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Effect of Blend Ratio of Plastic Pyrolysis Oil and Diesel Fuel on the Performance of Single Cylinder CI Engine

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Abstract

Depleting quantity of Conventional Fuel has been focused as a greater problem these days. Day by day, quantity of Petroleum, Crude Oil has more utilisation and lesser production. Increasing use of Petrol & Diesel has made the people of the world to think for some alternative way for energy resources. At the same time. Other rising problem against the people of the world is increase in plastic waste and recycling of the same. Both of the issues are focused and efforts are made to get optimum solution. An experimental setup has been prepared for Plastic Pyrolysis oil and Diesel Blend to be used in single cylinder, 4-stroke CI engine. Plastic Pyrolysis oil is obtained from plastic waste by pyrolysis process. Pyrolysis process is a thermo-chemical decomposition of organic matter in absence of oxygen. Blending of pyrolysis oil with diesel helps to reduce the consumption of diesel fuel. The variation in the Blending ratio of Plastic Pyrolysis Oil and Diesel fuel affects the engine performance as well as exhaust emission data. To understand the variation in Engine performance, different Blends of Plastic Pyrolysis Oil and Diesel Fuel were prepared and experimentations were done by running these blends separately in engine with various loads at Injection Pressure of 190 bar. Blends were prepared for 10%, 20%, 30% and 50% of Plastic Pyrolysis Oil with 90%, 80%, 70% and 50% of Diesel Fuel respectively. Effect of Engine performance of each were compared by Graphical representation of different performance parameters.

Keywords: Plastic Pyrolysis Oil, Blend Ratio, Engine Performance, Diesel Fuel, CI Engine

I. INTRODUCTION

Use of plastic in our daily activities seemed to be increased from years. In an online article, dated April 4, 2013 of the daily newspaper The Times of India of the author Dhananjay Mahapatra it was stated that ‘"We are sitting on a plastic time bomb," the Supreme Court said on Wednesday after the Central Pollution Control Board (CPCB) informed it that India generates 56 lakh tonnes of plastic waste annually, with Delhi accounting for a staggering 689.5 tonnes a day. "Total plastic waste which is collected and recycled in the country is estimated to be 9,205 tonnes per day (approximately 60% of total plastic waste) and 6,137 tonnes remain uncollected and littered," the CPCB said. [1]

The energy crisis as well as the environmental degradation are the major problems mankind is facing today. Demand of energy has been increased day by day because of the increased population on the earth. By the year 2100, the world population is expected to be in excess of 12 billion and it is essential that the demand of energy will be increased by five times of what it is now. According to the world energy report, we get around 80% of our energy from conventional fossil fuels like oil (36%), natural gas (21%), and coal (23%). It is well known that the time is not so far when all these sources will be completely exhausted.

To overcome both of the issues stated above, the alternative fuel i.e. Plastic Pyrolysis Oil can be used in CI Engine. As the CI Engine generally available are designed to work effectively with Diesel Fuel only, to use Plastic Pyrolysis Oil in the CI Engine, one need to blend it with Diesel Fuel. The same has been carried out in this research work. Blending of 10%, 20%, 30% and 50% of Plastic Pyrolysis Oil with 90%, 80%, 70% and 50% of Diesel Fuel respectively were prepared to be used in CI engine. And effect of these different blend ratios on performance of CI Engine were compared through graphical representation of different Performance parameters against load.

II. LITERATURE SURVEY

Effect of Blend ration of different alternative fuel on Engine Performance were carried out. Number of researchers have been presented experiments with different alternative fuels for the IC engine. It is concluded that biodiesel of different vegetable oils like karanja oil, mahua oil, Jatropha oil and Gases like CNG, LPG, hydrogen etc. can be used as an alternative fuels for IC engines.

Pritinika Behera et al. [2] [2013] in their research paper have stated their experiments on DI diesel engine with transformer oil. The experiments were done for single cylinder CI engine fuelled with used transformer oil (UTO) and Diesel Blends on varying concentration of UTO from 10% to 60%, out of which UTO40 was found to be optimum blend. In this research, ignition delay of UTO – Diesel blend was found to be shorter by 1 – 3 °CA than the same of Diesel Fuel, while HC, CO and NO emissions were found to be higher with 5.9% lower smoke value than those of Diesel Fuel. S. Murugan et al. [3] [September 2012], in their research paper of Diesel engine fuelled with Tyre Pyrolysis Oil (TPO), have stated that the engine performs better with lower emissions when DEE was admitted at the rate of 170 g/h with TPO and the peak pressure for TPO – DEE with 130 g/h flow rate is higher by about 3 bar than DF at full load. The thermal efficiency and NOx emissions were found to be reduced by 2.5% & 5% respectively for TPO – DEE than the diesel fuel, while HC, CO and smoke emissions were found to be higher for TPO–DEE operation by 2%, 4.5% and 38% respectively than diesel mode. Ignition delay was increased by 2.8 °CA for TPO – DEE than diesel fuel. Abhishek Sharma et al. [4] [March 2013], in their Investigation on the behaviour of a DI diesel engine fuelled with Jatropha Methyl Ester (JME) and Tyre Pyrolysis Oil (TPO) blends, had used five different blends of varying TPO of concentration from 10% to 50%. There was a reduction in the efficiency with 30%, 40% and 50% TPO in the blend at full load. It was found that JMETPO blend could be directly used as a fuel without any engine modification. Among all the blends, JMETPO20 was found to deliver the optimum results. For JMETPO20 CO, HC, Smoke emissions, cylinder peak pressure and combustion duration were found to be reduced by 9.09%, 8.6%, 26%, 1 bar and 0.54 °CA respectively at full load, while BSEC and NO_X emissions were found to be increased by 7.8% and 24% respectively. Ignition delay and brake thermal efficiency remains almost same as diesel fuel for JMETPO20. Rasim Behcet et al. [5] [June 2011], used anchovy fish oil as a blended fuel in CI engine. In this research, it was found decrease in engine torque, engine power, CO_2, CO, and HC emissions by 4.14%, 5.16%, 4.576%, 21.3% and 33.42% respectively for fish oil methyl ester (FOME) and its blends, while increase in SFC, O_2, NO_X and exhaust gas by 4.96%, 9.63%, 29.37% and 7.54% were found.

III. PLASTIC PYROLYSIS OIL

Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen (or any halogen). It involves the simultaneous change of chemical composition and physical phase, and is irreversible. The word is coined from the Greek-derived elements pyro "fire" and lysis "separating".

Pyrolysis differs from other high-temperature processes like combustion and hydrolysis in that it usually does not involve reactions with oxygen, water, or any other reagents. In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs. Bio-oil is produced via pyrolysis, a process in which biomass is rapidly heated to 450–500°C in an oxygen-free environment and then quenched, yielding a mix of liquid fuel (pyrolysis oil), gases, and solid char. Variations in the pyrolysis method, biomass characteristics, and reaction specifications will produce varying percentages of these three products. Several technologies and methodologies can be used for pyrolysis, including circulating fluid beds, entrained flow reactors, multiple hearth reactors, or vortex reactors. The process can be performed with or without a catalyst or reductant.

The original biomass feedstock and processing conditions affect the chemical properties of the pyrolysis oil, but it typically contains a significant amount of water (15%–30% by weight), has a higher density than conventional fuel oils, and exhibits a lower pH (2–4). The heating value of pyrolysis oil is approximately half that of conventional fuel oils, due in part to its high water and oxygen content, which can make it unstable until it undergoes further processing. Bio-oil can be hydro-treated to remove the oxygen and produce a liquid feedstock resembling crude oil (in terms of its carbon/hydrogen ratio), which can be further hydro-treated and cracked to create renewable hydrocarbon fuels and chemicals. Hydro-treating stabilizes the bio-oil preventing molecule-to-molecule and molecule-to-surface reactions and eventually produces a finished blend-stock for fuels. Bio-oil can be deoxygenated from its high initial oxygen content of 35-45 percent by weight (wt%) on a dry basis all the way down to 0.2 wt%. [6]

Donglei Wu et al. [7] [February 2010] produced experimental setup for low temperature conversion of plastic waste into light hydrocarbons. For this purpose 1 litre volume, energy efficient batch reactor was manufactured locally and tested for pyrolysis of waste plastic. The feedstock for reactor was 50 g waste polyethylene. The average yield of the pyrolytic oil, wax, pyrogas and char from pyrolysis of PW were 48.6, 40.7, 10.1 and 0.6%, respectively, at 275 ◦C with non-catalytic process. Using catalyst the average yields of pyrolytic oil, pyrogas, wax and residue (char) of 50 g of PW was 47.98, 35.43, 16.09 and 0.50%, respectively, at operating temperature of 250 ◦C.

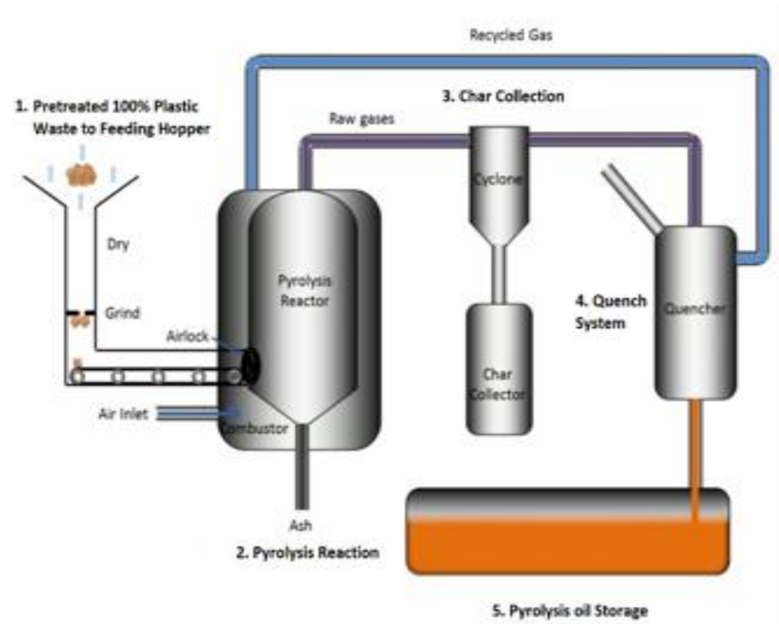

Fig. 1: Production of Plastic Pyrolysis Oil

The steps involved in conversion of plastic waste into liquid fuel are shown in fig. 1 & description is given below:

- Mechanical segregation of plastic waste from mixed MSW dump yard/storage.
- Transportation of segregated plastic waste through conveyor belt for optical segregation. Optical segregation of plastic waste is done (only HD, LD, PP and multilayer packaging except PVC). Shredding of plastic waste and dislodging dust and impurities.
- Transportation of segregated (100% plastic waste) into feeding hopper (reactor). Feeding of plastic waste into reactor for random depolymerisation in presence of additives.
- Produced raw gases are sent to char collector where solid char particles are separated from gases. Char collector contains a cyclone coil to separate char particles from gases.
- After that, raw gases are sent to quench system or condenser to separate recycled gases and Pyrolysis oil.

Plastic Pyrolysis Oil used for this research work was tested in certified laboratory for its properties and test results are stated in the table 1 given below.

Table – 1
Properties of Plastic Pyrolysis Oil

SR NO	*TEST TYPE*	*TEST RESULT*	*UNIT*
1	*Acidity, Inorganic*	*NIL*	*N/A*
2	*Appearance*	*DARK RED*	*Visual*
3	*Kinematic Viscosity cSt at 40 °c*	*1.69cSt*	*cSt*
4	*Flash point °C*	*22*	*°C*
5	*Fire Point °C*	*26*	*°C*
6	*Gross Calorific Value*	*10980*	*Cal/kg*
7	*Density*	*0.788*	*gm/ml*
8	*Oil Impurity*	*0.01%*	*% by Wt.*
9	*Water %*	*40 ppm*	*% by Wt.*
10	*Pour Point*	*Above -2*	*°C*
11	*Sulphur*	*0.01*	*% by mass*
12	*Ash*	*0.001*	*% by mass*
13	*Sediment*	*0.001*	*% by Wt.*

IV. EXPERIMENTAL SETUP

The setup consists of single cylinder, four stroke, multi-fuel, research engine connected to eddy type dynamometer for loading. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to Diesel with some necessary changes. In both modes the compression ratios can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. Fig. 2: shows the experimental setup.

Fig. 2: Experimental Setup

Table – 2
Engine Specifications

Number of Cylinders	*Single cylinder*
Number of Strokes	*4*
Swept Volume	*552.64 cc*
Cylinder Diameter	*80 mm*
Stroke Length	*110 mm*
Connecting Rod Length	*234 mm*
Orifice Diameter	*20 mm*
Dynamometer Rotor Radius	*141 mm*
Fuel	*Diesel*
Power	*3.7 kw*
Speed	*1500 rpm*
Compression Ratio Range	*12 to 18*
Inj. Point variation	*0 to 25 BTDC*

The injection point and spark point can be changed for research tests. Setup is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle measurements. These signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The setup has stand-alone panel box consisting of air box, two fuel flow measurements, process indicator and hardware interface. Rotameters are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement.

The Experimental setup is utilised to observe Variable Compression Ratio (VCR) engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance and combustion analysis. Lab view based Engine Performance Analysis software package “Engine soft” is provided for on line performance evaluation.

The engine specifications used in above stated setup are given in table 2.

V. EXPERIMENTAL METHODOLOGY

The steps involved in Experimental methodology are given below:

1) Before starting of Experiment with any of the selected Injection Pressures, necessary overhauling and reconditioning practice were done including replacement of piston rings by the authorised service executive provided by manufacturer.
2) Water supply was initiated along with the starting of Engine. Water Head was kept maintained at 7.5 cm and Fuel supply line was checked for any leakages.

3) According to IS: 10000 Part V, Constant speed engine was kept running at idling condition for 2 hours with Blended fuel, before taking the readings.
4) After completing Engine running at idling conditions, Injection Pressure was checked whether it is as per the reading conditions or not.
5) Load was set to desired condition and Exhaust Probe of Fire Gas Analyser was inserted into the Exhaust pipe of Engine. Exhaust Gas Analyser was kept initially ready by completing fresh air purge and Leak test. The procedure was continued approximately 10 minutes on the same load and then readings of Exhaust gas Analyser were taken.
6) Meanwhile Engine RPM were measured by Tachometer along with measurement of Temperature and Relative Humidity by digital Hygrometer. Atmospheric pressure was assumed to be 100 kPA.
7) At the end of the 10 minutes measurement, FC was measured by setting stop watch for 2 minutes.
8) Steps 4 to 7 were repeated for another load. The whole procedure was repeated for the experiments with another Injection Pressure range.

VI. RESULT DATA

Calculated performance parameters from the experiments performed for each of the blend ratio i.e. P10D90 (10% Plastic Pyrolysis Oil – 90% Diesel), P20D80 (20% Plastic Pyrolysis Oil – 80% Diesel), P30D70 (30% Plastic Pyrolysis Oil – 70% Diesel) and P50D50 (50% Plastic Pyrolysis Oil – 50% Diesel) are given separately in table 1, table 2, table 3 and table 4 respectively below.

Table – 3
Performance Data of Engine Experiment with P10D90

IP (kW)	*BP (kW)*	*FP (kW)*	*IMEP (bar)*	*BMEP (bar)*	*FMEP (bar)*	*IThEff (%)*	*BThEff (%)*	*SFC (kg per kWh)*	*Fuel (kg/h)*	*Torque (Nm)*	*Mech Eff. (%)*
1.953	*0.000*	*1.953*	*2.893*	*0.000*	*2.893*	*63.654*	*0.000*	*NA*	*0.261*	*0.000*	*0.000*
2.164	*0.211*	*1.953*	*3.219*	*0.314*	*2.905*	*64.957*	*6.328*	*1.356*	*0.283*	*1.382*	*9.742*
2.374	*0.421*	*1.953*	*3.540*	*0.627*	*2.913*	*64.981*	*11.511*	*0.745*	*0.310*	*2.764*	*17.714*
2.586	*0.632*	*1.953*	*3.864*	*0.945*	*2.919*	*65.536*	*16.027*	*0.534*	*0.335*	*4.145*	*24.455*
2.795	*0.841*	*1.953*	*4.185*	*1.260*	*2.925*	*64.179*	*19.321*	*0.443*	*0.370*	*5.527*	*30.106*
2.999	*1.045*	*1.953*	*4.509*	*1.572*	*2.937*	*62.187*	*21.680*	*0.395*	*0.410*	*6.909*	*34.862*
3.210	*1.257*	*1.953*	*4.848*	*1.898*	*2.950*	*61.028*	*23.896*	*0.358*	*0.447*	*8.291*	*39.156*
3.415	*1.461*	*1.953*	*5.174*	*2.214*	*2.960*	*63.159*	*27.031*	*0.316*	*0.459*	*9.673*	*42.798*
3.614	*1.661*	*1.953*	*5.507*	*2.531*	*2.976*	*66.133*	*30.391*	*0.281*	*0.464*	*11.054*	*45.955*
3.802	*1.849*	*1.953*	*5.851*	*2.845*	*3.006*	*65.052*	*31.633*	*0.270*	*0.497*	*12.436*	*48.628*
4.012	*2.059*	*1.953*	*6.192*	*3.177*	*3.014*	*64.149*	*32.917*	*0.259*	*0.531*	*13.818*	*51.313*
4.218	*2.265*	*1.953*	*6.542*	*3.512*	*3.030*	*63.861*	*34.287*	*0.249*	*0.561*	*15.200*	*53.690*

Table – 4
Performance Data of Engine Experiment with P20D80

IP (kW)	*BP (kW)*	*FP (kW)*	*IMEP (bar)*	*BMEP (bar)*	*FMEP (bar)*	*IThEff (%)*	*BThEff (%)*	*SFC (kg per kWh)*	*Fuel (kg/h)*	*Torque (Nm)*	*Mech Eff. (%)*
1.832	*0.000*	*1.832*	*2.679*	*0.000*	*2.679*	*64.409*	*0.000*	*NA*	*0.240*	*0.000*	*0.000*
2.050	*0.217*	*1.832*	*3.011*	*0.319*	*2.692*	*67.851*	*7.195*	*1.185*	*0.254*	*1.382*	*10.603*
2.266	*0.433*	*1.832*	*3.340*	*0.639*	*2.701*	*62.296*	*11.912*	*0.716*	*0.306*	*2.764*	*19.121*
2.478	*0.646*	*1.832*	*3.676*	*0.958*	*2.718*	*62.590*	*16.312*	*0.523*	*0.333*	*4.145*	*26.061*
2.692	*0.859*	*1.832*	*4.001*	*1.277*	*2.723*	*63.734*	*20.348*	*0.419*	*0.356*	*5.527*	*31.926*
2.902	*1.070*	*1.832*	*4.331*	*1.597*	*2.735*	*64.254*	*23.685*	*0.360*	*0.380*	*6.909*	*36.862*
3.113	*1.280*	*1.832*	*4.658*	*1.916*	*2.742*	*61.702*	*25.378*	*0.336*	*0.425*	*8.291*	*41.130*
3.320	*1.487*	*1.832*	*4.989*	*2.235*	*2.754*	*63.590*	*28.491*	*0.299*	*0.440*	*9.673*	*44.805*
3.528	*1.695*	*1.832*	*5.316*	*2.554*	*2.761*	*63.303*	*30.421*	*0.280*	*0.469*	*11.054*	*48.056*
3.743	*1.911*	*1.832*	*5.652*	*2.885*	*2.767*	*62.563*	*31.937*	*0.267*	*0.504*	*12.436*	*51.048*
3.951	*2.119*	*1.832*	*5.979*	*3.206*	*2.773*	*65.080*	*34.898*	*0.244*	*0.511*	*13.818*	*53.624*
4.167	*2.335*	*1.832*	*6.332*	*3.547*	*2.784*	*64.580*	*36.182*	*0.235*	*0.543*	*15.200*	*56.026*

Table – 5
Performance Data of Engine Experiment with P30D70

IP (kW)	*BP (kW)*	*FP (kW)*	*IMEP (bar)*	*BMEP (bar)*	*FMEP (bar)*	*IThEff (%)*	*BThEff (%)*	*SFC (kg per kWh)*	*Fuel (kg/h)*	*Torque (Nm)*	*Mech Eff. (%)*
1.679	*0.000*	*1.679*	*2.509*	*0.000*	*2.509*	*61.336*	*0.000*	*NA*	*0.228*	*0.000*	*0.000*
1.894	*0.215*	*1.679*	*2.839*	*0.322*	*2.516*	*65.004*	*7.385*	*1.150*	*0.243*	*1.382*	*11.361*

2.107	*0.428*	*1.679*	*3.173*	*0.645*	*2.528*	*60.164*	*12.229*	*0.695*	*0.292*	*2.764*	*20.326*
2.317	*0.638*	*1.679*	*3.512*	*0.967*	*2.544*	*60.565*	*16.686*	*0.509*	*0.319*	*4.145*	*27.551*
2.527	*0.848*	*1.679*	*3.843*	*1.290*	*2.553*	*62.221*	*20.886*	*0.407*	*0.339*	*5.527*	*33.567*
2.735	*1.056*	*1.679*	*4.176*	*1.612*	*2.564*	*61.946*	*23.917*	*0.355*	*0.368*	*6.909*	*38.610*
2.941	*1.262*	*1.679*	*4.506*	*1.933*	*2.573*	*59.466*	*25.512*	*0.333*	*0.413*	*8.291*	*42.902*
3.147	*1.468*	*1.679*	*4.836*	*2.255*	*2.580*	*61.795*	*28.822*	*0.295*	*0.425*	*9.673*	*46.642*
3.353	*1.674*	*1.679*	*5.163*	*2.578*	*2.586*	*60.913*	*30.409*	*0.279*	*0.459*	*11.054*	*49.922*
3.555	*1.876*	*1.679*	*5.495*	*2.900*	*2.595*	*60.394*	*31.873*	*0.267*	*0.491*	*12.436*	*52.775*
3.753	*2.074*	*1.679*	*5.830*	*3.222*	*2.608*	*63.442*	*35.063*	*0.242*	*0.494*	*13.818*	*55.267*
3.943	*2.264*	*1.679*	*6.173*	*3.544*	*2.629*	*61.731*	*35.444*	*0.240*	*0.533*	*15.200*	*57.417*

Table – 6
Performance Data of Engine Experiment with P50D50

IP (kW)	*BP (kW)*	*FP (kW)*	*IMEP (bar)*	*BMEP (bar)*	*FMEP (bar)*	*IThEff (%)*	*BThEff (%)*	*SFC (kg per kWh)*	*Fuel (kg/h)*	*Torque (Nm)*	*Mech Eff. (%)*
1.620	*0.000*	*1.620*	*2.398*	*0.000*	*2.398*	*64.301*	*0.000*	*NA*	*0.207*	*0.000*	*0.000*
1.828	*0.208*	*1.620*	*2.728*	*0.310*	*2.418*	*67.034*	*7.625*	*1.129*	*0.224*	*1.382*	*11.375*
2.035	*0.414*	*1.620*	*3.047*	*0.621*	*2.426*	*62.398*	*12.711*	*0.677*	*0.267*	*2.764*	*20.370*
2.238	*0.618*	*1.620*	*3.368*	*0.930*	*2.438*	*68.028*	*18.789*	*0.458*	*0.270*	*4.145*	*27.619*
2.440	*0.820*	*1.620*	*3.692*	*1.240*	*2.452*	*66.918*	*22.482*	*0.383*	*0.299*	*5.527*	*33.597*
2.643	*1.022*	*1.620*	*4.027*	*1.558*	*2.469*	*69.647*	*26.947*	*0.319*	*0.311*	*6.909*	*38.691*
2.836	*1.216*	*1.620*	*4.361*	*1.870*	*2.492*	*68.827*	*29.506*	*0.291*	*0.338*	*8.291*	*42.870*
3.035	*1.414*	*1.620*	*4.680*	*2.181*	*2.499*	*68.704*	*32.022*	*0.268*	*0.362*	*9.673*	*46.609*
3.230	*1.610*	*1.620*	*5.002*	*2.493*	*2.509*	*68.958*	*34.365*	*0.250*	*0.384*	*11.054*	*49.835*
3.431	*1.811*	*1.620*	*5.341*	*2.819*	*2.522*	*65.762*	*34.707*	*0.247*	*0.428*	*12.436*	*52.777*
3.623	*2.003*	*1.620*	*5.668*	*3.133*	*2.535*	*67.153*	*37.122*	*0.231*	*0.442*	*13.818*	*55.280*
3.819	*2.198*	*1.620*	*5.987*	*3.446*	*2.540*	*63.769*	*36.711*	*0.234*	*0.491*	*15.200*	*57.570*

VII. GRAPHICAL REPRESENTATION AND DISCUSSION

A. Fuel Consumption:

Fig. 3 shows the variation of Fuel Consumption with Engine loads for various blend proportions in the diesel Fuel. From the figure given, we can analyse the variation of Fuel Consumption with varying load. As load increases, fuel consumption increases. Plastic Pyrolysis Oil is added as a blended fuel in proportion of 10%, 20%, 30% and 50% with diesel Fuel. It is clearly seen from the graph that fuel consumption in 20% Blend i.e. P20D80 Fuel, is quite similar to Diesel fuel. Fuel consumption in 10% Blend is a bit higher than Diesel fuel for medium loads and at higher loads, the same is lower than diesel fuel. For lower to medium loads, Fuel Consumption is higher for 20% Blend than in 30% Blend and the same repeats for 10% Blend than 20% Blend. So, Fuel consumption increases with decrease in blend proportions and it seems minimum for 50% Blend proportion i.e. for P50D50 Fuel. This can be due to gradually increasing calorific value with the increase in blend ration of plastic pyrolysis oil. More heat release will be there with more calorific value and thus lesser fuel is consumed with increase in blend percentage of plastic pyrolysis oil.

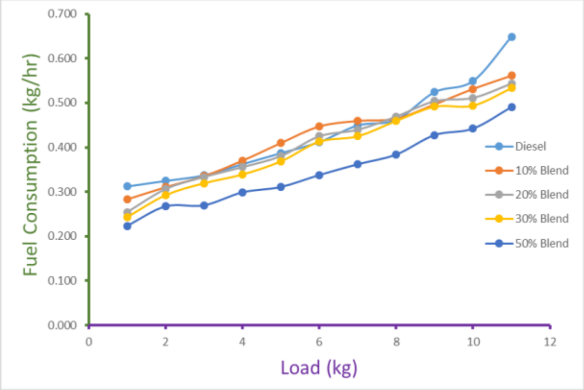

Fig. 3: Fuel Consumption vs Load for various Blend Proportions

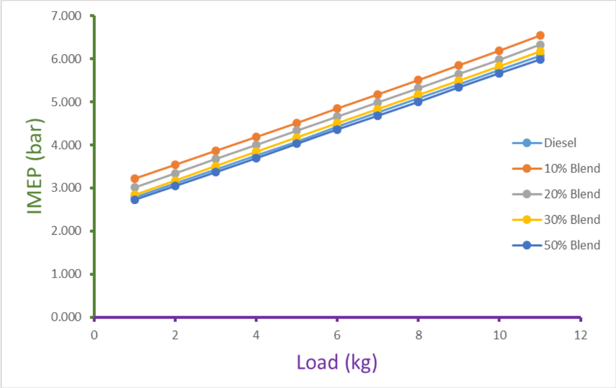

Fig. 4: IMEP vs Load for various Blend Proportions

B. Indicated Mean Effective Pressure (IMEP) & Brake Mean Effective Pressure (BMEP):

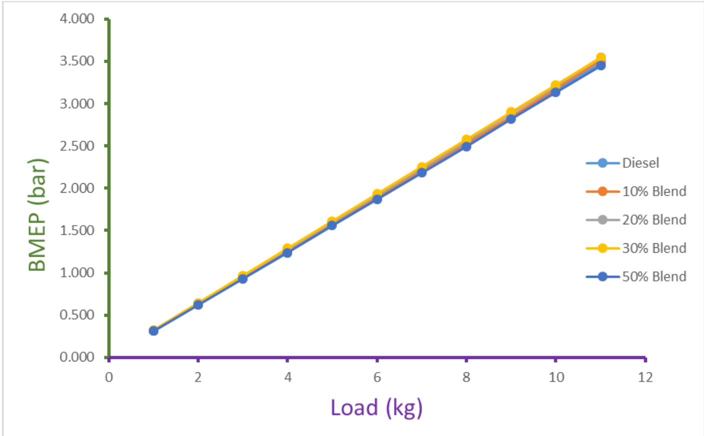

Fig. 5: BMEP vs Load for various Blend Proportions

Fig. 4 & 5 shows the effect of load on Indicated Mean Effective Pressure (IMEP) & Brake Mean Effective Pressure (BMEP) respectively for various blends of Plastic Pyrolysis Oil in Diesel Fuel. There is no major variation in BMEP for different Blends at lower loads. At higher loads, peak pressure is minimum for 50% Blend proportion. Peak pressure gradually increases with increase in Blend Proportion for 10% to 30% Blend at higher loads.

IMEP increases with increase in load. Peak pressure in Diesel Fuel is lesser than all the Blend Proportions except 50% blend of plastic pyrolysis oil with 50% diesel fuel. There is a consistent decrease in peak IMEP with increase in blend proportion of plastic pyrolysis oil. This also, may be due to increase in calorific value with increase in Blend proportion of plastic pyrolysis oil. With greater calorific value, heat release rate increases and large amount of heat get released with lesser peak pressure of the cylinder. So increase in Blend proportion of plastic pyrolysis oil proves to be healthy for engine operation because of lesser value of cylinder peak pressure.

C. Indicated Thermal Efficiency & Brake Thermal Efficiency:

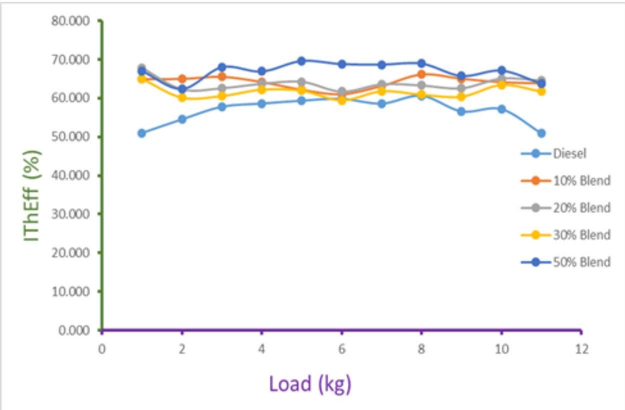

Fig. 6: IThEff vs Load for various Blend Proportions

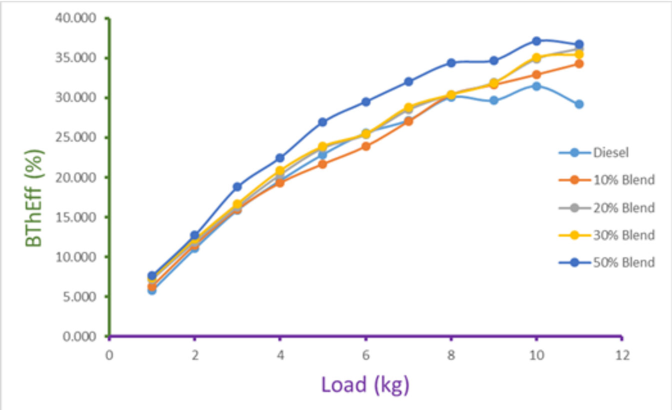

Fig. 7: BThEff vs Load for various Blend Proportions

Fig. 6 & 7 focuses on the variation of IThEff & BThEff respectively with load for various Blend Proportion of Plastic Pyrolysis Oil in Diesel Fuel. Both IThEff & BThEff seems lowest for Diesel Fuel and Highest for 50% Blend Proportions. Higher thermal efficiencies of Blended fuel than the diesel fuel is because of lesser fuel consumption in case of blended fuel. 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.

D. Specific Fuel Consumption:

Fig. 8 shows the variation in SFC with load for different Blend Proportions. SFC decreases with increase in load. It is very much clear from the graph that SFC is maximum for Diesel Fuel than any of the Blend Proportion for lower and higher loads. SFC 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.

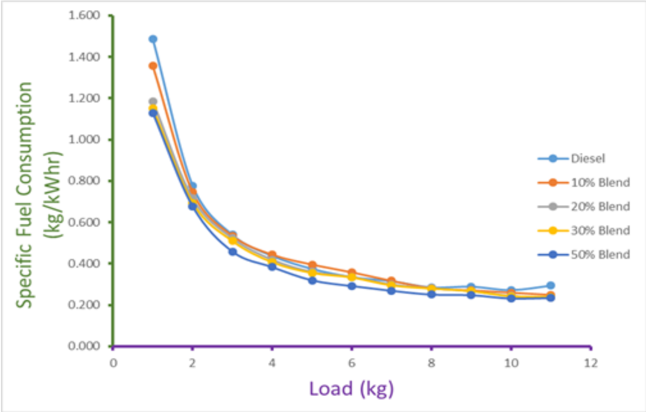

Fig. 8 SFC vs Load for various Blend Proportions

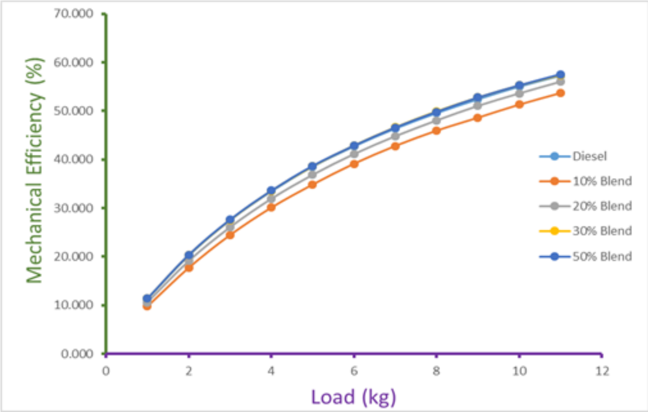

Fig. 9 Mechanical Efficiency vs Load for various Blend Proportions

E. Mechanical Efficiency:

Fig. 9 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 Diesel Fuel.

Increasing Blending ratio from 10% to 50%, 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 50% proportion of plastic pyrolysis oil and efficiencies of 30% and 50% blends are almost similar, which is nearly comparable to diesel fuel. So, in Mechanical Efficiency, again increased Blend proportion up to 30% is proved to give optimum result than any other Blend ratio. The comparison of Mechanical Efficiency for Different Fuel and Blends at different loads is easily visible and understood from the figure.

F. HC, CO_2 & NO_X Emissions:

Fig. 10, 11 & 12 emphasises on variation of HC, CO_2 & NO_X respectively, with load for Different Blend Proportions. From the graphs of Emissions vs Load, we can conclude that HC Emissions are significantly lower with Diesel Fuel than the Blends of Plastic Pyrolysis Oil. At all the loading conditions, HC Emissions are increasing with increase in blend proportions. But there is a major increase in this emission after 30% blend of plastic pyrolysis oil and it becomes much higher in case of 50% blend proportion.

This may be due to less volatility of plastic pyrolysis oil. HC content of the fuel are not equally distributed in the cylinder area and thus some particles remains unburned which creates higher HC Emissions. Similarly, NO_X Emissions are increasing with increase in blend proportion and value becomes much higher in case of 50% blend proportions. CO_2 Emissions are found to be decreasing with increase in blend proportion and it is due to late combustion of blended fuel with higher blend percentage of plastic pyrolysis oil. So it gets lesser time for oxidation of CO with oxygen.

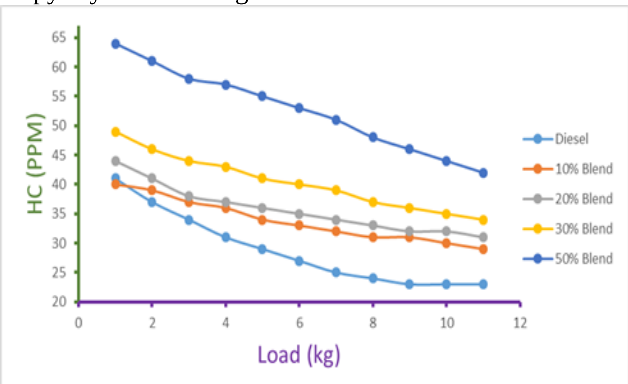

Fig. 10: HC Emissions vs Load for various Blend Proportions

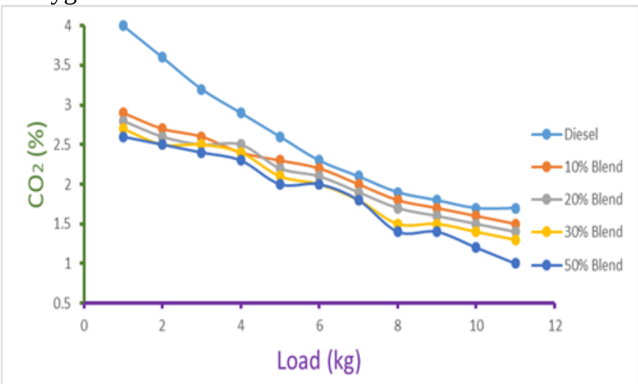

Fig. 11: CO_2 Emissions vs Load for various Blend Proportions

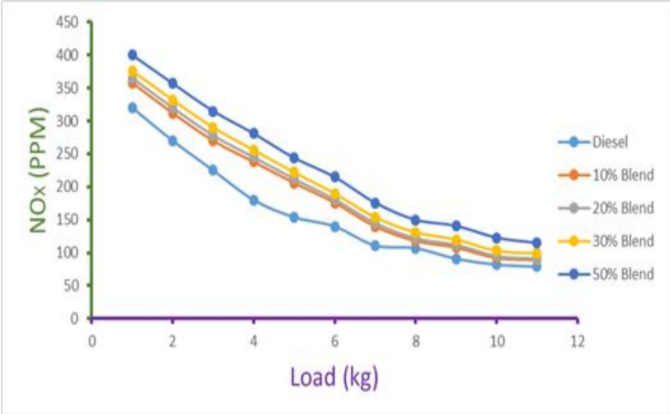

Fig. 12: NO_X Emissions vs Load for various Blend Proportions

VIII. CONCLUSION

Focussing on Performance only, higher blend proportion of plastic pyrolysis oil proves to give positive impact. Efficiencies are increasing and fuel consumption is decreasing with increase in blend proportion. But at the same time there is much hike in exhaust emission after 30 % blend proportion of plastic pyrolysis oil. Results of 20% blend proportion of plastic pyrolysis oil are nearly similar to diesel fuel. But increase in exhaust emission is having major value than increase in performance after 30% blend of plastic pyrolysis oil. So considering Performance and Exhaust Emissions, 30% Blend of Plastic Pyrolysis Oil is having optimum values than other Blend Proportion of Plastic Pyrolysis Oil and Diesel Fuel.

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