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Experimental Investigation on Multi Cylinder Spark Ignition Engine Fuelled With Waste Plastic Oil with Oxygenated Fuels

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Abstract: In the current day situation, emissions associated with the exhaust of automobiles resulting in global warming are a major threat to the entire world and also harmful to health. In this perspective, waste plastic solid is presently getting renewed interest. Plastics have now become indispensable materials in the modern world and application in the industrial field is continuously increasing. As substitute, non-biodegradable, and renewable fuel, waste plastic oil is getting rising attention. An experimental investigation is conducted to evaluate the emission and performance characteristics of a multi-cylinder spark ignition engine fuelled with Plastic Petrol derived from waste plastic by the process of pyrolysis. Petrol is blended with waste plastic pyrolysis oil as 10%WPPO and 85% petrol as blend-I and 20%WPPO and 75% petrol as blend-II. The performance and emission characteristics are found for both the blends and compared with the characteristics of petrol. Some amounts of oxygenated fuels viz., ethanol and methanol are added in the concentration of 5% each to the both the blends and their characteristics are compared to the blends without oxygenate fuels and sole petrol. The tests are conducted using each of the Gasoline and Plastic Petrol with oxygenated fuel additives with the engine working at variable load of 0 to 7 kg for constant speed at 1500 rpm. The differences in the measured performance from the baseline operation of the engine with petrol, blends with addition of oxygenated fuels and without addition of oxygenated fuels are compared. It resulted that, by adding additives the brake thermal efficiency of the engine improved. The CO and HC emissions are reduced but NOX and CO2 emissions are increased for all the blends when compared to petrol.
Keywords: Plastic Petrol, pyrolysis, ethanol and methanol.

I. INTRODUCTION

Now a day's plastic is the most important product for human beings in day to day life activities. In the other hand increasing the population, the demand of plastic is also increased due its tremendous applications in the different fields and products. The production of plastic is maximized throughout the globe which reflects the maximized in plastic wastage around the globe and its landfills about 2020.Plastics are cannot be degrade by its own, it's take the more than billions of years to hide naturally. This statement gives the how seriousness and how dangerous to globe which cause the environmental pollution. To reduce the production of plastic and environmental pollution, an alternative solution is identified that to recycle the plastics and re use it where it suitable according to applications. Albeit plastic reusing can diminish same measure of plastic squanderer, transformation of plastic waste into fuel as increased a great deal of consideration nowadays so as to satisfy the vitality need either because of the consumption of non-renewable energy sources or because of the quick ascent in cost of delivering oil fuel. Oil created from plastic squanders is named as waste plastic oil (WPO). Different techniques have been embraced to deliver WPO, for example, catalytic conversion thermo chemical treatment and pyrolysis system. Out of these strategies, pyrolysis system has been seen as beneficial technique for creating WPO. Pyrolysis is the procedure of thermally corrupting long chain polymer particles into littler and less perplexing atoms through high pressure and high heat. During pyrolysis three significant items are delivered, which is oil, gas and roast of char. Parameter, for example, pyrolysis temperature, kind of reactor habitation time sort of impetus utilized and sort of fluidized gas and its stream rate impacts the measure of WPO created. Numerous analysts have declared that the physiochemical properties of WPO are like diesel and thusly, WPO can be utilized on diesel engines either in slick frame or can be mixed with diesel with expansion of added substances. The current audit centers on the use of WPO as fuel and presents the exhibition and outflow attributes as utilized on spark engines

II. OBJECTIVES OF PRESENT WORK

From the literature survey made it has been observed that experimental work has not been done using waste plastic oil on a spark ignition petrol engine to study the performance characteristics of waste plastic oil. Hence the objective of the present work is to study the characteristics of a multi cylinder spark ignition engine with derived WPO blends with petrol as a fuel in various forms with and without by adding oxygenated fuels like ethanol and methanol of the performance characteristics like Brake specific fuel consumption, Brake thermal efficiency (η_{bth}) and Volumetric efficiency (η_{vol}) and also emission characteristics like CO, HC, CO_x, NO_x and CO_2 emissions are determined.

III. METHODOLOGY & EXPERIMENTATION

A. Fuel Extraction from Plastic Waste Disposal through Plasma Pyrolysis Technology (PPT)

Plasma Pyrolysis Technology (PPT)-Plasma Pyrolysis is a state of the art technology, which integrates the thermo-chemical properties of plasma with the pyrolysis process. The intense and versatile heat generation capabilities of Plasma Pyrolysis technology enable it to dispose of all types of plastic waste including polymeric, biomedical and hazardous waste in a safe and reliable manner. Pyrolysis is the thermal disintegration of carbonaceous material in oxygen-starved atmosphere. When optimized, the most likely compounds formed are methane, carbon monoxide, hydrogen, and carbon dioxide and water molecules.

B. Process Technology

In Plasma Pyrolysis, firstly the plastics waste is fed into the primary chamber at 850°C through a feeder. The waste material dissociates into carbon monoxide, hydrogen, methane, higher hydrocarbons etc. Induced draft fan drains the pyrolysis gases as well as plastics waste into the secondary chamber where these gases are combusted in the presence of excess air. The inflammable gases are ignited with high voltage spark. The secondary chamber temperature is maintained at 1050°C. The hydrocarbon, CO and hydrogen are combusted into safe carbon dioxide and water. The process conditions are maintained such that it eliminates the possibility of formation of toxic dioxins and furans molecules (in case of chlorinated waste). The conversion of organic waste into non-toxic gases (CO2, H2O) is more than 99%. The extreme conditions of Plasma kill stable bacteria such as bacillus stereo-thermophilus and bacillus subtilis immediately. Segregation of the waste is not necessary, as the very high temperatures ensure treatment of all types of waste without discrimination. PVC plastics waste is not used and if used, it was less than 1%. In case PVC is used, the chlorine can be converted into hydrochloric acid as a by-product.

C. Composition and Properties of Plastic Pyrolysis Oil:

Waste plastic pyrolysis oil (WPPO) is a mixture of C_{10}-C_{30} organic compounds. Waste plastic oil has the calorific value and sulphur content lesser than petrol. The chemical composition of WPO is shown in the Table.1. WPO is a higher aromatic content fuel with ring structure. Waste plastic oil gives on weight basis 75% of liquid hydrocarbon, which is a mixture of petrol, diesel and kerosene, 5 to 10 % residual coke and the rest is LPG. The properties of measured WPPO, diesel and gasoline are compared in Table.2.

Table.1.Chemical composition of waste plastic oil

Composition	Percentage
C_{10}	61
C_{10} to C_{13}	2.4
C_{13} to C_{16}	8.5
C_{16} to C_{20}	4.6
C_{20} to C_{23}	7.1
C_{23} to C_{30}	16.4

Table.2.Comparison of properties of WPPO with regular petrol and Diesel

S.No	Specifications	Petrol	WPPO	Diesel
1	Color	Light brown	Pale black	Orange
2	Specific gravity at 28 °C	0.7423 to 0.77	0.7254	0.84 to 0.88
3	Gross calorific value(kJ/kg)	45600	44350	46500
4	Kinematic viscosity, cSt @ 40°C	0.37 to 0.44	2.52	1.7
5	Flash point °C By Abel's method	-43	42	50
6	Octane rating	83	95	-
7	Fire point °C	-49	45	56

Kinematic viscosity of WPPO is higher than Petrol. The impact of this kinematic viscosity on performance for blends 10% WPPO and 20% WPPO are general increase in kinematic viscosity at higher temperatures, which results in lower oil consumption and less wear. Another impact is reduced kinematic viscosity at lower temperatures, which will improve starting and lower fuel consumption.

D. Experimental Setup

The setup consists of Maruthi 800 three cylinders, four stroke, Petrol engine connected to Eddy current dynamometer for engine loading which is connected to water cooling jacket shown in Fig.1 and the detailed specifications of the Maruthi 800 petrol engine given in table.3. The setup has standalone type independent panel box consisting of air box, fuel tank, manometer, fuel measuring unit, digital speed indicator. The engine is connected with AVL Five gas analyzer for testing emissions.

Fig.1. Schematic diagram of Maruti 800 Petrol Engine Test Setup

Fig.2. AVL Five Gas Analyzer

Table.3. Maruti 800 petrol engine specifications

Engine make and model	Maruti 800
Number of cylinders	Three in-line
Orientation	Vertical
Arrangement of valves	Overhead
Fuel type	Gasoline
Cooling Medium	Water cooled
Number of strokes	4 strokes
Ignition	Spark ignition
Fuel delivery	Carburetor type
Bore	68.55mm
Stroke	72mm
Compression ratio	8.7:1
Cubic capacity	796cc

The exhaust gas analyzer (AVL Digas 444) is used to measure the exhaust emission like HC, Co, Co2, O2 and NOx emission has shown in Fig. 2. The Liquid crystal display shows the constituents of the gas once the gas is allowed to flow in. It is a standard output device for the AVL digas 444.

E. Experimental Procedure

The engine is subjected to the constant speed of 1500rpm and by varying the load applied through hydraulic dynamometer the performance and the emissions of the engine are measured. The crude plastic pyrolysis oil is taken and filtered with primary filters as the crude oil has more sedimentation. Hence these filtered plastic pyrolysis oil used for blending with the petrol. Here waste plastic pyrolysis fuel is blended with petrol as 10% plastic pyrolysis oil(PPO) and 90% petrol (blend-1) and 20% plastic pyrolysis oil(PPO) and 80% petrol (blend-2) .Two oxygenated fuels viz.,Ethanol and methanol are added to the blends in 5% of concentration to each blend. The experiments are carried for sole petrol and petrol blended with waste plastic pyrolysis oil. To improve the efficiency and reduce emissions oxygenated fuel additives like ethanol and methanol of 5% each added to both the blends separately and experimented the performance and emission characteristics of each blend individually and compared with petrol. Table.4 shows the properties of fuel additives which are used in experimental work.

Table.4.Properties of the fuels

S.NO	Specifications	Petrol	PPO	Ethanol	Methanol
1	Specific gravity at 28 °C	0.7423 to 0.77	0.7254	0.759	0.792
2	Gross calorific value(KJ/Kg.K)	44600	42350	27250	20550
3	Octane number	83	95	110	112

IV. RESULTS AND DISCUSSIONS

A series of Engine performance Tests and Engine Emission tests were carried out on a 3 cylinder maruthi-800 spark ignition engine at a constant engine speed of 1500 rpm and by varying load. Petrol and waste plastic petrol oil blends are used to run the engine and 5% of Oxygenated fuels are added to the blends and the detailed explanatory results are presented as follows here.

A. Engine Performance Characteristics

1) *Brake specific fuel consumption:* The variation of Brake specific fuel consumption (BSFC) with load at 1500 rpm speed shown in the fig.4. Here comparisons are made between brake specific fuel consumptions of petrol and petrol blended with 10% and 20% of plastic pyrolysis oil. From this we can conclude that as the load is increasing the BSFC decreasing for all the blends. BSFC is lower for petrol compared PPO10 and PPO20 with increasing in load. The petrol has minimum BSFC of 0.12 Kg/kW.hr at 7 kg load. Compared to PPO10, PPO20 has lower BSFC with increasing load. The BSFC values observed for PPO10 and PPO20 are 0.391kg/kW.hr and 0.130kg/kW.hr. Respectively at the load of 7 kg. Fuel consumption rate is more for PPO10 than sole petrol and PPO20. Petrol and PPO20 has similar BSFC. As the calorific value of fuel is less the consumption rate is more to meet the required fuel energy input

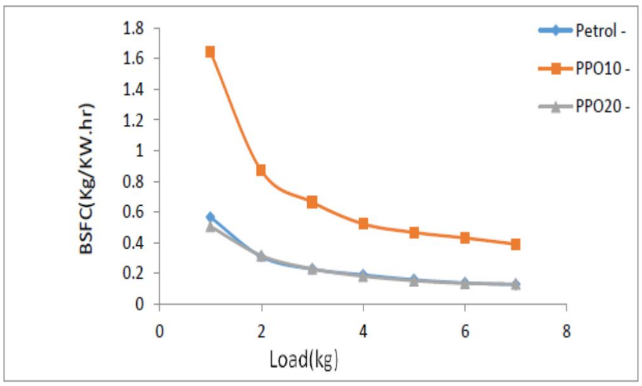

Fig.4. Load Vs BSFC of PPO10, PPO20 and petrol.

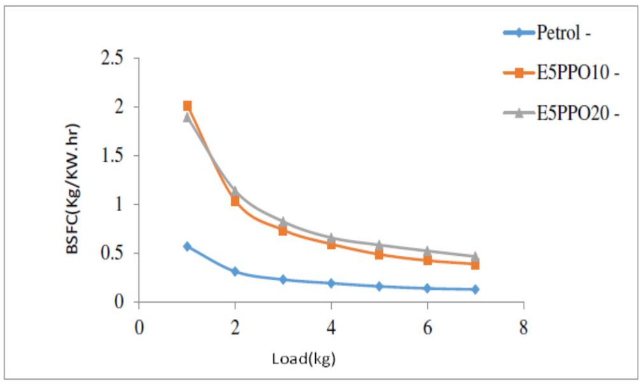

Fig .5. Load Vs Brake specific Fuel consumption. (Ethanol added blend).

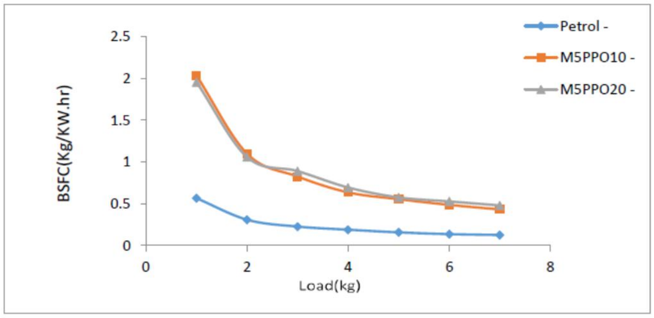

Fig.6.Load Vs Brake Specific Fuel consumption (Methanol added blends).

The variation of Brake Specific Fuel consumption with load for constant speed at 1500 rpm is shown in the fig.5. Here 5% of Ethanol is added to the blends of PPO10 and PPO20 respectively and compared with petrol .We conclude that due lower calorific value the brake specific fuel consumption of E5PPO10 blend and E5PPO20 blend fuels are increased when compared to petrol. The BSFC values are decreased for all the blends with increasing load. The BSFC value of E5PPO10 at 7kg load is observed as 0.387kg/kW.hr which is less than the BSFC value of PPO10 and more than petrol. The BSFC value of E5PPO20 at 7kg load is observed as 0.464kg/kW.hr which is more than PPO10, PPO20, E5PPO10 and petrol. The variations of Brake Specific Fuel consumption with load for constant speed at 1500 rpm is shown in the fig.6. Here 5% of Methanol is added to the blends of PPO10 and PPO20 respectively and compared with petrol. We conclude that due lower calorific value, M5PPO10 and M5PPO20 blends fuel consumption is more than petrol. The BSFC values of all blends are decreased with increasing load. The BSFC value of M5PPO10 is observed as 0.432kg/kW.hr which is more than the value of PPO10, E5PPO10 and petrol. The BSFC value of M5PPO20 is observed as 0.48kg/kW.hr which is more than the value of PPO20, E5PPO20 and petrol.

2) *Brake thermal efficiency (η_{bth}):* The variation of Brake thermal efficiency with load for constant engine speed at 1500 rpm is shown in the fig.7. The brake thermal efficiency of petrol is compared with the brake thermal efficiency of PPO10 and PPO20 blends. We can conclude that the brake thermal efficiency of PPO10 blend is more than petrol and PPO20 blend due to higher fuel consumption. We can observe that the brake thermal efficiency is gradually increasing at all load conditions because of minimum heat dissipation and increase in brake power developed. The maximum brake thermal efficiency is observed for PPO10 at 7kg load is 20.16%. The brake thermal efficiency of Petrol and PPO20 at 7kg load is 17.65% and 16.8% respectively which is less than PPO10.

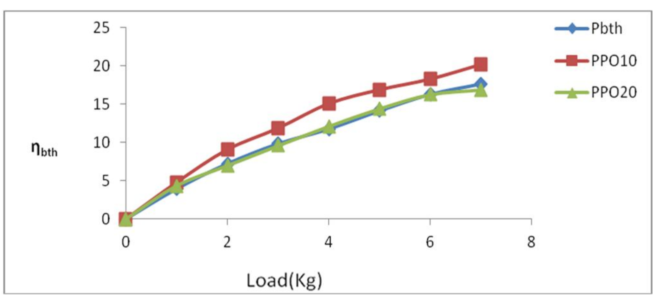

Fig.7. Load Vs Brake thermal efficiency

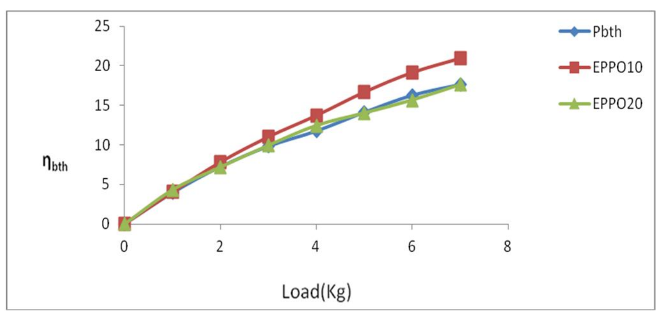

Fig.8. Load Vs Break thermal efficiency (Ethanol added blends).

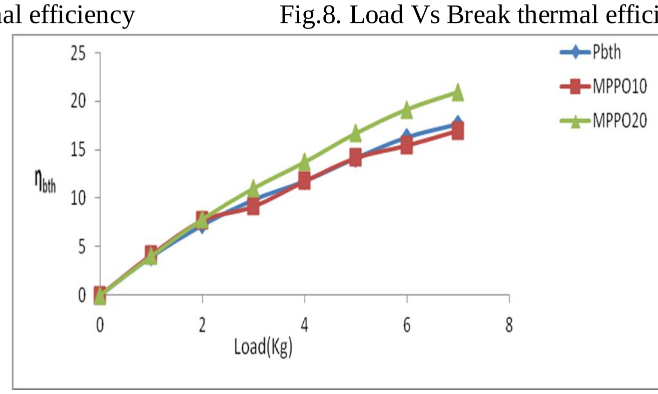

Fig.9. Load Vs Break thermal efficiency (Methanol added blends).

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The variation of Brake thermal efficiency with load for a constant engine speed at 1500 rpm is shown in the fig.8.The brake thermal efficiency of petrol is compared with the brake thermal efficiency of PPO10 and PPO20 by adding 5% Ethanol to each of the blends. We can conclude that PPO10 blend has higher brake thermal efficiency than PPO20 blend and sole petrol due to high fuel consumption and lower calorific value. We can observe that the brake thermal efficiency is gradually increasing at all load conditions because of minimum heat dissipation and less volatility of ethanol. The maximum break thermal efficiency observed at 7kg load for E5PPO10 is 20.95%. The break thermal efficiency for petrol and E5PPO20 is observed as 17.65% and 17.5% respectively, which is less than the value of PPO10 and more than the value of PPO20. The variation of Brake thermal efficiency with load for constant engine speed at 1500 rpm is shown in the fig.9. The brake thermal efficiency of petrol is compared with the brake thermal efficiency of PPO10 and PPO20 by adding 5% Methanol to each of the blends. We can conclude that PPO10 blend has higher brake thermal efficiency than PPO20 blend and sole petrol due to high fuel consumption. We can observe that the brake thermal efficiency is gradually increasing at all load conditions because of minimum heat dissipation. The maximum break thermal efficiency observed is 18.78% for M5PPO10 at 7kg load. The break thermal efficiency of M5PPO2 at 7kg load is observed as 16.9%, which is less than petrol, PPO10, E5PPO10, E5PPO20, M5PPO10 and more than PPO20.

3) *Volumetric efficiency (η_{vol}):* The variation of Volumetric efficiency with load for constant engine speed at 1500 rpm is shown in the fig.10 .The volumetric efficiency of PPO10, PPO20 and petrol are compared. We can observe that PPO20 blend has higher volumetric efficiency than PPO10 blend and sole petrol. The volumetric efficiency is increased for all the blends with increasing load. The maximum values of volumetric efficiency are obtained at 7 kg load for PPO10, PPO20 and petrol are 31.87%, 34.17% and 22.53% respectively. Hence we can state that by addition of the PPO blends to the petrol the volumetric efficiency is increased

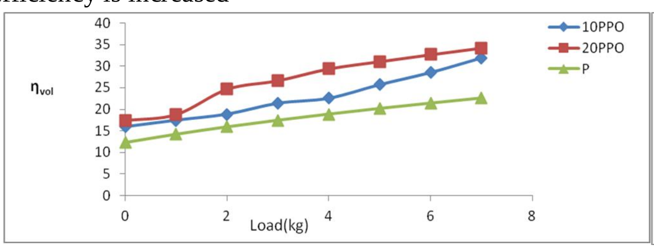

Fig.10..Break power Vs Volumetric efficiency

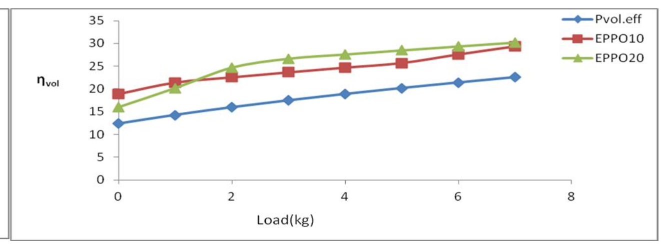

Fig.11 Load Vs Volumetric efficiency (Ethanol added blends)

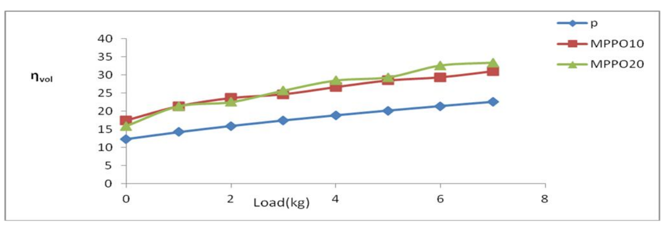

Fig .12.Load Vs Volumetric efficiency (Methanol added blends).

The variation of volumetric efficiency with load for constant engine speed at 1500 rpm is shown in the fig.11.Here 5% of Ethanol is added to the PPO10 and PPO20 blends and compared with petrol. We can observe that E5PPO20 blend has higher volumetric efficiency than E5PPO10 blend and sole petrol due to more air consumption. The volumetric efficiency is increased for all blends with increasing load. The maximum values of volumetric efficiency are obtained at 7 kg load for E5PPO10, E5PPO20 and petrol are 29.38%, 30.24% and 22.53% respectively. When compared to the PPO10 and PPO20 blends by adding ethanol the volumetric efficiency is decreased for E5PPO10 and E5PPO20 blends. Hence we can state that the petrol has less volumetric efficiency compared to all blends. The variation of volumetric efficiency with load for constant engine speed at 1500 rpm is shown in the fig.12. Here 5% of Methanol is added to the PPO10 and PPO20 blends and compared with petrol. We can observe that the volumetric efficiency is increased with increasing load for all blends. M5PPO10 and M5PPO20 blends have more volumetric efficiency when compared to petrol and less volumetric efficiency when compared to PPO10 and PPO20 blends. The maximum volumetric efficiency is obtained at 7 kg load for M5PPO10, M5PPO20 and petrol is 31.06%, 33.42% and 22.53% respectively. Hence by observing all the obtained results of volumetric efficiency of all blends, PPO20 blend has more volumetric efficiency of 34.17%.

B. Engine Emission Characteristics

1) CO emissions:

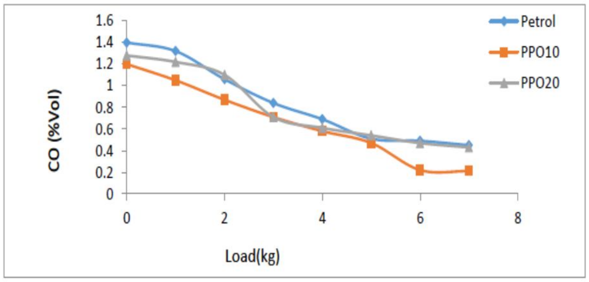

Fig.13. Load (kg) Vs CO (%vol) emissions.

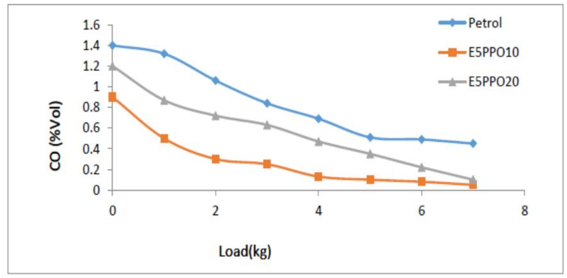

Fig.14. Load (kg) Vs CO (%vol) emissions (Ethanol added blends).

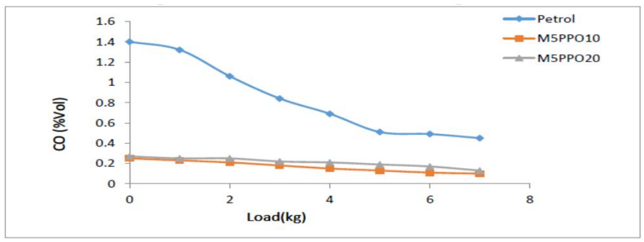

Fig.15.Load (kg) Vs CO (%vol) emissions (Methanol added blends).

The effect of the petrol with plastic pyrolysis blends, on the CO emissions is shown in the Fig.13. A graph is plotted between load and CO emissions. From this we can conclude that with increase in concentration of plastic pyrolysis oil the CO emissions are reduced compared to sole petrol.PPO10 blend has much lower emission at full load compared to PPO20 blend and sole petrol. The effect of the petrol with plastic pyrolysis blends, on the CO emissions is shown in the Fig.14. Here 5% of Ethanol is added to the each of the two blends. We can conclude that by adding Ethanol the CO emissions are further reduced than the normal blends and sole petrol. This is due to the addition of ethanol and additive concentrations because of leaner combustion due to the presence of oxygen in ethanol. Owing to the leaning, CO emissions decrease tremendously. The effect of the petrol with plastic pyrolysis blends, on the CO emissions is shown in the Fig.15.Here 5% of Methanol is added to the each of the two blends. We can conclude that by adding Methanol the CO emissions are further reduced than the normal blends and sole petrol.

2) HC emissions: The effect of HC emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.16. From this we can conclude that the emissions of hydrocarbons of PPO10 blend is more than PPO20 blend and sole petrol.

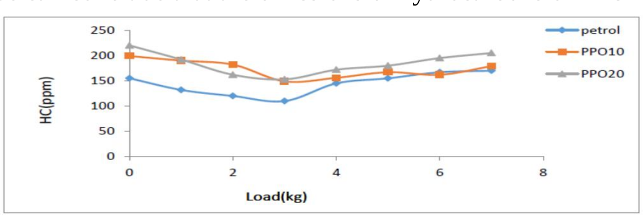

Fig.16.Load (kg) Vs HC (ppm) emissions.

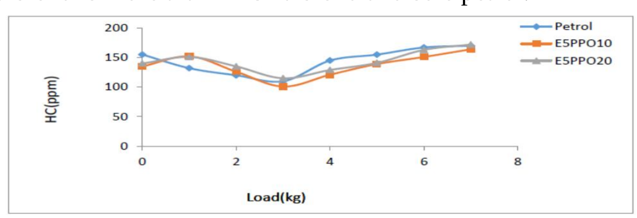

Fig.17. Load (kg) Vs HC (ppm) emissions (Ethanol added blends).

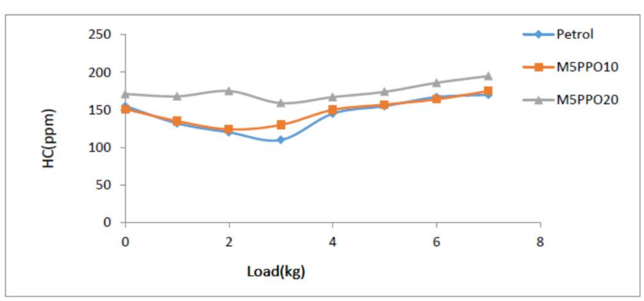

Fig.18.Load (kg) Vs HC (ppm) emissions (Methanol added blends).

The effect of HC emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.17. When added 5% of Ethanol to the each of the blends and compared with the HC emissions of sole petrol. From this we can conclude that PPO20 blend is more compared to the PPO10 blend and sole petrol and PPO10 blend HC emissions are low when compared with sole petrol due to fact that, ethanol has lower flame speed compared to sole fuel operation. As a result, the less mass fraction of the fuel is burnt in the case of ethanol blends petrol with PPO. The effect of HC emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.18. When added 5% of Methanol to the each of the blends and compared with the HC emissions of sole petrol. From this we can conclude that PPO20 blend is more compared to the PPO10 blend and sole petrol and PPO10 blend HC emissions are reduced gradually with increase in load when compared to sole petrol.

3) *NO_X Emissions:* The effect of NO_X emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.19. From this we can conclude that the NO_X emissions for both the blends increased than the petrol and when compared to both the blends emissions the PPO10 blend has less NO_X emissions than the PPO20 blend.

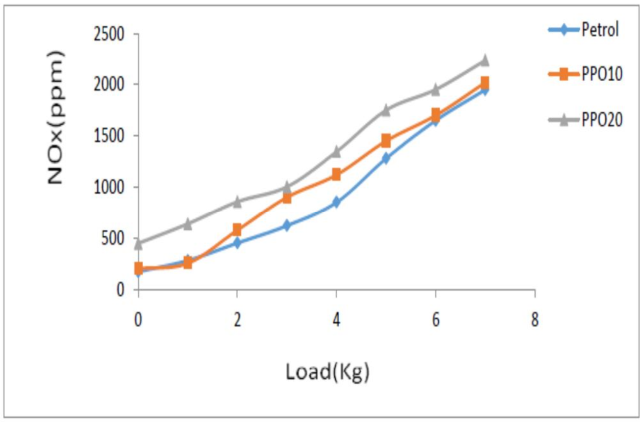

Fig.19...Load (kg) Vs NOx (ppm) emissions.

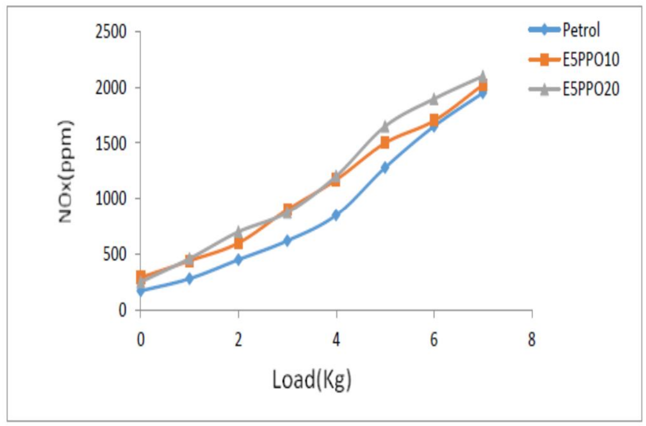

Fig. 20. Load (kg) Vs NOx (ppm) emissions (Ethanol added blends).

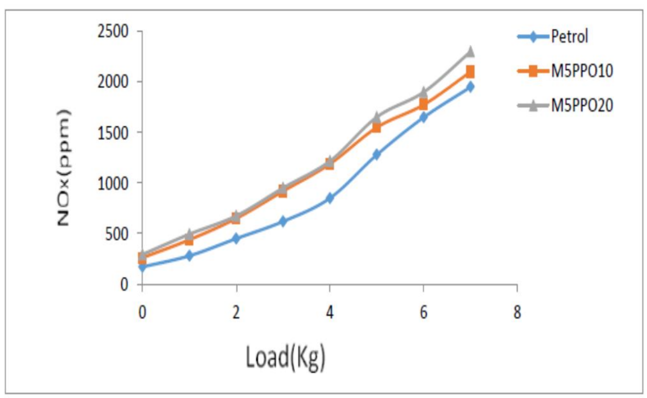

Fig.21. Load (Kg) Vs NO_X (ppm) emissions (methanol added blends).

The effect of NOx emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.20. Here 5% of Ethanol is added to both the blends and their NOx emissions are compared with sole petrol. From this we can conclude that the NOx emissions are reduced by adding ethanol but they are greater than sole petrol NOx emissions. The effect of NOx emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.21. Here 5% of Methanol is added to both the blends and their NOx emissions are compared with sole petrol. From this we can conclude that the NOx emissions are reduced by adding Methanol but they are greater than sole petrol NOx emissions and ethanol added blends. One reason behind the decrease in NOx emission of the fuel blends might be lower calorific value of methanol, as found in Table 4. Besides, methanol is an oxygenated fuel and it prompts progressively complete combustion. Consequently, these impacts reduce the NOx emissions in the exhaust.

4) *CO_2 emissions:* The effect of CO_2 emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.22.From this we can conclude that the CO_2 emissions for both the blends increased than the petrol and when compared to both the blends emissions the 10%PPO blend has less CO_2 emissions than the 20% PPO blend.

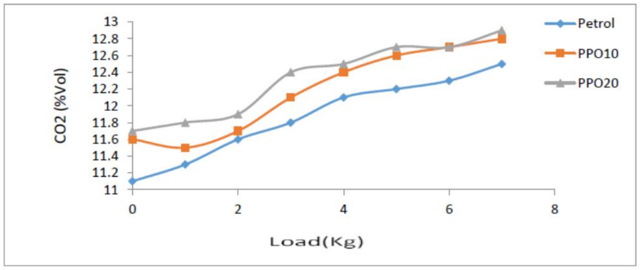

Fig.22. Load (kg) Vs CO_2 (%vol) emissions.

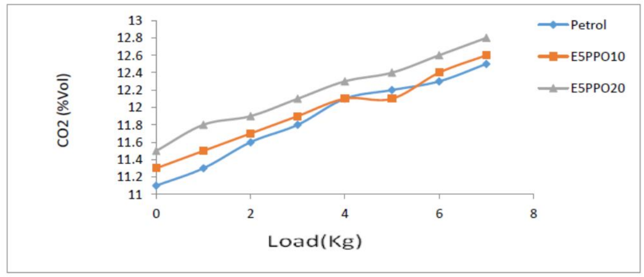

Fig.23.Load (kg) Vs CO_2 (%vol) emissions. (Ethanol added blends).

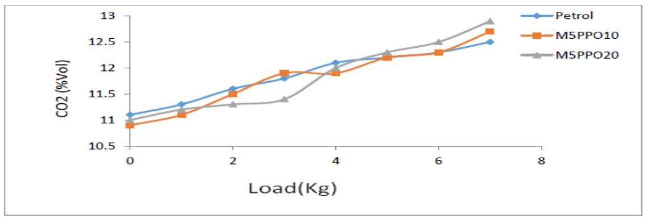

Fig.24. Load (kg) Vs CO_2 (%vol) emissions. (Methanol added blends).

The effect of CO_2 emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.23. Here 5% of Ethanol is added to both the blends and their CO_2 emissions are compared with sole petrol. From this we can conclude that the CO_2 emissions are reduced by adding ethanol but they are greater than sole petrol CO_2 emissions. The effect of CO_2 emissions with the blends of petrol and plastic pyrolysis oil is shown in the fig.24. Here 5% of Methanol is added to both the blends and their CO_2 emissions are compared with sole petrol. From this we can conclude that the CO_2 emissions are reduced by adding Methanol but they are greater than sole petrol CO_2 emissions and ethanol added blends.

V. CONCLUSIONS

From the above experimental study and obtained results on three cylinder Maruthi 800 spark ignition engine at full load (7kg) and constant speed 1500rpm condition. We can conclude the following:

1) The break specific fuel consumption an engine decreases with increase in load. Here we can observe that the BSFC is more for the 5% Methanol added PPO20 blend than other blends at break power of 3.86kW at 7kg load. Hence due to high fuel consumption this blend has less break thermal efficiency of 16.865% which is less than the break thermal efficiency of engine with sole petrol.
2) The Break thermal efficiency is more for 5% Ethanol added to the PPO10 blend than any other blends i., e 20.95% which is more than the break thermal efficiency of engine with sole petrol.
3) The volumetric efficiency of engine is high for PPO20 without addition of any oxygenated fuels.5% methanol added PPO20 blend has high volumetric efficiency than the Ethanol added blend.
4) The CO emissions were reduced by addition of ethanol to the blends when compared to sole petrol. It has the value of 0.23%vol of CO emissions when 5% ethanol added to PPO10 blend which is less than 5% Methanol added blend and sole petrol.
5) The HC emissions for plastic pyrolysis oil is less compared to sole petrol, but due to addition of oxygenated fuels these emissions are increased .We can observe that 5% of Ethanol and Methanol added to PPO20 has high emissions than sole petrol and PPO10 blends.
6) The NO_X emissions are increased with the petrol and PPO10 and PPO20 blends than sole petrol .By the addition of 5% of Ethanol and Methanol to the blends each the NO_X emissions are reduced as compared to the blends of petrol and PPO10, PPO20 which are higher than with the sole petrol.
7) The CO_2 emissions are increased with the petrol and PPO blends than sole petrol .By the addition of 5% of Ethanol and Methanol to the blends each the CO_2 emissions are reduced as compared to the blends of petrol and PPO but which are higher than with the sole petrol.
8) In BS4 emission norms, The Nitrogen oxide (NOx) limit is 80mg, whereas by the addition of 5% of Ethanol and Methanol to the blends each of the emissions are reduced to 60 mg Hence this Engine is meets with BS6 emission norms.

VI. FUTURE SCOPE

The present work can be done by increasing the blends percentage of waste plastic pyrolysis oil. The other types of oxygenated fuel additives can be added and can enhance the performance of the engine and reduce emissions. In the present work we observed that without adding the additives the engine misfiring and due abnormal combustion the knocking is more. So further techniques can be developed for reducing this. This work can also validated by using simulation models.

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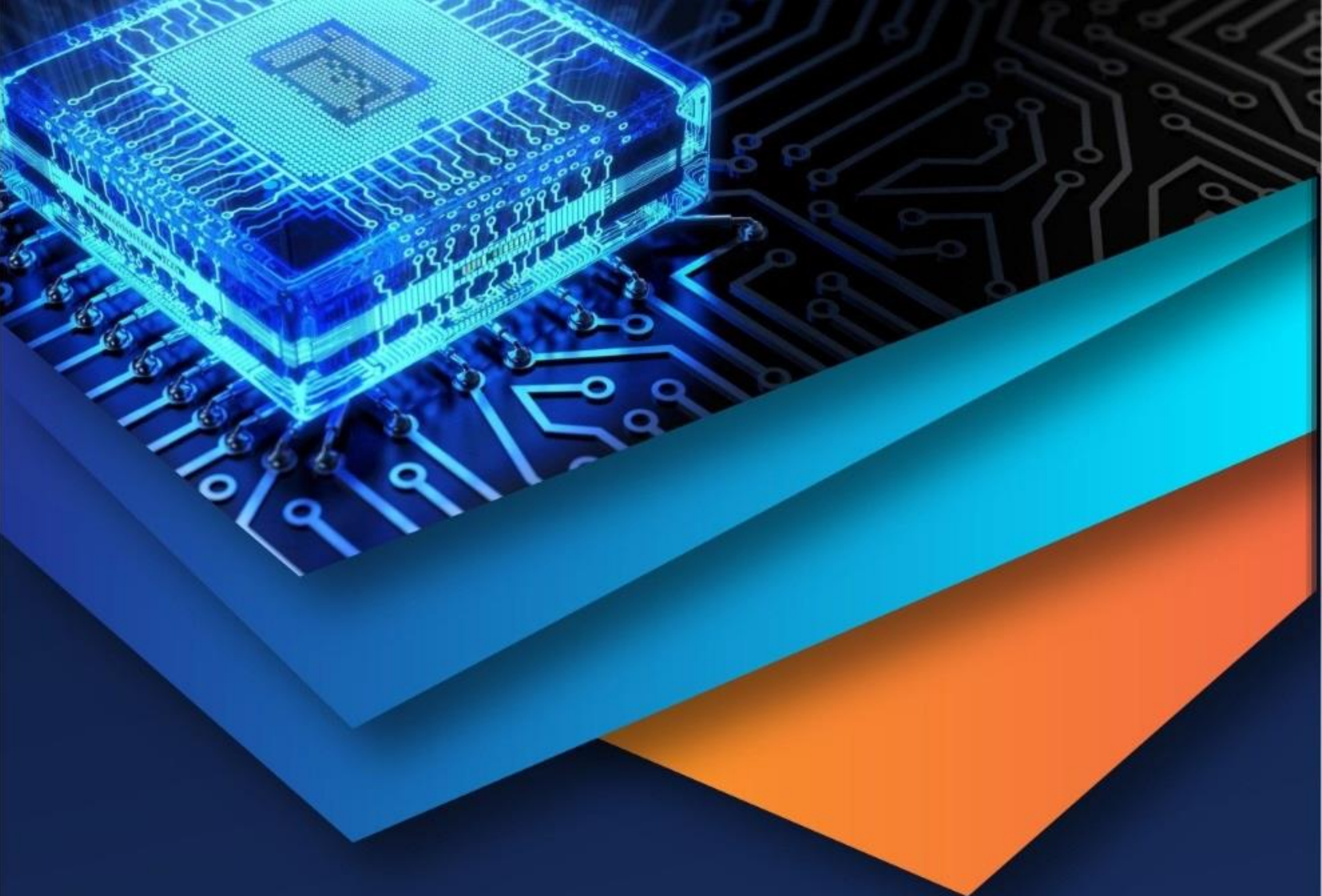

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