Experimental Investigation of Plastic Oil Blends on CRDi Engine for Various Fuel Injection Pressures

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Common Rail Direct Engine (CRDI) engines are used for transportation and other sectors due to their high fuel conversion efficiencies. Waste plastic pyrolysis oil can be a substitute to the depleting petroleum reserves. Plastic oils are durable and takes longer time to degrade because of stronger molecular bonds and it repel to natural processes of degradation. This investigation deals with the effect of increasing the fuel blend ratio and with increasing the fuel injection pressures on single cylinder, CRDI diesel engine using plastic oil and diesel blend. The fuel blend varies from 5:95%, 10:90% and 15:85% (Plastic pyrolysis oil and diesel) respectively with various fuel injection pressures of 400 bar, 500 bar and 600 bar. The emission, performance and combustion characteristics were evaluated and analyzed in this work. Plastic oil blends were able to operate in diesel engines without any engine modifications. The results shows the brake thermal efficiency increases with the increasing fuel injection pressure. The engine with the fuel injection pressure of 600 bar gives better brake thermal efficiency at the full load condition for the 15PDB fuel blend. Hence it was concluded that the increasing the pressure, increases the performance and decreases the emissions.

Keywords: Engine, Plastic Oil, Fuel Injection Pressure, Emissions, Performance

1. Introduction

Common Rail Direct Engine (CRDI) engine is the mostly used for transport, automobile, cultivating application and manufacturing sector a direct result of their raised fuel interpretation proficiency and similarly simple activity. These wide fields of use lead to expanding prerequisites of oil determined fills. The exhaustion of oil saves and expanding request additionally prompt a precarious emerge in fuel costs. Then again, their fumes discharges, for example, residue and nitrogen oxide (NOx)
are unsafe to regular habitat and living creatures. Much exertion is being paid worldwide to diminish the residue, carbon monoxide (CO), hydro-carbon (HC) and NOx discharges from diesel motors [1]. An option for diesel, plastics oil will take long to break down because of the toughness of the sub-atomic bonds in the plastic are so solid and it is oppose to characteristic cycles of debasement. Lot of environmental issues are arising due to the waste plastics. We can convert the waste plastics into oil by the pyrolysis method for the usage in CI engines as an alternate to depleting diesel fuel. The genuine reason for the work is to distinguish the substitute fuel for petro diesel by utilizing waste plastic oil, which assists with lessening the air contamination and plastic unloading in the dumping yard [2].

Bharat Stage Emission Standard is the emission standard regulated by the Indian government to control the air pollution from the CI engine and SI engines. This standard is according to European regulations, which was introduced in the year of 2000. Since then, norms have been released progressively. All vehicles produced after usage of emanation standards should follow the guideline. At that point it is required for all the produced vehicles once again to follow discharge standards. On 2010, Bharat Stage (BS) III discharge standards are authorized everywhere on the nation and BS IV in 13 significant urban communities the nation over and it has been actualized the whole way across the nation on April 2017. The public authority declared to skip BS-V standards and actualize BS-VI emanation standards until 2020. In late judgment, the high court has prohibited the deals and enlistment for the engine vehicles following the outflow standards BS-IV in the everywhere on the nation from first of April 2020. The standards by the public authority are assisting with cutting down the contamination level while the expense of the vehicles is expanding because of improved innovation and expanded fuel cost. However, this private cost is adjusted by the general wellbeing cost and sickness cost to the people groups [3].

Zizipus jujube methyl ester with aluminium oxide nanoparticles in CRDI engine gives higher brake thermal efficiency and heat release rate [4]. Plastic pyrolysis oil produced by the fast pyrolysis have similar properties as diesel. The produced oil was tested on a 4 cylinder diesel engine with various loads. At lower loads plastic oil takes longer ignition delay period causes stability issues [5]. Combustion and performance studies was done in a CI commercial diesel with PO30% plastic oil blend. BTE was higher than diesel [6]. Plastic oil was produced from municipal plastic waste and with diesel blend tested in the diesel engine. BTE is lower than diesel for all blends and loads. Combustion characteristics at the full load is higher than diesel fuel [7].

Plastic oil was manufactured from squander plastic material gathered where material if land fill zones, the plastic oil are separated by the cycle of pyrolysis. PO25 and PO50 and PO75 blend were arranged abuse plastics oil plus huge petro diesel fuel. At the current effort to the attributes of consuming of a steady rate of speed Petro-diesel motor be free exposed to feasible burden condition. The conclusion point is that thermal effectiveness of tested fuel blend with unadulterated artificial oil in poorer billet compared petro-diesel at all heap condition.at greatest burden the zenith point chamber pressure, heat discharge, copying lead time and start time that passed prepared testing oil and it’s combination be high compared with the petro-diesel. The pinnacle weight to the moving motor on perfect testing fuel is added on the subject of 6% however it's demonstrated helpless
warm productivity. Exposed to the test outcome it very well may be discovering that the burning cycles are basically influenced by the actual properties of the infused fuel [8].

CRDI Engine single chamber model is being analyze the motor was used to discover the impact of FIP and SOI timing on motor copying properties. This will result the warmth adaptable and sediment game plan also. Exploration paper was expressed at consistent pace of motor (1500rpm) at four distinctive FIPs (300, 500, 750, and 1000) in four diverse SOI timing and diverse fuel infusion Measure. Consuming attributes of the motor were tried upheld on In-chamber pressure level information. Roundabout infusion CI DICI motor, fuel vaporization and that heat energy move attributes feeling fuel-air blending is additionally in-juncture by the FIP and SOI timing. The Injection boundary unit's significant control the charge per unit of weight raise (ROPR), and warmth energy discharge rate (HRR), which thus stun the warmth move from motor chamber also, power yield of the motor. Thereof it's critical to limit the fuel infusion parametric amount to assembled effective and cleanable burning CI diesel motor [9].

2. Experimentation

First diesel fuel is used in the Common Rail Direct Injection (CRDI) engine to give benchmark information. Information's are digitized by utilizing PC. The test motor was kicked utilizing unadulterated petro diesel and permitted to run for 30 minutes prior to taking readings. The subsequent stage motor astute settled and came to consistent state. The gauge information were noticed the motor burden was changed utilizing eddy current dynamo meter and the equivalent was recorded. Vaporous set free fuel utilization was likewise on record from the relative sensors. Regardless change in various infusion pressure the motor become required temperature infusion weight will be changed by 240 PE IC motor programming and furthermore change in various burdens from 0kg, 3kg, 6kg, 9kg, and 12kg.

The various combinations of waste plastic oil were prepared and finished to look at the test motor. The blend is set up on the proportion of (D: PO) 95:05, 90:10 and 85:15 with a small amount of plastic oil (5%, 10%, 15%) added to the volume of diesel. The properties of the test oils were given in table 1. Viscosity and density of the mixed fuel with increment in PO%. The calorific estimation of pyrolysis oil mix are lower contrasted with petro diesel fuel. Cetane number of plastic pyrolysis oil blend is lower than petro diesel fuel.

| Properties                      | Diesel | Plastic Oil |
|---------------------------------|--------|-------------|
| Specific Gravity(g/cc)          | 0.84   | 0.83        |
| Kinematic Viscosity(cSt) at 40℃ | 2.15   | 2.64        |
| Calorific Value (kJ/kg)         | 43500  | 44200       |
| Cetane Number                   | 54     | 50          |
| Flash point(℃)                  | 45     | 40          |
| Fire Point(℃)                   | 48     | 44          |
The burning cycle successful of motor improves if the Injection fuel pressure is expanded. By this because of improved atomization and arranged of fuel and air [10]. And furthermore the copying chamber is arranged impact the combination of the air and test fuel contributes the performance demonstration and release tail pipe emanation of the test motor. The tail pipe emanation like NOx should be prohibited as they are risk to individual just as the Mother Nature. thus EGR in the test framework is incorporate to decrease the discharge of NOx. The undertaking manages discover the substitute fuel for the petro diesel that can be utilized for agribusiness and car use of CRDI motor. This requirements extra of certain components like ECU, fuel rail, wiring hardness, high weight siphon and different kind of sensor of the CRDI motor.

In this framework depends on the variety in the weight in the estimating tube, properly loaded up with plastic oil + and petro diesel mixes. At he high weight diesel combination in siphoned to the cylinder the test fuel makes pressure wave recognize by the weight sensor in the cylinder.

While the fuel shot, the weight in the cylinder was kept up at steady weight at 400 bars. In the arrangement the line power is proceeds under observation by utilizing pressure sensors. The test arrangement impact the fuel was taken out and the estimations were found the middle value of. The consequence of fuel infusion power (FIP) beginning of infusion (SOI) timing and infusion technique on the motor execution, discharge and ignition properties were accounted in the CRDI motor. Point by point specialized particulars of the test motor are given underneath. The Test motor tail pipe discharge and copying qualities of the fuel is inspected with 400, 500, and 600 bars by differing the infusion pressure utilizing ECU. While the test explores the temperature of the fuel is kept up at 20°C by utilizing infusion fuel condition unit.

Figure 1. Block diagram of the experimental setup

The engine emission was checked by the tail pipe emission by using AVL Smoke and Gas analyzers, Figure 2 & 3. Their specifications were given in table 2 & 3. The tail pipe emission gas sample was traveled through a moisture trap and a paper
filter to arrest moisture & condensation and PM from enter the analyzer test cell. Performed the experiments using 5%, 10% and 15% plastic PPO oil and diesel blends at constant speed condition on the standard CRDI diesel engine setup. The performance characteristics including engine BP, brake thermal efficiency, SFC, mechanical efficiency, and TFC were studied. The results indicated no significant power reduction in the engine operation.

![Test Engine](image)

**Figure 2. Test Engine**

| Specifications          | Parameters                     |
|------------------------|-------------------------------|
| Make                   | KirloskarTV1                  |
| Number of cylinders    | 1                             |
| Number of strokes      | 4                             |
| Fuel                   | Diesel                        |
| Rated power (HP)       | 6.97 @ 1500 rpm               |
| Type of dynamometer    | Eddy current dynamometer      |
| Cylinder diameter (mm) | 87.5                           |
| Stroke length (mm)     | 110                           |
| Compression ratio      | 17.5:1                        |
| Orifice diameter (mm)  | 20                            |
3. Result and Discussion

The combustion attributes of plastic oil and its mixes in a diesel motor were examined. As an overall conduct it is seen that brake thermal effectiveness increments with load, pressure proportion for all the fills while explicit fuel utilization diminishes.

Table 3. AVL Gas Analyzer Specifications

| Type            | AVL Gas Analyzer |
|-----------------|------------------|
| Power           | 11 - 22 Voltage and 25W |
| Start up Time   | 6 min            |
| Connector Gas   | 180 l/H, Max. over pressure 450 hp |
| Response Time   | T95 < 15 sec     |
| Operating Temp  | 5-45°C           |
| Storage Temp    | 28 degree celsius|
| Relative Humidity | < 95 % Non-condensation |
| Inclination     | 0 to 90 degree celsius |
| Dimensions      | 270×370×95 mm    |
| Weight          | 4.5 Kg           |
Figure 4. Performance test of B-15% engine @ 400 bar

Figure 5. Emission test of B-15% engine @ 400 bar
Figure 6. Performance test of B-15% engine @ 500 bar

Figure 7. Emission test of B-15% engine @ 500 bar

Figure 4 & 6 shows the performance test for the B-15% plastic oil blend with injection pressure 500bar. Values of PPO, B15% with values are very close trend with 400bar corresponding to variation of load. SFC diminishes with load for all the tried energizes. The petroleum necessity designed for creating BP/unit descends at advanced burdens. This is obvious from the SFC noted for 1.73~0.68 kg/kWh. It was seen that SFC for B-15% with Injection pressure 500bar Lower in all the cases. In the CRDI motor, transformation of substance power addicted to heat power was less significant for a little at the same time as operation by means of squander plastic oil. Consequently the CRDI motor attracts extra fuel to get together the heap those outcomes in Lower SFC for B-15%. Contrasting and B-15% at
500 bar Injection Pressure. Brake thermal efficiency chart were drawn for varying loads B-15% at 500bar pressure. It is noted that brake thermal efficiency of the testing oil the level of 4.95~12.54%. Which deduce that, at elevated Injection Pressure the squander plastic oil reduced the brake thermal efficiency with diesel. PPO blends with higher injection pressure are affected by these properties which effect in the poor combustion [11].

Figure 5 & 7 shows the emissions for the fuel injection pressure of 400 and 500 bar. CO emissions decrease continuously for 500bar injection pressure to 400bar injection pressure, and the value of emission in volume percentage for B15% maximum load are 1.10 and 0.16%, and at full load. The reason behind decreased CO emission may be due to increase in Injection pressure combustion efficiency and better mixing. It can be noticed that the decreased in the value of CO emission with Increase in load. CO₂ exhaust emission measured at exhaust tail at different blends with B-15% with 500bar injection Pressure with respect to loads. CO₂ emissions Reduced gradually from no load peak load. Waste plastic oil decreases CO₂ emissions at all blends value is more at peak load. NOx emission for diesel and B-15% with injection pressure 500 bar is 12 ppm and 88 ppm. The engine performance, exhaust emission and combustion characteristics of 15% with injection pressure 500 bar is lower than 400 bars, the engine performance and emission characteristics of a engine working with B-15 % with 500bar blends were investigated. The following conclusions have been drawn based on the experimental results. HC Emissions are decreasing with increase in injection pressure. But there is a major decrease in this emission B-15% blend of plastic Pyrolysis oil. This may be due to increase in injection pressure [12].

![B 15% PERFORMANCE TESTS OF DIESEL ENGINE AT 600 BAR](image)

Figure 8. Performance test of B-15% engine @ 600 bar
Brake power for B-15% plastic oil blend with injection pressure 600bar values of PPO, B15% with values are very close trend with 400bar corresponding to variation of load. SFC diminishes by means of weight for all the tried energizes, figure 8. The testing oil prerequisite for creating BP/unit descends at advanced burdens. This is clear from the SFC noted for 1.94~0.75 kg/kWh. It was seen that SFC for B-15% with Injection pressure 600bar lower in all the cases. In the CRDI motor, transformation of compound energy into heat power was less important for some time operation with testing oil. Henceforth the CRDI motor attracts extra testing oil to get together the heap with the intention of outcomes during Lower SFC for B-15%. Contrasting and B-15% at 400 bar Injection Pressure. Brake thermal efficiency chart were drawn for varying loads B-15% at 600bar pressure. Its noted that brake thermal efficiency of the testing oil found in the level of 4.41~11.37%. Which deduce that, at higher Injection Pressure testing plastic oil reduced the brake thermal efficiency with diesel. PPO blends with higher injection pressure are affected by these properties which effect in the poor combustion [13].

Figure 9 shows the emissions for the fuel injection pressure of 600 bar. CO emissions reduce continuously for 600bar injection pressure to 500bar injection pressure, and the value of emission in volume percentage for B15% maximum load are 1.10 and 0.16%, and at full load. The reason behind decreased CO emission may be due to increase in combustion efficiency and better mixing. It can be noticed that the decreased in the value of CO emission with Increase in load. CO2 exhaust emission measured at exhaust tail at different blends with B-15% With 600bar injection Pressure with respect to loads. CO2 emissions increased gradually from no load peak load. Injection pressure 600bar CO2 emissions at all blends value is more at peak load. NOx emissions. NOx emission for diesel and B-15% with injection pressure 600 bar is 35 ppm and 559 ppm. The engine performance, exhaust emission and combustion characteristics of 15% with injection pressure 600 bar is higher than 400 bars,
the engine performance and emission characteristics of a engine working with B-15 % with 600bar blends were investigated. The aoutcome results have been ataken as per experimentation results. HC Emissions are standard with increment in infusion pressure. However, there is no adjustment in this discharge B-15% mix of plastic Pyrolysis oil. This might be because of expansion in infusion pressure. Smoke Emissions are essentially higher with B-15% infusion pressure at 600bar. At all the stacking conditions, Smoke Emissions are expanding with increment in Injection pressure. Yet, there is a significant expansion in this emanation B-15% mix of plastic pyrolysis oil. This makes higher Smoke Emissions beneath the diesel esteems due to high cetane number

4. Conclusion
Plastic oil blend with various injection pressure gives the following,
- BTE increases slightly with increase in load, maximum BTE obtained in B-15% blend. BTE for 600bar pressure is higher than 400 bar pressure at peak load.
- SFC decreases with the increase in pressure.
- CO emissions decreases with increase PPO blend compared with diesel. CO$_2$ emission increases with rise in injection pressure.
- HC emission of 600bar is lower than 500bar. NOx emission of 600bar is greater than 500bar.

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