diesel fuel.

3) Variation of Air Fuel Ratio with Brake Power

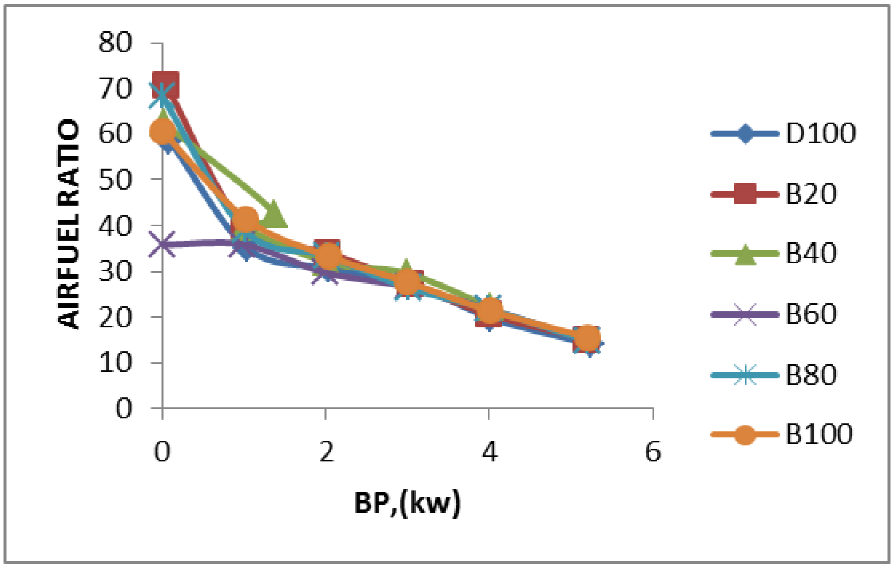

Fig. 6: Variation of Air fuel ratio with Brake power

Fig. shows the air fuel ratio of plastic pyrolytic oil blends and diesel comparing between air fuel ratio and brake power. High latent heat of vaporization and high volatility so it will vaporize easily to form a homogenous mixture with air. B100 is best for low fuel consumption. At no load conditions the B20 has the highest air fuel ratio of 70.69, whereas B60 has the lowest ratio of 35.8. And at full load conditions all the blends have nearly same ratios but comparatively B40 has the highest air fuel ratio. As the load increases the air fuel decreases this is due to more consumption and also because of the air fuel mixing process is affected by the difficulty in atomization of biodiesel due to its higher viscosity.

4) Variation of Mechanical Efficiency with Brake Power

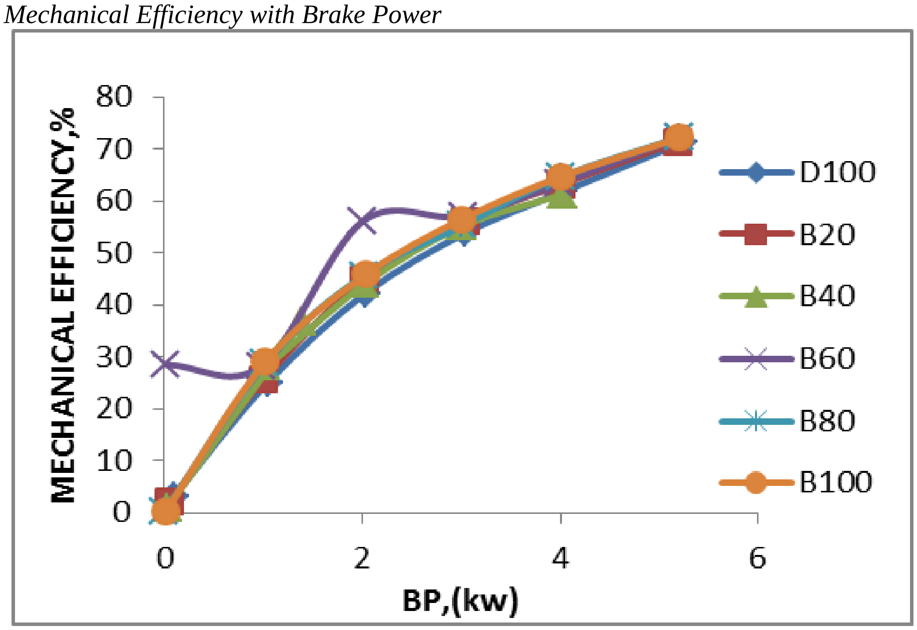

Fig. 7: Variation of Mechanical efficiency with Brake power

Fig. Focuses on the variation of Mechanical Efficiency with loads for various Fuel and Blend Proportions. Mechanical Efficiency increases gradually with increase in loads. At lower loads, mechanical efficiency is minimum and at full load condition, we get maximum mechanical efficiency. Comparing, different Fuels and Blends, we get maximum Mechanical Efficiency for B60.

It becomes almost constant up to the 100% proportion of plastic pyrolysis oil and efficiencies of 80% and 100% blends are almost similar, which is nearly comparable to diesel fuel. So, in Mechanical Efficiency, the comparison of Mechanical Efficiency for Different Fuel and Blends at different loads is easily visible and understood from the figure.

5) Variation of Volumetric Efficiency with Brake Power

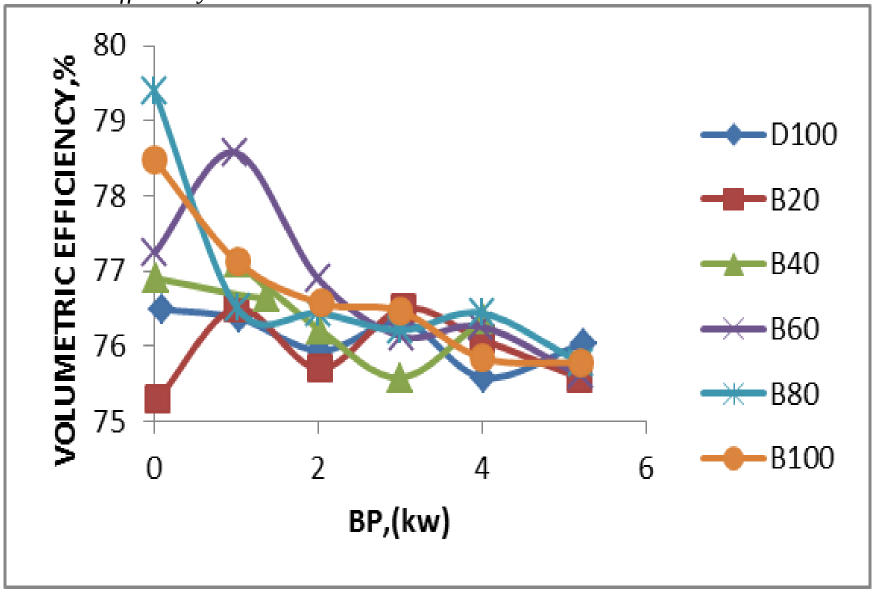

Fig. 8: Variation of Volumetric Efficiency with Brake Power

The figure shows that the variation of volumetric efficiency with load for different proportions. At no load conditions the volumetric Efficiency is high for B80 compared to D100. B20 has the lowest efficiency of 75.3% at no load conditions compare to others. And at higher loads the volumetric Efficiencies of D100 and B20, B40, B60, B80 and B100 are almost same. At load 1 there is a sudden increase in volumetric efficiency for B60 compare to other blends, The graph for the blends are in zigzag in nature because of breathing of engine for the particular combinations .i,e ratio actually induced at ambient conditions to the swept volume of the engine

6) Variation of Exhaust Gas Temperature with Brake Power

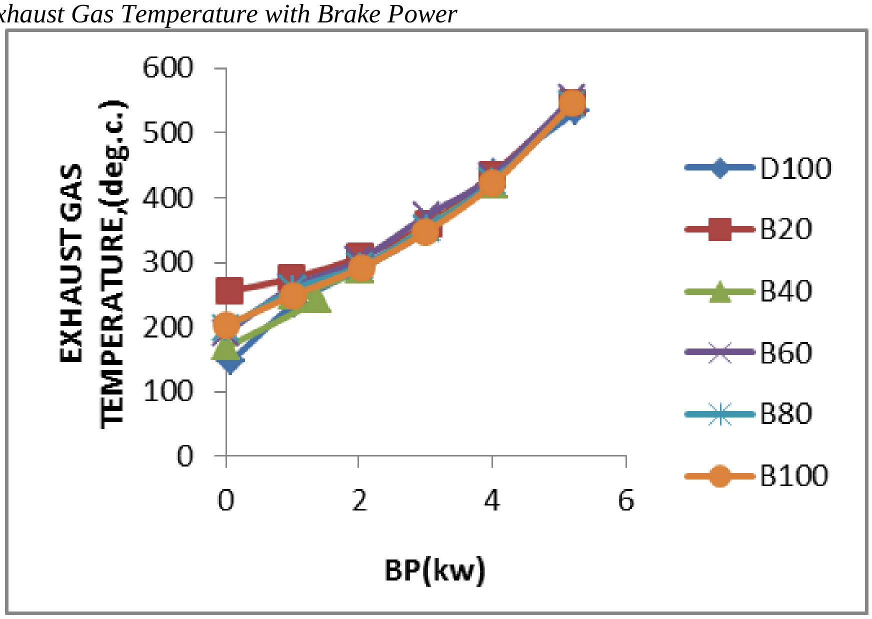

Fig. 9: Variation of Exhaust Gas Temperature with Brake Power

The figure shows that the Exhaust Gas Temperature with Brake power, exhaust gas temperature increases with increase in load. B20 has the maximum exhaust gas temperature with diesel fuel and B100 has the minimum. It results that exhaust gas temperature decreases with increase in blend proportion. And as the load increases the exhaust gas temperature also increases, At zero load the D100 is the minimum temperature i,e 148.25 and whereas B20 is maximum temperature of 255.28 . The reasons for lower exhaust gas temperatures for blends are due to lower viscosity which results a lesser penetration of the fuel into the combustion chamber and the lesser amount of heat is developed.

Emission Characteristics

7) Variations of Unburnt Hydrocarbon Vs Brake Power

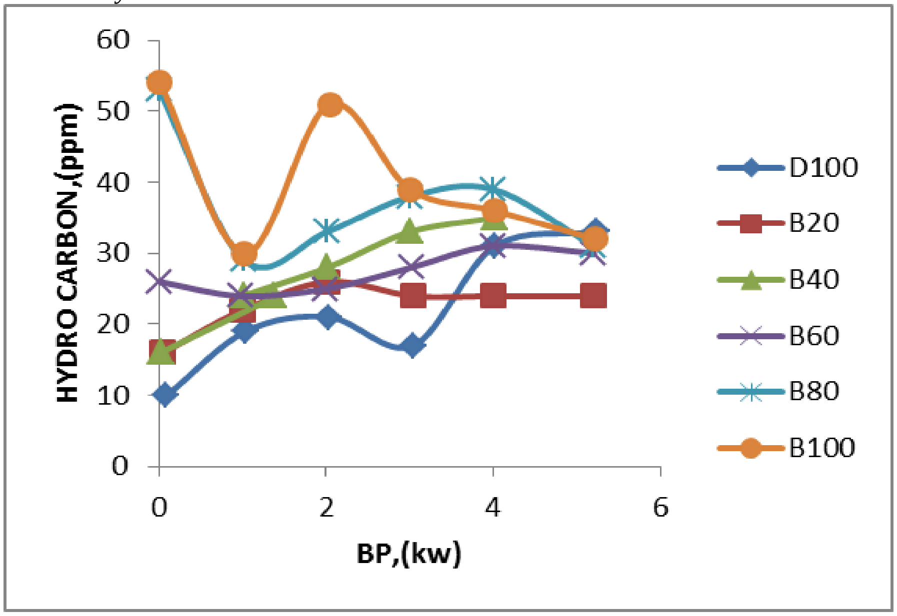

Fig. 10: Variations of Unburnt Hydrocarbon Vs Brake Power

Fig shows the variation of unburnt hydrocarbon with load at for different proportions. hc varies from 10 ppm at no load to 33ppm at full load condition for D100. And also it varies from 54ppm at no load to 33ppm at full load for B100. We can conclude that Hydrocarbon Emissions are significantly lower with Diesel Fuel than the Blends of Plastic Pyrolysis Oil. One is that the fuel spray does not propagate deeper into the combustion chamber and gaseous hydrocarbons remain along the cylinder wall and the crevice volume and left unburned. The other one is unsaturated hydrocarbons present in the B100 which are unbreakable during the combustion process. Unburnt hydrocarbon emission is the direct result of incomplete combustion. It is apparent that the hydrocarbon emission is increasing with the percentage of Diesel mixed in the blend. This may be due to less volatility of plastic pyrolysis oil. Hydrocarbon content of the fuel not equally distributed in the cylinder area and thus some particles remains unburned which creates higher Hydrocarbon Emissions.

8) Variations of Carbon Dioxide Vs Brake Power

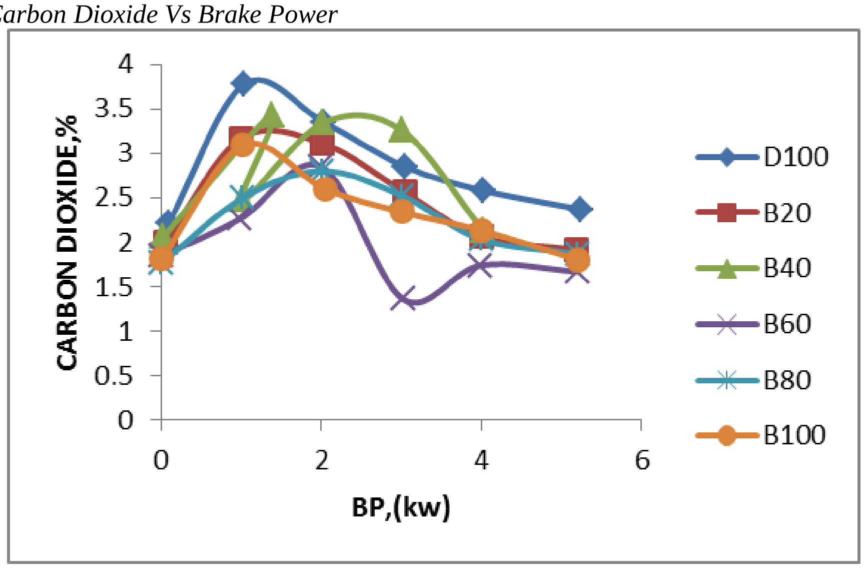

Fig. 11: Variations of Carbon Dioxide Vs Brake Power

Fig shows the variation of carbon dioxide with load at different proportions. At no load conditions B80 has the minimum carbon dioxide emission compared to other blends i.e 1.76% and at load 2 it was 2.8% later as there is a increase in load then the emission decreases finally at full load it was 1.87%. Similarly for D100 at no load condition carbon dioxide emission is 2.21% , and it has higher emission at load 1 i.e 3.78% later at full load it will decreases and reaches to 2.37%. Similarly all blends (B20, B40, B60, B100) also carbon dioxide emissions are decreasing with increasing load.

9) Variations of Carbon Monoxide Vs Brake Power

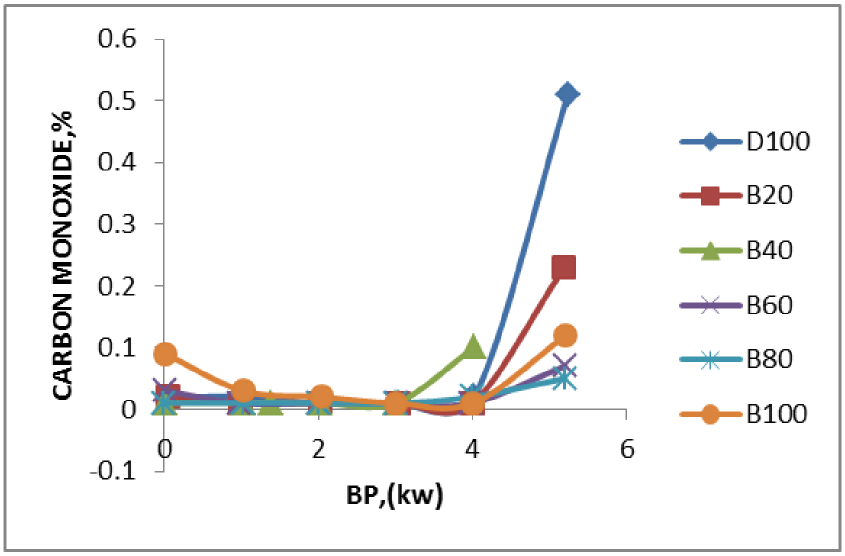

Fig. 12: Variations of Carbon Monoxide Vs Brake Power

Fig shows the variation of carbon monoxide with load for different proportions. At no load condition carbon monoxide varies from 0.01% to 0.05% for full load for B80 and it is the minimum variation .and whereas CO varies from 0.09 at no load to 0.12 at full load for B100. And for 100% diesel the CO varies from 0.02 at no load to 0.52 at full load i.e there is a sudden increase in CO. The reason for this is the fuel air mixture filled inside the cylinder is very lean and some of the mixtures nearer to the wall and crevice volume, the flame will not propagate. Therefore, they do not find time to undergo combustion which results higher CO emission for DTPO-DF blends than that of D100. However, the CO emissions for D100 blends lie below 0.9% which is a maximum value of CO emission from diesel engines.

10) Variations of Oxides of Nitrogen Vs Brake Power

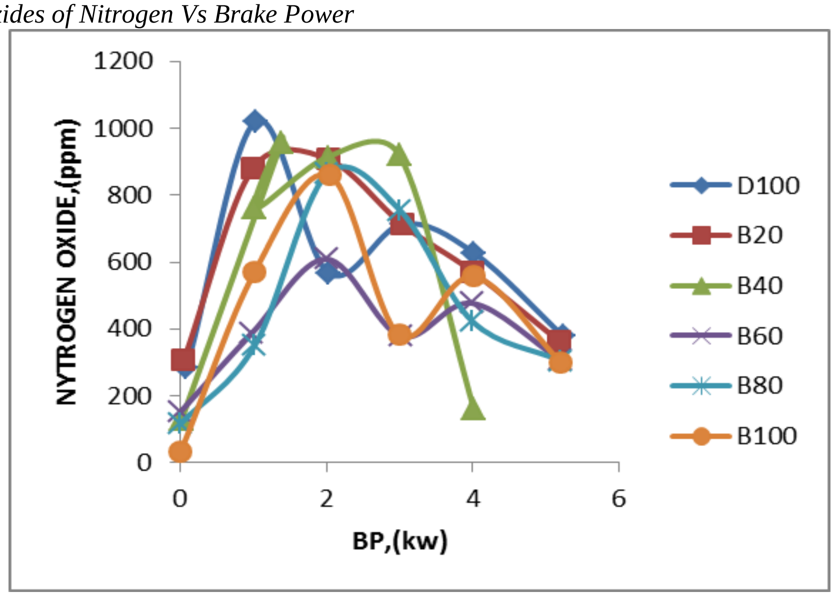

Fig. 13: Variations of Oxides of nitrogen Vs Brake power

Fig shows the variation of oxides of nitrogen with load for different blend proportions. From the graph it is observed that Oxides of nitrogen Emissions are increasing with increase in blend proportion and value becomes much higher in case of 100% blend proportions. AT no load condition B100 has the minimum NOx of 33.whereas at maximum load it has 300. Similarly at no load conditions the other blends (D100, B20, B40, B60, and B80) are having NOx of (284,306,128,153,115). At maximum load conditions (378,362,159,307,305). And D100 has the highest NOx of 1021 at load 1. Two important parameters result in the formation of NOx. One parameter is stoichiometry and the other one is in-cylinder temperature. If the stoichiometry of the combustion is lean, then lower NOx is formed (B100). .

B. Combustion Characteristics

1) Variation of Pressure with Crank angle

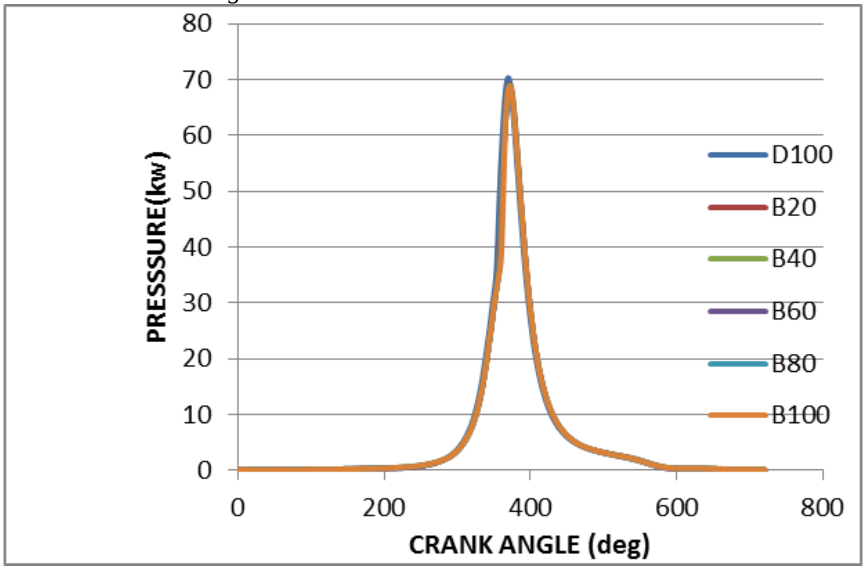

Fig. 14: Variation of Pressure with Crank angle

Fig. shows the typical variation of cylindrical pressure with respect to crank angle. In CI engine the cylindrical pressure is depends on the fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. . And whereas all other blend proportions have the B20(68.99), B40(68.32),B60(67.29),B80(67.41),B100(68.25). And for further crank angles the cylindrical pressure falls below D100. So as the crank angle reaches to 600deg then the pressure reduces to zero. This reduction in cylindrical pressure may be due to lower calorific value and slower combustion rates.

2) Variation of Cumulative heat release with Crank angle

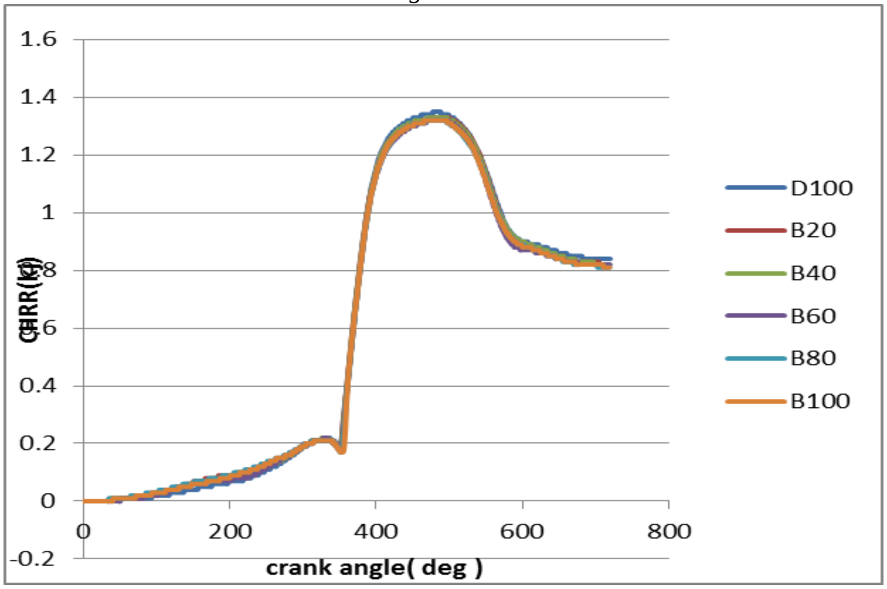

Fig. 15: Variation of Cumulative heat release with Crank angle

The variation of cumulative heat release with crank angle is shown in Figure 7.3.2. The cumulative heat release of B100, B20, B40, B60, B80 is found to be lesser compared to diesel fuel. At zero angles the CHRR value for all blend proportions are zero. At initially there is little decrease in the CHRR; this is due to the ignition of fuel air mixture prepared during the delay period. And as the crank angle increases gradually the value of CHRR increases and at 480deg to 487deg there is a sudden increase in CHRR value for all blends and diesel 100%. .

3) Variation of Net heat release with Crank angle

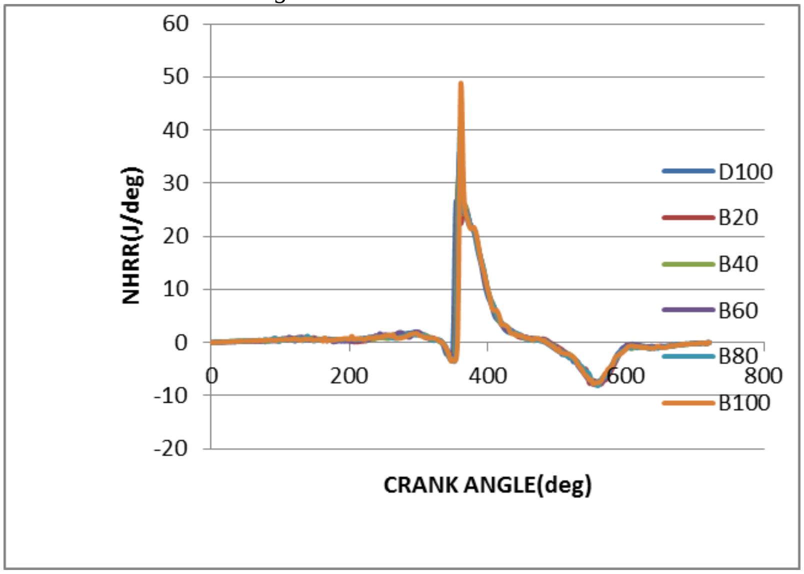

Fig. 16: Variation of Net heat release with Crank angle

The variation in net heat release rate is shown in Figure. The B100 has the higher heat release rate at crank angle 380deg; this may be attributed to low vaporization, high viscosity low peak pressure of the blends compared to that of diesel. The higher density as well as viscosity of the Waste plastic pyrolytic oil (WPPO) blends results in improper mixture formation. This results in poor atomization of the fuel which results in reduced heat release rate of the Waste plastic pyrolytic oil (WPPO) blends by combustion. For further crank angle i.e from 380deg there is a reduction in NHRR for all blends and increase in D100 , this is due to premixed and uncontrolled combustion phase.

4) Variation of Net mass fraction burned with Crank angle

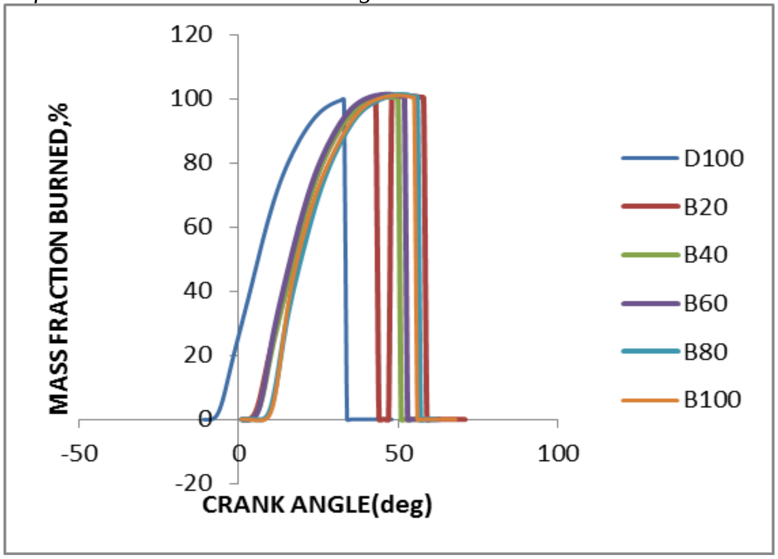

Fig. 17: Variation of Net mass fraction burned with Crank angle

Fig shows that the variation of mass fraction burned with different crank angles. it is observed from the above graph that for all blends at zero crank angle the value pf mass fraction burned is zero , but whereas for D100 it is in negative from certain value i,e -11deg. And there is a gradual increase of MFB for B20 up to the maximum value of 100.97 % at 39deg. And for B40(100.53% at 36deg) , B60(101.42% at 37deg) , B80(101.35% at 38deg), B100(101.07% at 38deg) , D100(99.8% at 33deg). Since from this observation we conclude that B20 has the highest percentage of MFB and D100 has the lowest percentage of MFB comparatively with all other blends. Due to the combustion duration is short for induction flow rate of pyrolysis oil compared to diesel.

VII. RESULT AND DISCUSSION FOR INJECTION PRESSURE 200

A. Variation of Brake Thermal Efficiency with Brake Power

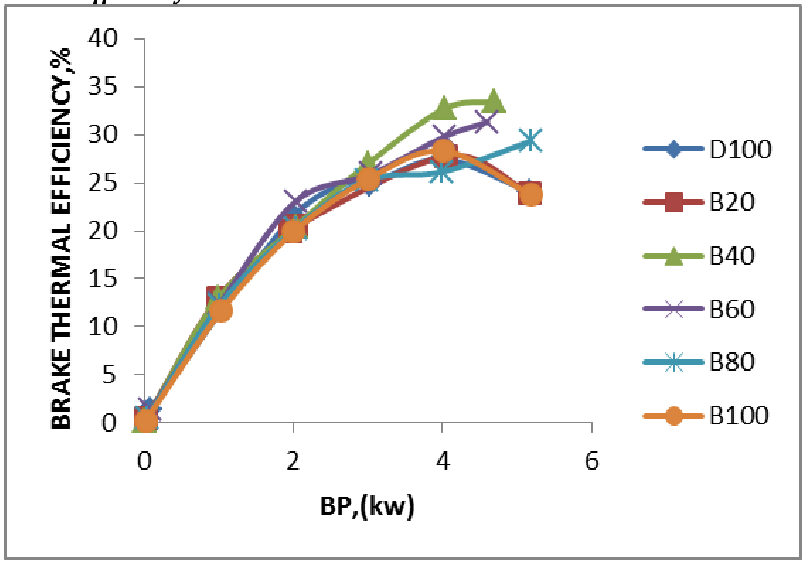

Fig. 18: Variation of Brake Thermal Efficiency with Brake Power

Figure shows the variation of brake thermal efficiency with brake power for various blend proportion with diesel fuel. The efficiency varied from 1.42% at low load to 27.45% at 14.16kg of load and it decrease to 24.07% at full load for diesel fuel. The efficiency varied from 0.48% at lower load to 27.75% at14.16kg of load and it deceases to 23.94% at full load for B20 (PO20) blended with diesel fuel at the injection pressure of 200bar. And also the efficiency varied from 0.2% at lower load to 33.44% at full load for B40 (PO40).the efficiencies for B60, B80 and B100 are 31.33%, 29.31% and 23.74 respectively at full load. It may be observed that the brake thermal efficiency is increased from 24.07% to 33.44% at full load for B20 and B40 respectively, when the fuel injection pressure is 200bar.

B. Variation of Specific Fuel Consumption with Brake Power

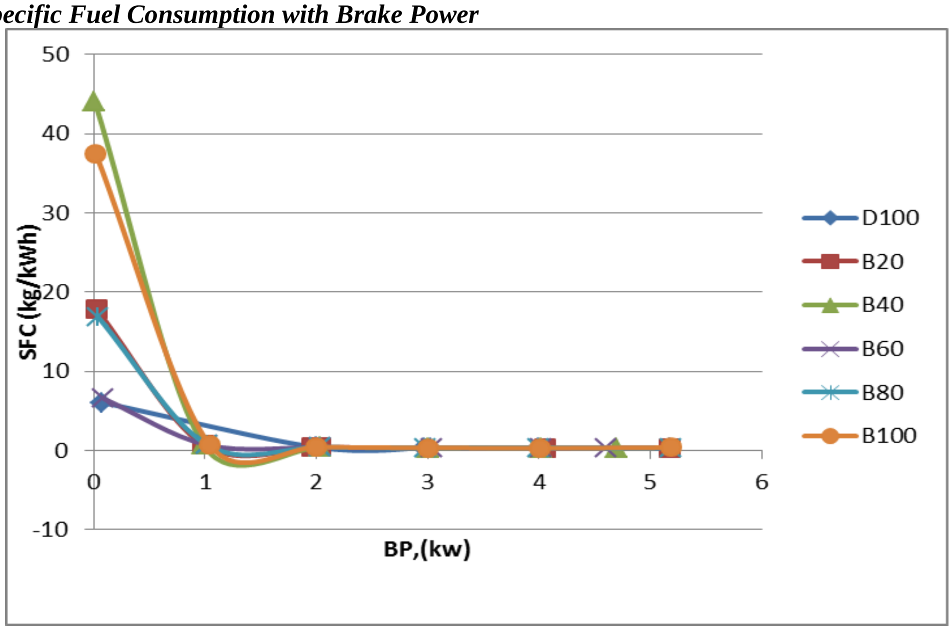

Fig. 19: Variation of Specific fuel consumption with Brake power

Fig. shows the variation in Specific fuel consumption with load for different Blend Proportions. Specific fuel consumption decreases with increase in load. It is very much clear from the graph that Specific fuel consumption is maximum for 40% of blend than any of the Blend Proportion at lower loads. And SFC is maximum for 100% of pyrolysis oil at higher load. Specific fuel consumption is decreasing with increase in Blend proportion of plastic pyrolysis oil in diesel fuel from B20 to B40; this is also because of the same reason for decrease in fuel consumption with increase in blend percentage of plastic pyrolysis oil. Due to higher calorific value of the plastic pyrolysis oil, enough required heat can be produced with lesser amount of fuel. And increases from B40 to B100, due to the lower calorific value of PO-DF blends. The amount of fuel necessary to deliver the same power output with PO-DF blends is higher with increasing the percentage of PO.

C. Variation of Air Fuel Ratio with Brake Power

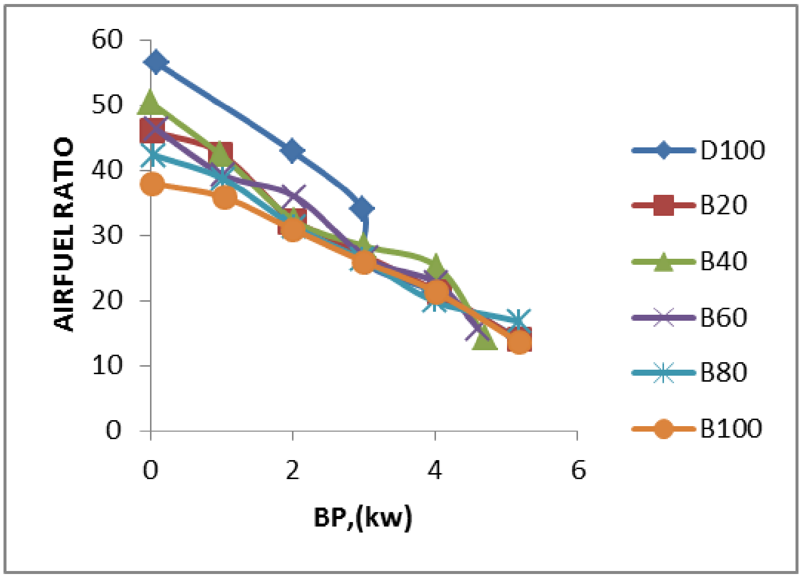

Fig. 20: Variation of Air fuel ratio with Brake power

Fig. shows the air fuel ratio of plastic pyrolytic oil blends and diesel comparing between air fuel ratio and brake power. High latent heat of vaporization and high volatility so it will vaporize easily to form a homogenous mixture with air. B100 is best for low fuel consumption. At no load conditions the D100 has the highest air fuel ratio of 56.45 as compared to any other blend proportions, it seems that the PPO-DF blends has less air fuel ratio compared to diesel fuel at no load condition. .

D. Variation of Mechanical Efficiency with Brake Power

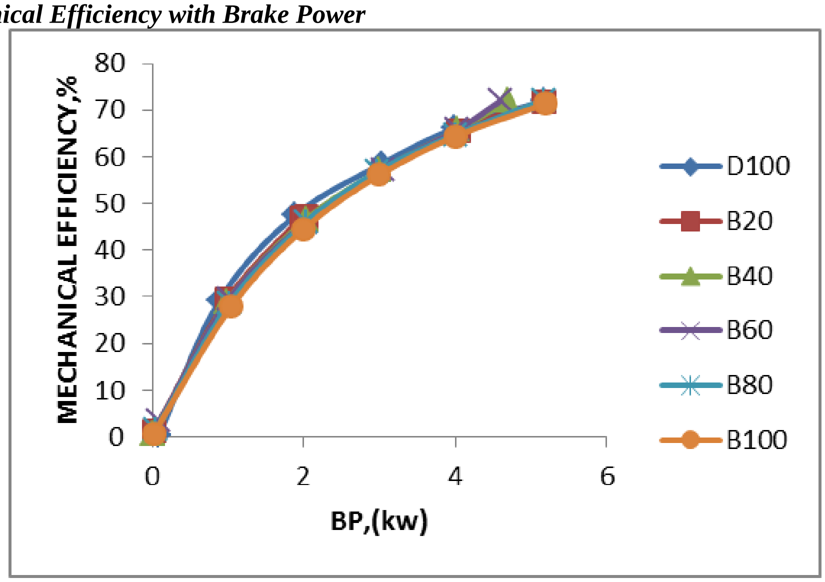

Fig. 21: Variation of Mechanical efficiency with Brake power

Fig. Focuses on the variation of Mechanical Efficiency with loads for various Fuel and Blend Proportions. Mechanical Efficiency increases gradually with increase in loads. At lower loads, mechanical efficiency is minimum and at full load condition, we get maximum mechanical efficiency. Comparing, different Fuels and Blends, we get maximum Mechanical Efficiency for B80.

Increasing Blending ratio from 20% to 80%, gives positive impact on Mechanical Efficiency as it seems increasing. This increase in Mechanical Efficiency reduces after 30% proportion of plastic pyrolysis oil in diesel fuel. It becomes almost constant up to the 100% proportion of plastic pyrolysis oil and efficiencies of 80% and 100% blends are almost similar, which is nearly comparable to diesel fuel. So, in Mechanical Efficiency, the comparison of Mechanical Efficiency for Different Fuel and Blends at different loads is easily visible and understood from the figure.

E. Variation of Volumetric efficiency with Brake power

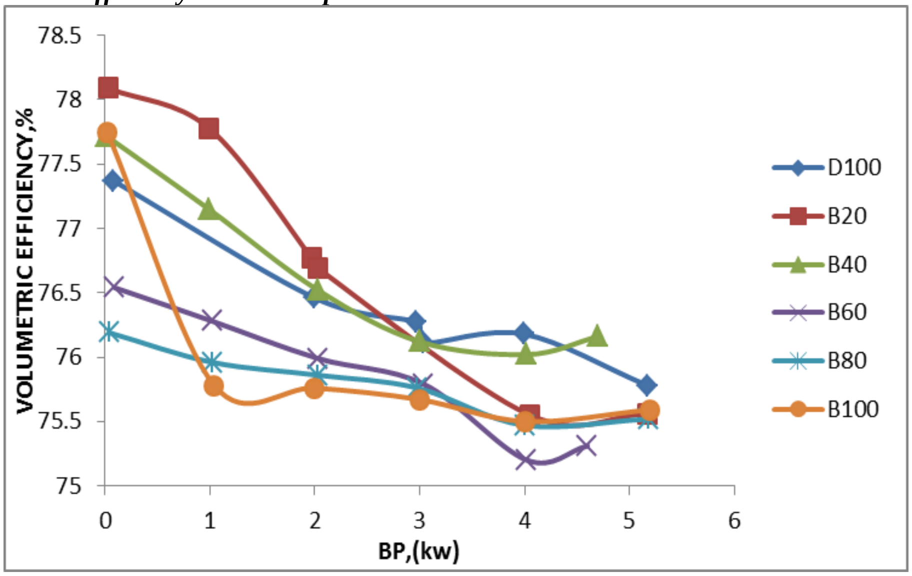

Fig. 22: Variation of Volumetric efficiency with Brake power

The figure shows that the variation of volumetric Efficiency with load for different proportions. At no load conditions the volumetric efficiency is high for B20 compared to B100. B80 has the lowest efficiency of 76.19% at no load conditions compared to others. And at higher loads B40 has the highest efficiency of 76.16%. B60 has the lowest of 75.31%. At load 1 there is a sudden decrease in volumetric efficiency for B100 compared to other blends. The graph for the blends are in zigzag in nature because of breathing of engine for particular combinations that is ratio actually induced at ambient conditions to the swept volume of engine.

F. Variation of Exhaust Gas Temperature with Brake Power

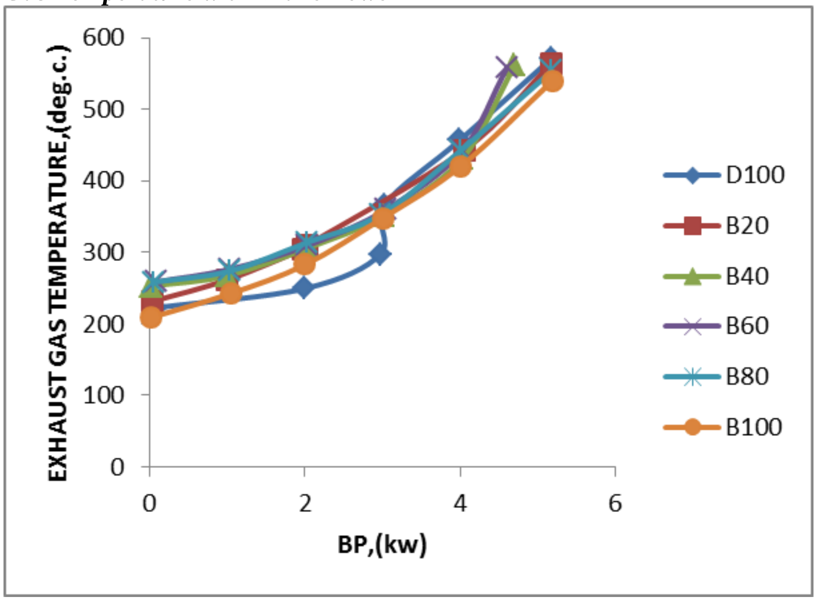

Fig. 23: Variation of Exhaust Gas Temperature with Brake power

Figure shows the exhaust gas temperature variation with brake power. It may be seen that the exhaust gas temperature increases with increasing load and decreases with increase in the blend concentration and the values are lesser compared to DF. The exhaust gas temperature varies from 222.6 °C at no load to 570.62°C at full load for DF whereas it varies from 231.46°C at no load to 563.63°C at full load for B20. For B40 it varies from 252.9 °C at no load to 561.23°C at full load. And it goes on decreasing, for B60,B80 and B100 are 558.63°C, 553.75°C, and 540.14°C respectively at full load. The reasons for lower exhaust gas temperatures for PO- DF blends are due to lower viscosity which results a lesser penetration of the fuel into the combustion chamber and the lesser amount of heat is developed.

G. *Emission Characteristics*

1) Variations of Unburnt Hydrocarbon Vs Brake power

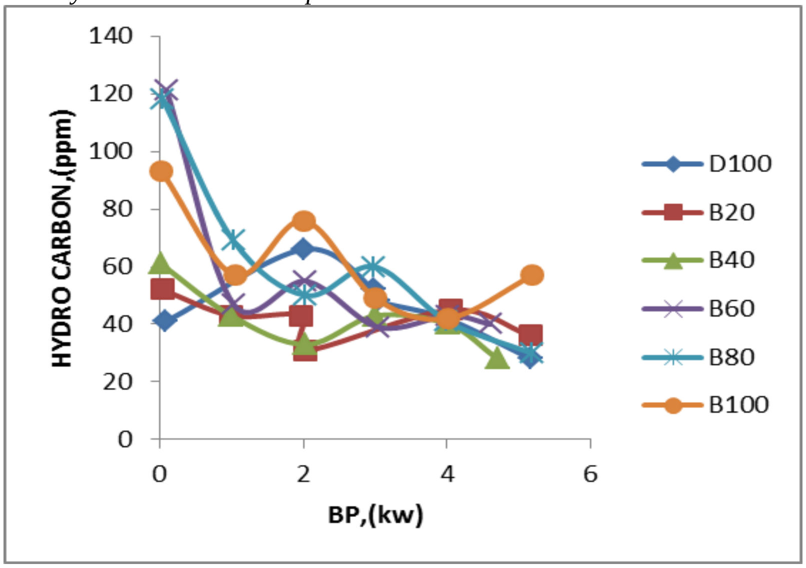

Fig. 24: Variations of Unburnt Hydrocarbon Vs Brake power

Figure shows the variation of Hydrocarbon (HC) emissions for the plastic pyrolysis oil with diesel fuel at different loads. HC emissions for PO-DF are higher compared to DF at full load. Part load values for PO-DF are marginally closer to DF. HC varies from 28 ppm to 66 ppm for DF. It can be observed that for B20, it varies from 31 ppm to 52 ppm, for B40 from 28 ppm to 61 ppm, for B60 from 39 ppm to 121 ppm, for B80 and B100 varies from 30ppm, 42ppm to118ppm, 93ppm respectively. Higher HC emissions are probably due to higher viscosity, density, poor volatility and fuel rich mixtures at higher loads. Part load values for PO-DF are marginally closer to DF. .

2) Variations of Carbon dioxide Vs Brake Power

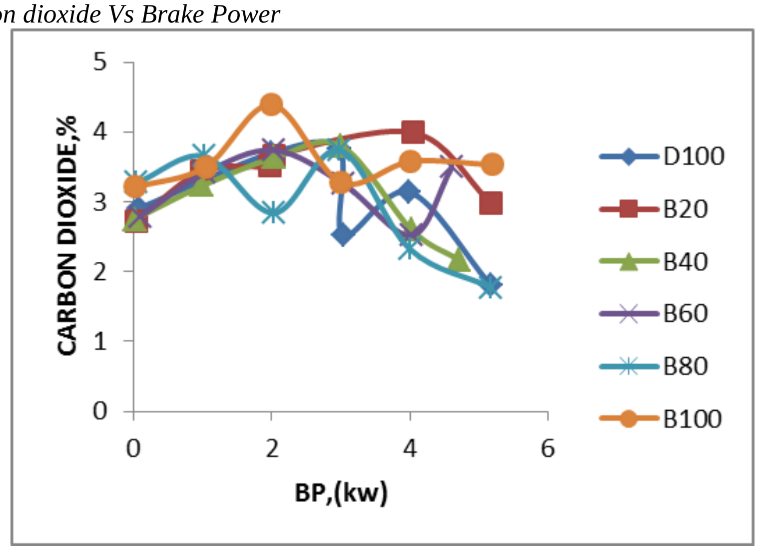

Fig. 25: Variations of Carbon dioxide Vs Brake power

Fig. Shows the variation of carbon dioxide with load at different proportions. At no load conditions B20 has the minimum Carbon dioxide Emission compared to other blends i,e. 2.72% and at load 2 B100 has high i,e 4.39% later there is increase in load then the emission decreases finally at full load it was 3.53% similarly for D100 at no load conditions carbon dioxide emission is 2.91% and it has higher emission at load 1 that is 3.76%, later at full load it will decreases and reaches to 1.8% , similarly for all blends i,e B20,B40,B60,B80 also carbon dioxide emissions are increasing with increase in load. .

3) Variations of Carbon monoxide Vs Brake Power

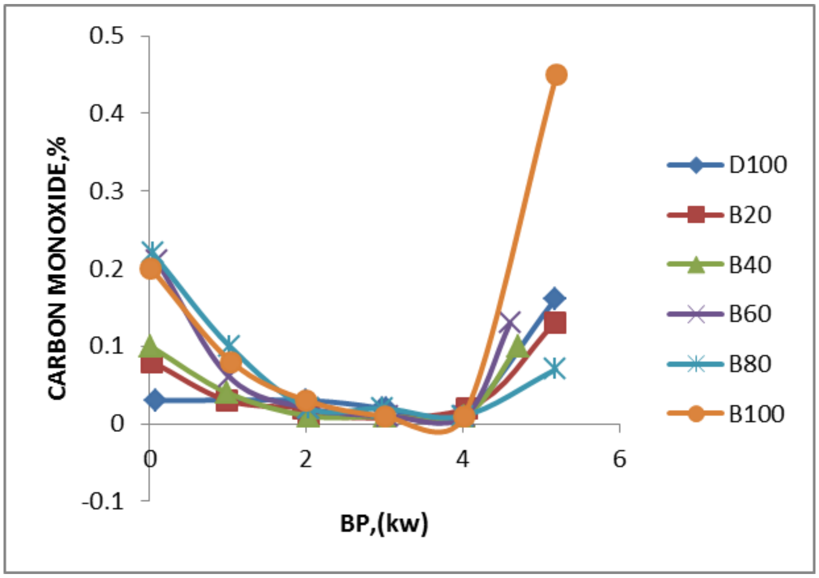

Fig. 26: Variations of Carbon monoxide Vs Brake power

Figure shows the comparison of Carbon monoxide emission with brake power. Generally, CI engines operate with lean mixtures and hence the CO emission would be low. CO emission for the PO-DF blends is less compared to DF. The concentration vary from 0.01% to 0.16% for diesel fuel and 0.01% to 0.13% forB20, whereas it varies from 0.01% to 0.1% for B40.for B60 it varies from 0.01% to 0.21%, and for B80 and B100 it varies from 0.01%,0.01% to 0.22%,0.45% respectively. B40 gives less CO emission compared to any other blended fuels and diesel fuels. B100 gives the maximum CO emission is 0.45% at full load. It is because the fuel air mixture filled inside the cylinder is very lean and some of the mixtures nearer to the wall and crevice volume, the flame will not propagate. .

4) Variations of Oxides of nitrogen Vs Brake Power

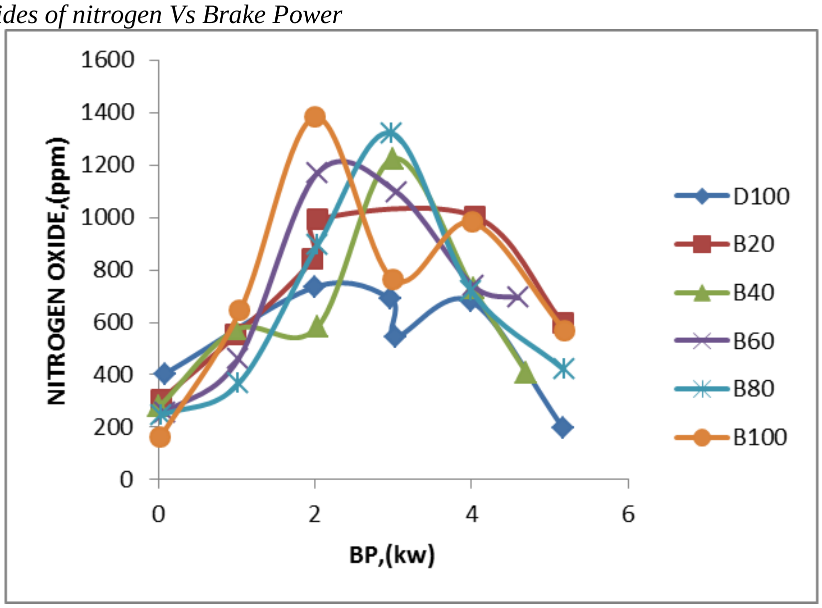

Fig. 27: Variations of Oxides of nitrogen Vs Brake power

NOx emissions are compared and depicted in Figure. NOx varies from 404 ppm at no load to 688 ppm at 14.16kg of load and it sudden decreases to 198ppm at full load for diesel fuel. It can also be observed that NOx varies from 305 ppm at no load to 1003 ppm at 14.16kg of load and decreases to 596 ppm at full load for B20 and for B40 it varies from 279 ppm at no load to 1224 at 10.5kg of load and it decreases to 409ppm at full load. For B60 it varies from 256ppm at no load to 1169ppm at 10.41kg of load and decreases to 693ppm at full load.

H. Combustion Characteristic

1) Variation of Pressure with Crank Angle

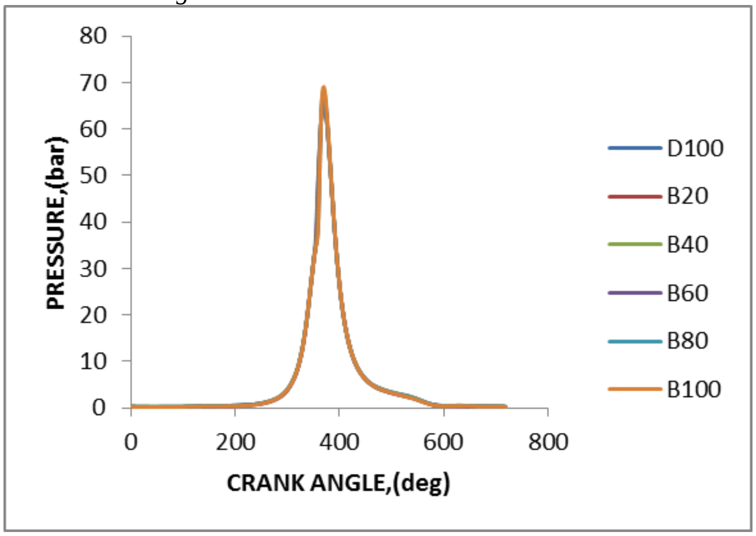

Fig. 28: Variation of pressure with crank angle

Fig. Shows the typical variation of cylindrical pressure with respect to crank angle. In CI engine the cylindrical pressure is depends on the fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. The cylindrical Pressure of D100, B20, B40, B60, B80 and B100 are increases up to the crank angle 370deg and then decreases. The cylindrical pressure of B100 is 69.07bar at the crank angle 370 deg is the highest pressure. Cylindrical pressure of PO-DF blends are highest compared to DF at the crank angle 370deg. due to higher calorific value of PO-DF blended oil. Further crank angles the cylindrical pressure falls below D100.

2) Variation of Cumulative Heat Release with Crank Angle

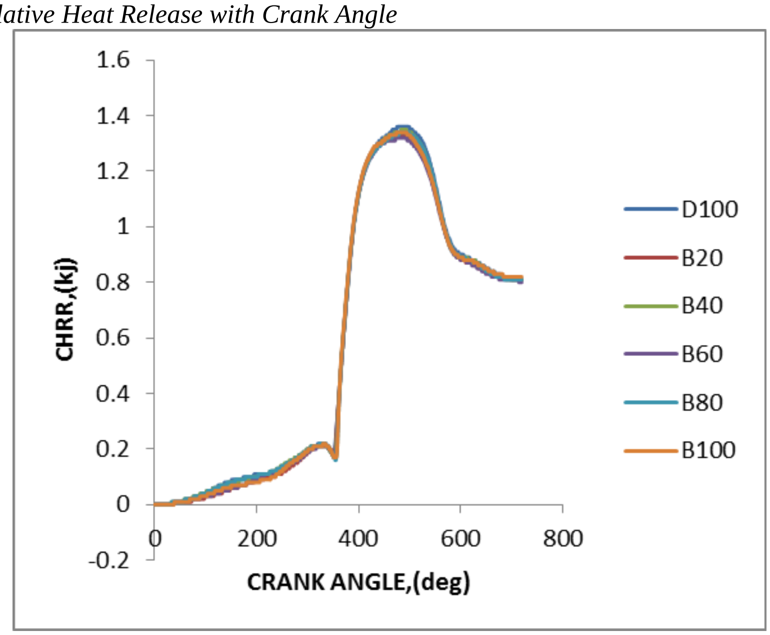

Fig. 29: Variation of Cumulative heat release with Crank angle.

The variation of cumulative heat release rate with crank angle is shown in Figure. The cumulative heat release rate of B100, B20, B40, B60, B80 is found to be lesser compared to diesel fuel. At ZERO angles the CHRR value for all blend proportions are zero. At initially there is little decrease in CHRR; this is due to the ignition of fuel air mixture prepared during the delay period. And as the crank angle increases gradually the value of CHRR increases. And at 475deg to 499deg there is a sudden increases in CHRR value for all blends and diesel 100% but comparatively D100 has the maximum CHRR of 1.36kj compared to other blends at this stage, due to the reason that the fuels with longer ignition delay shows higher rate of heat release at initial stage of combustion and increase in cylinder peak pressure and from that 499deg again there is decrease in the CHRR of all blends.

3) Variation of Net Heat Release Rate with Crank Angle

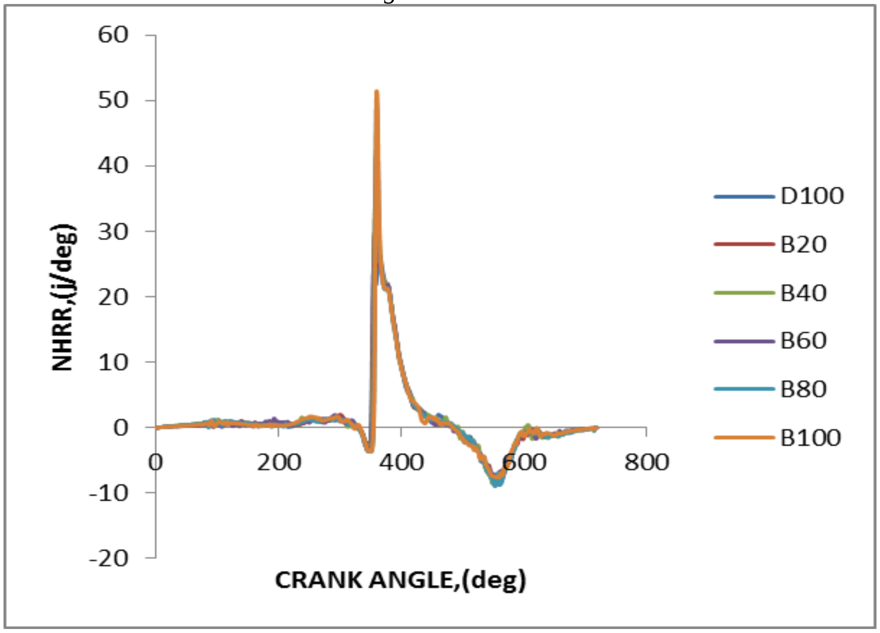

Fig. 30: Variation of net heat release rate with Crank angle

The variation of net heat release rate with crank angle is shown in Figure. The B100 has the higher net heat release rate at crank angle 360deg and for further crank angles the net heat release rate decreases. The net heat release rate increases with increasing blend percentage of PO-DF. .The heat release rate for all other tested fuel was higher than that of the diesel fuel up to the crank angle 360deg, and from 360deg crank angle heat release rate for all other tested fuel was slightly less than that of diesel fuel. This may be attributed to low vaporization, high viscosity and low peak pressure of blends as compared to that of diesel fuel. This is due to premixed and uncontrolled combustion phase. .

4) Variation of Net Mass Fraction Burned with Crank Angle

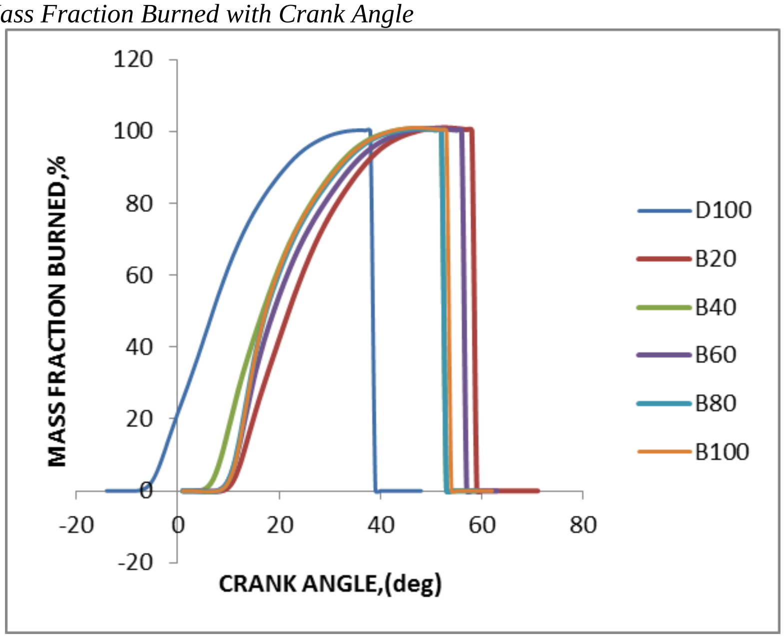

Fig. 31: Variation of net mass fraction burned with Crank angle

Fig shows that the variation of mass fraction burned with different crank angles. it is observed from the above graph that for all blends at zero crank angle the value of mass fraction burned is zero , but whereas for D100 it is in negative from certain value i,e -11deg . And there is a gradual increase of MFB for B20 upto the maximum value of 100.97 % at 36deg. And for B40(100.79 at 37deg) , B60(101.86% at 38deg) , B80(100.77% at 38deg), B100(101.04% at 36deg) , D100(100.33% at 36deg). Since from this observation we conclude that B60.

VIII. Conclusion

- Due to higher calorific value of the plastic pyrolysis oil, enough required heat can be produced with lesser amount of fuel. And thus specific fuel consumption consistently decreases with increase in percentage of plastic pyrolysis oil in diesel fuel for both 180 and 200 pressures.
- Pyrolysis process was one of the best methods to treat waste plastic under solid waste management technique.
- Unburned hydrocarbon emission of waste plastic pyrolysis oil is less than that of diesel; for the different load.
- The exhaust gas temperature for waste plastic pyrolysis oil is higher than diesel for engine performance.
- With waste plastic pyrolysis oil there was increase in CO emission level compared to diesel Operation for both the pressures.
- Waste plastic pyrolysis oil can be used alternate fuel to the diesel.
- The lower in cylinder temperature is the reason for the lower NOX levels at the full loads even though there is a difference in pressures.

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