Experimental study on performance and emission character of C. I. engine fuelled with plastic oil (PO) along with diesel fuel blending

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Abstract. In this experimental investigation evaluate the sound effects of plastic fuel in a single cylinder four stroke diesel engine. Plastic oil fuel produced from desecrate plastic with the help pyrolysis technique which most suitable for conversion. Also chemical and physical properties are tested for various blends as per the ASTM standard. Selected diesel engine tested with plastic oil and diesel fuel blend. Blending endowment selected for the testing of engine such as PO25, PO50, PO75 and PO100 for a load 25%, 50%, 75% and 100% of load of engine. In each experiment test, load on engine is increased and recorded the specific fuel consumption, mechanical efficiency, brake thermal efficiency. Also simultaneously measure the tail pipe emission of engine such as Carbon Monoxide, UBHC emission and Oxides of Nitrogen emission etc. obtained results are compared with standard performance characteristics of diesel engine. Finally these investigations prove the PO oil and its blending with diesel fuel are suitable for selected engine. Up to PO75 may use as a source of alternative fuel for CI engine without any major modification.

Keywords: Waste Plastic fuel, Properties, Engine Performance, Emission.

Nomenclature:

PO : Plastic oil / fuel
PO100 : 100% Plastic oil / fuel
PO75 : 75% Plastic oil
PO50 : 50% Plastic oil
PO25 : 25% Plastic oil
B.S.F.C. : Brake specific fuel consumption
BTE : Brake thermal efficiency
MechE : Mechanical Efficiency
CO : Carbon monoxide
NOx : Oxides of Nitrogen emission
1. Introduction

In universal the majority appropriate and functional power production element is a diesel engine because of its elevated fuel translation energy competence, uniformity and physical condition. A diesel engine plays major roles in different areas such as in automobile, agricultural and power generation due to their better energy efficiency in case of thermal and acceptance usages [1]. Now a day’s utilization of diesel fuel increases extremely forms the last 50 years. These are happening due to the higher requirement and cost of fuels increases tremendously. Higher Use of diesel fuel produces large quantity of exhaust emissions due to this affecting badly on environment. [2]. In this regard, need to find a potential solution for diesel fuel simultaneously and report the reduction of engine exhaust emission from alternate source of fuel.

So, production of straight plastic oil PO from waste plastic by pyrolysis process is a solution for diesel fuel in C.I. engine [4]. From this dual benefit can be achieved by receiving energy from wastes and solving disposal [3]. Discarding of unused plastic covers in landfills and it is a dangerous for the sustainable nature point of view. The power lively in dissipate plastic could be obtained by catalytic pyrolysis process as misuse of plastic fuel. Development of waste plastic to fuel may used as another source of energy for diesel engines [6]. These studies provide a sustainable answer to controlling waste plastic problem to the municipal cooperation also. So this investigation carried out to bridge the gap among worldwide plastic production and waste plastic creation remain broaden [9]. This replacing diesel fuel requirement somewhat which is currently eliminate the need of fast depleting fossil source of unsophisticated oil speed [13].

In these experimental tests four fuel blends are chosen, by mixing in various portions. With the help of this overall running cost of engine may decrease. Different trials are conducted at no load to overload condition of engine only, because the diesel engines are generally operated in these series. The main function of this work, investigating the different outcome for blending of Plastic fuel in a diesel engine without any modification required in CI engine. Finally suggest the best blending of PO fuel for diesel engine. So that employment of plastic oil can solve the misuse dumping trouble of plastic as well as it could be new substitute source of fuel for C. I. engine.

2. Development of waste plastic to useful fuel and its properties

Switch of waste plastics into useful fuel believes a promising solution for diesel fuel in CI engine [14]. Since this is liveliness comfortable. This could be obtained by conventional processing plant method such as pyrolysis gasification, hydro cracking, catalytic cracking and many more [5]. Out of these majority capable technologies is the pyrolysis method. The manufacturing technique for the obtaining of waste plastics to liquid fuel is found pyrolysis of the plastics and compression this result in hydrocarbons. Related with production of waste plastic into liquid fuel, first of all collected the waste plastic from the different dumping area such as municipal waste and reprocess industry of waste plastic [12]. Then it cutout in small chips then these plastic chips washed and stove till the moisture content totally removed. Then these plastics small chips putted in the reactor where they get crumble at temperature 460 °C to 600 °C. Misused plastic oil has been equipped with depolymerization of plastics, this development was carried in a specifically developed chamber in the nonappearance of oxygen and in the appearance of proprietary catalyst. Experiment test set up run for 460 °C to 600 °C for one hour in a permanent reactor. There are three various cracking methods was used such as hydro cracking, catalytic cracking and thermal cracking to obtain the final fuel form the waste plastic feedstock. After obtaining the fuel from plastic finally tested the various properties of this fuel as per the ASTM standard. The tested fuel properties of blended fuel
satisfied the limit as per the ASTM standards. Comparisons of all fuel properties of diesel and its blends are put side by side in Table 1.

| Property                          | Diesel | PO100 | PO75  | PO50  | PO25  |
|-----------------------------------|--------|-------|-------|-------|-------|
| Density (kg/m³)                   | 830    | 790   | 800   | 810   | 815   |
| Viscosity (cSt)                   | 2.81   | 2.21  | 2.69  | 2.73  | 2.78  |
| Calorific value (kJ/kg)           | 43400  | 39400 | 40000 | 41500 | 42300 |
| Cloud point (°C)                  | -1.2   | 14.5  | 8.2   | 5.4   | 3.2   |
| Pour point (°C)                   | -3.7   | 9.7   | 4.9   | 2.4   | 1.8   |
| Flash point (°C)                  | 52.4   | 32.2  | 35.4  | 45.6  | 48.4  |
| Fire point (°C)                   | 57     | 37    | 39.4  | 49.6  | 52.8  |
| Cetane Index                      | 52     | 62    | 60    | 58    | 54    |
| Sulphur content (% of wt.)        | 0.49   | 0.44  | 0.44  | 0.45  | 0.46  |

According to the standard requirement of I.C. engine fuel, properties of plastic oil seem suitable to make use in diesel engine with no any significant adjustment or changes requirement. However, quality of selected blending of fuel appears better and it able to provide superior performance in diesel engine. On these bases, present work focused to find performance and emission distinctiveness in a single cylinder stationary Kirloskar compression ignition engine.

3. Experimental Test setup

The experiment test are did on a single cylinder four stroke direct injection engine, which generating a power 7HP at 1500rpm. The realistic illustration of test setup as shown in figure1, also the engine specifications are given in Table 2. Engine is in a straight line connected to eddy current dynamometer for different loading applications. Signal of different parameter collected through a interfaced computer by measuring the air flow, fuel flow, mean effective pressure, load and speed of engine. All these parameters of engine is communicated with various sensor to COM port of computer. With the help of control panel control the various operating condition of engine as per the experimental test requirement and recorded the result of testing. “Apex Innovations Pvt. Ltd.” The actual schematic representation of selected engine test setup is shown in Fig. 1 and the technical specifications of the engine as mentioned in Table 2.

| Sr. No. | Narrative            | Specification       |
|---------|----------------------|---------------------|
| 1.      | Industry             | Kirloskar oil engine Ltd , Pune |
| 2.      | Type of engine       | Four stroke diesel engine |
| 3.      | Cylinder             | Single              |
| 4.      | Stroke               | 110mm               |
| 5.      | Cubic capacity       | 661 cc (0.661 liter) |
| 6.      | Bore                 | 87.5 mm             |
| 7.      | Net Power            | 7 HP @ 1500 rpm     |
| 8.      | Compression Ratio    | 17.5:1              |
3.1 Testing procedure

At the time of starting of engine first ensure that electric supply is switched ON then check the water supply connection of engine as well as dynamometer. Check whether the selected blending of fuel filled for testing purpose inside of fuel tank. After checking all requirement start the engine and warm up for 10 minutes for better performance. Start the computer and put the values of blended fuel like density calorific value for the measurement of engine performance parameter. Then select the run option for recording the data of particular test. Each experiment test was carried out for compression ratio of 17.5:1 at constant speed of 1500rpm for various load conditions such as 25%, 50%, 75% and 100%. Selected test was run for fifteen to twenty minutes for one test of each blended fuel.

In each trial, load on engine and blends of fuel PO20, PO50, PO75 and PO100 changed as per designed plan. For the trail purpose considered the input parameters of engine load and various blends of fuel. Simultaneously measure the output performance parameter of engine such as Mechanical efficiency, Thermal Efficiency specific fuel consumption, and exhaust emission in form of carbon monoxide, hydrocarbon emission and oxides of nitrogen emission. For each operating trial the performance and tail pipe pollutant intensity are measured. Shows the following diagram of selected test set up.

![Computerized C. I. Engine Test Rig](image)

4. Results and discussion

In this part of paper represent the effects of various PO blending on performance of diesel engine. As a wide-ranging operating condition of engine it is pragmatic efficiency such as thermal efficiency, mechanical and volumetric efficiency. But here mainly two efficiency considered for this study purpose thermal and mechanical respectively. This both efficiency increases with as an increasing with blending of fuels as well as load also. Plastic oil with its blends matches or closely all performance with standard performance characteristics curve of diesel engine. Also in these section explained the higher regulated pollutants produced by engine for various blending and load condition such as carbon monoxide, hydrocarbon emission and oxides of nitrogen emission.
4.1 Brake Thermal Efficiency.
The differences of thermal efficiency versus load for selected blends of PO and diesel fuel are shown in Fig. 2. It is shows the thermal efficiency neat about 36% for diesel fuel at full load condition of engine. Brake thermal efficiency for different blended of fuel PO25, PO50, PO75 and PO100 are 36.95%, 37.42%, 32.5% and 31.4% correspondingly at top load. It is observed that brake thermal efficiency was lower for all types of blends as weigh against to diesel fuel. This may happen due to poor atomization particles in plastic blended fuel so engine suffered from lower efficiency at lower load of engine.

![Figure 2. Thermal Efficiency vs Load](image)

Superior BTE are recorded at part and full load conditions of engine due to proper mixture of atomization done inside of the combustion chamber, may cause responsible for better performance obtained at this condition of engine.

4.2 Brake specific fuel consumption (BSFC)
Comparisons between specific fuel consumption versus engine load for various blending of fuel are shown in Fig. 3.
Figure 3. Brake Specific fuel consumption vs. Load

Here observed that at low load condition of engine BSFC are more particularly for PO100 fuel it indicate a value of 0.42 Kg/k-W. As per standard acceptation it shows that BSFC of various PO blended fuels decreases with the increase in load at starting of engine and then start to increases with increase in load on engine. Increased BSFC obtained at lower load because of lower atomization fuel due the properties of plastic fuel may cause suffer incomplete combustion fuel. In case of full load condition of engine BSFC also observed higher. These results happened due to improper mixing of air- fuel inside of combustion cause of rich fuel entered in cylinder. Surrounded by all trials of fuels that the bsfc for PO100 found to be highest and for PO25 is lowest. The ideals values of for BSFC at full load are 0.32 for diesel fuel. But in case all blended fuel, it shows 0.38 Kg/kW-h, 0.334 kg/kW-h, 0.329 kg/kW-h, 0.29 kg/kW-h and 0.27 Kg/kW-h for PO100, PO75, PO50, PO25 and diesel fuel respectively. The lowest and highest BSFC may attribute for the reason of its properties such as density, viscosity and energy content in the fuel.

4.3 Mechanical Efficiency:
It shows the association of brake power and indicated power created inside of engine after burning of PO and diesel fuel blending inside of combustion chamber of engine. It also measure the useful work performed by the engine. Comparison of mechanical efficiency with related to the load on engine for varying conditions are as shown in figure 4.
From the above graph, it indicates consistent increases mechanical efficiency with low load to higher load condition of engine. PO75 blended fuel shows slightly more mechanical efficiency for low load to full load. These may happened due to improved premixed combustion phase of PO blends at the time of atomization of fuel. Mechanical efficiency for PO 100 blends to be low load 90.12% and 88.44% at full load. Finally we conclude that mechanical efficiency for all blended fuel is nearly same about conventional diesel fuel.

4.4 NOx emission:
Comparisons of NOx emission versus engine load for various blending of fuel are as shown in figure 5. NOx emission is direct function of highest temperature and oxygen present in combustion chamber [11].

Graph shows the slightly increasing rate of oxide of nitrogen emission with different load consistently for all types of blends (PO25, PO50, PO75 and PO100 blends). Combustion theory related to NOx emission main cause that higher temperature present inside of combustion. This may happened because of increasing load continuously on engine so demand of burning fuel at high load increases to
meet the requirement of power. Sometimes may be happened excess amount of oxygen present in combustion chamber which cause responsible for more temperature lead to high NOx emission. In this case various PO blends shows the higher NOx emission as compare to diesel fuel. The NOx emissions of PO100 are 55% more than that of diesel fuel and at 100% load and 45% higher at 75% loads condition of engine.

### 4.5 Carbon Monoxide (CO) Emission:
Comparisons of Carbon monoxide emission versus engine load are as shown in figure 6. The largest part underlying principle behind creation of CO emission from engine is that insufficient of oxygen present inside of combustion chamber also it shows incomplete combustion of fuel [8, 10].

![Figure 6. Carbon monoxide emission vs Load](image)

Above graph shows the carbon monoxide emissions decrease with increases in load for all trial. Diesel fuel process creates less amount of emission among all type of PO blends. While the highest emission produced by all PO blends because of sufficient time is not available for mixing of PO blends with fuel due that improper mixing of air-fuel may attend and cause for generation of incomplete combustion and less amount of oxygen present over inside combustion chamber.

Main cause of more CO emission of PO blends due to high amount of fuel injected inside of the combustion chamber at same load application which consequence to emit higher CO emission. Also the another cause for higher CO emission is that a reduced amount of cetane number and higher aromatic content of the fuel were participated in combustion process due to this reason extended time of ignition delay may occur and responsible for Carbon monoxide emission.

### 4.6 Hydrocarbon (HC) Emission:
Comparisons of hydrocarbon emission versus engine load are as shows in figure 7. The main factor affecting on hydrocarbon emission is the incomplete combustion of fuel sconstituent part and improper mixing of fuel inside combustion chamber. Wall flame quenching is a part of more concentration of HC emission in exhaust line of engine.
Above graph shows that hydrocarbon emission for type of blend are increases with increase in load on engine. At lower load condition of engine hydrocarbon emission will be less because of lean air fuel mixture present at starting of engine. At full condition more amount of fuel admitted at inside of cylinder for burning of fuel may cause higher emission for all type of blends due its properties such as density, calorific value. Plastic oil 75% indicates the lesser amount of HC emission as compared to plastic oil 50%.

PO100 indicate the slighter more value of HC emission among at all loads. More amount of hydrocarbon emission of all plastic oil blends could be recognized due their longer ignition period of time. Which cause less time available for complete combustion of each constitute of fuel which responsible for incomplete combustion of fuel.

5. Conclusions

In this research work represent the performance and emission character of plastic oil for CI engine which are run by different blending of plastic fuel. Following are conclusion made on the basis experimental testing.

- Pyrolysis is suitable method for production of fuel from misused or waste plastic. All properties obtained from testing are found to be within ASTM standard limit.
- Selected single cylinder engine is able to work firmly for selected plastic fuel blends at PO100, PO75, PO50 and PO25.
- PO25 fuel is the top blending performance of fuel for CI engine among all selected load condition.
- Brake thermal obtained for all blends of fuel should be satisfactory and it provide the need of power for engine at load condition.
- Specific fuel consumption obtained from WPO blended was slighter higher that the diesel fuel due its
- The BSFC found to be .38 kg/kW-hr to 0.29 kg/kW- hr for PO100 blending of fuel. This is acceptable limit as per the standard requirement of diesel engine.
- Mechanical Efficiency was found be better for all condition of load, it’s near about 90% at full load condition of engine for PO100% of blending. Every load established acceptable performance of engine at all load blended of fuel.
• NOx emission is higher for all blending of plastic fuel compared to diesel fuel, due to higher temperature rate produced by the engine for plastic oil.
• Carbon monoxide emission decrease for all operating condition of engine. It was found more in PO 100 fuel due to deficiency of oxygen in combustion.
• Hydrocarbon emission more from low load to high load condition due because incomplete combustion occurred due to the large amount fuel admitted at higher load. But PO75 has lesser emission as compared to PO50.

More experimentation and optimization needs to be done for find out the best blending of WPO fuel to achieve finest engine performance of C. I. engine.

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