Performance Test on Compression Ignition Engine by Blending Ethanol and Waste Plastic Pyrolysis Oil with Cetane Additive

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Abstract: The demand for diesel fuel is higher than that of petrol throughout the world hence seeking alternative to mineral diesel is a natural choice. Alternative fuels should be easily available at lower cost, environment friendly and fulfill energy needs without modifying engine’s operational parameters. Waste to energy is the trend in the selection of alternate fuels. In this work, Waste Plastic Pyrolysis oil (WPPO), Ethanol, Diesel blend with Cetane additive has been attempted as an alternative fuel. A Twin cylinder, Direct Injection engine was used to assess the engine performance and emission characteristics of waste plastic pyrolysis oil with cetane additive. Experimental results of blended plastic fuel and diesel fuel were compared.

Keywords: cetane additive, diesel engine performance, emission characteristics, ethanol, waste plastic pyrolysis oil

1. Introduction
An efficient energy conservation and management has become an important action in industrial field as energy is considered as a major element in the production cost. This positive approach has changed the pattern of energy use all over the world. Hence the developed countries have shown raise in their productivity, maintaining the unchanged energy consumption levels. Alternative fuels should be available abundantly and at low cost, be environment friendly and fulfill energy security needs without sacrificing engine’s operational performance. Waste to energy is the development in the choice of alternate fuels. Fuels like alcohol, biodiesel, fuel from waste plastics are several of the tried out alternative fuels for the internal combustion engines.

The demand for diesel fuel is higher than that of gasoline throughout the world hence seeking alternative to mineral diesel is a natural choice. Plastics have turn into as vital part in day today life, due to their lightweight, durability, energy efficiency, coupled with a faster rate of production and design flexibility, this process such as thermalpyrolysis andcatalytic pyrolysis can be used to securelychange into waste plastics into hydrocarbon fuels that can be used in diesel engines. Disposal of the waste plastics poses a great hazard to the environment and an effective method has not yet been implemented. Due to its non-biodegradable nature, the plastic waste contributes significantly to the problem of waste management also. Panda et al \textsuperscript{1}stated that the production of liquid fuel from plastic waste is a better alternative as the calorific value of the plastic pyrolysis oil is almost to the values of
diesel fuels. Alan Hasen et al \(^2\), in this review the properties and specifications of ethanol blended with diesel fuel are discussed. Cenk Sayin et al \(^3\) in his performance study, ethanol was blended with diesel fuel from 0% to 15% and with an increment of 5%, and the injection timings were varied. It was observed that ethanol in the blend increases the levels of NO\(_x\) and CO\(_2\) emissions and decreases the CO and UHC emissions considerably. Viswanath et al \(^4\) carried out experimental investigation using waste plastic pyrolysis oil with silica as catalyst. Waste plastic pyrolysis oil was mixed with diesel in proper ratios and used as fuel in diesel engine. Results showed increased exhaust temperature and higher NO\(_x\). Mani et al \(^5\) had tried waste plastic pyrolysis oil produced from thermal pyrolysis as fuel in diesel engines and observed that NO\(_x\) higher at peak loads and higher unburnt hydrocarbon and increased smoke levels. Osami Nishida et al \(^6\) had tried waste plastic pyrolysis oil obtained from thermal pyrolysis as fuel in marine diesel engines. Since waste plastic oil has almost nil sulphur, SO\(_x\) production been almost nil compared to Heavy Fuel Oil used in marine engines. Ozcanli et al \(^7\) carried thermal pyrolysis of waste plastics and subsequently distillate those to observe better performance as fuel. In emission, increased in NO\(_x\) has been observed even in light phase oil. Ahmad Rozaimee Mustafa et al \(^8\) carried out cultivation of microalgae using sungaisurawater source for biodiesel production. Bridjesh et al \(^9\) conceded experimental investigation of variable compression ratio diesel engine using Calophylluminophyllum Biodiesel. Ramaraao et al \(^10\), done the experimental investigation on performance and emission characteristics of CI engine using nanoadditives with biodiesel.

In this research paper, the diesel engine performance was evaluated by blending ethanol with waste plastic oil and diesel at definite mixing ratios of (Ethanol: WPPO: Diesel) 5:5:90, 10:10:80 and 15:15:70 respectively. The cetane additive AC2010A added to blended fuel is 1ml per 1000ml of blended fuel. The objectives were followed as, to evaluate CI engine performance and emissions characteristics with blended diesel, Waste Plastic Pyrolysis oil (WPPO) and Ethanol and to observe a substitute fuel by comparing the blended fuel results with base diesel.

2. Experimental Setup

A Twin cylinder, constant speed, Direct Injection engine was used to assess the engine performance and emission characteristics of plastic pyrolysis oil. The diesel runs under different load conditions at a constant speed of 1800 rpm with the different plastic oil proportions. The diesel engine was directly attached with an eddy current dynamometer for varying the loads from zero load (0%) to full load (100%). Based on the engine power produced, the engine load range is varied from zero load condition of 0%, 25%, 50%, 75% and full load condition of 100%. The engine loads are varied manually with help of an eddy current dynamometer. AVL smoke meter was attached for measuring the smoke opacity and exhaust gas temperatures. The test rig was installed with AVL indimicro software to obtain various readings and results during operation. A five gas analyzer was used to measure the emission characteristics such as UHC, CO, NO\(_x\), CO\(_2\) and O\(_2\) values from the exhaust gas.

2.1. Benefits of Cetane additive

Additives can increase the viscosity to make sure adequate lubrication of the injection pump, also it stabilizes the mixture in the presence of a high-water content, to ensure fuel is homogeneous under all conditions. It has good detergent properties to ensure fuel injection equipments remain clean and provide good atomization. Prime benefit of using the additive includes:

- Improved engine power and torque.
- Improved cetane number.
- Reduced emissions of carbon dioxide.
- Reduced corrosion.
- Reduced engine noise.
Table 1. Properties of Diesel, Plastic oil and Ethanol

| Sl.No | Properties                   | Diesel Fuel | Plastic Oil | Ethanol  |
|-------|------------------------------|-------------|-------------|----------|
| 1     | Density (kg/m³)              | 852         | 794         | 790      |
| 2     | Calorific Value (kJ/kg)      | 46450       | 44344       | 27710    |
| 3     | Kinematic Viscosity (cSt)    | 3.10        | 2.13        | 1.05     |
| 4     | Flash point ºC               | 53          | 42          | 16.5     |
| 5     | Fire point ºC                | 57          | 46          | 98       |
| 6     | Cetane Number                | 55          | 52          | 9        |
| 7     | Sulphur (%)                  | < 0.037 %   | < 0.023 %   | -        |

Blended fuel in the blended ratio of Ethanol 10%; WPPO 10%; Diesel 80% was tested and its properties are tabulated in Table 2.

Table 2. Properties of Blended Fuel

| Sl.No | Properties                   | Blend of E/WPPO/D | E/WPPO/D with cetane additive |
|-------|------------------------------|-------------------|------------------------------|
| 1     | Kinematic Viscosity (cSt)    | 2.34              | 2.34                         |
| 2     | Cetane Number                | 51                | 58                           |
| 3     | Carbon Residue (%)           | 0.01 %            | 0.01 %                       |
| 4     | Sulphur (%)                  | 0.04 %            | 0.04 %                       |

3. Results and Discussion

The engine performance and emission analysis test of Waste Plastic Pyrolysis oil, Ethanol, Diesel with a cetanee additive with different blends were tested and evaluated for varied load condition.

3.1. Variability of SFC Vs Load

The variability of Specific Fuel Consumption (SFC) for varied loads (kW) applied on the engine for various ratios of waste plastic pyrolysis oil, ethanol and diesel blends with AC 2010A Additive were shown below in the Figure 1.

![Figure 1. Variation of SFC with engine loads](image-url)
The Specific fuel oil consumption of blended oil is slightly higher than diesel oil. The E5/WPP5/D90 blend has specific fuel oil values much nearer to diesel. From the graph, it is derived that the diesel has a lower SFC because of high calorific value, with blended fuels such as E5 and E10 the equivalent SFC was very closer but higher than that for the pure diesel fuel. This was observed due to the slightly lower calorific value and higher viscosity of the plastic pyrolysis oil.

3.2. Variation of Brake Thermal Efficiency Vs Load
The variation of the brake thermal efficiency (BTE) for different loads with blended fuel at different ratios of diesel, waste plastic pyrolysis oil, ethanol and cetane additive blends were shown in figure 2. The brake thermal efficiency of blended oil is slightly lower than diesel oil. The E5/WPP5/D90 blend has brake thermal efficiency values almost like diesel.

![Figure 2: Variation of BTE with engine loads](image)

The higher viscosity of the blended fuel reduced the brake thermal efficiency. The BTE of the E5 blended fuel was similar to that of the diesel performance. It is observed that BTE of 26% at maximum load condition and it was only 2% variation from that of the pure diesel performance.

3.3. Variation of Load with NOx
The variation of nitrogen oxide emission from diesel, waste plastic pyrolysis oil, ethanol and cetane blends are slightly lower than the pure diesel fuel performance at maximum loads and it was shown in figure 3.
Because of more air action, much elevated than stoichiometric values, diesel engines produce more NO\textsubscript{x} at part load conditions and at higher loads. Diesel has higher calorific value than that of waste plastic oil, so a lesser amount of diesel was injected into the combustion chamber. Due to this more heat was liberated during the combustion and it was increases the combustion chamber temperature.

### 3.4. Variation of Load with CO

The various Carbon Monoxide emissions for varying blends were shown in figure 4. The Carbon Monoxide emissions from blended fuel area bit more than the normal diesel fuel at all loads. Diesel engines produce little amount of CO when compared to NO\textsubscript{x} and particulate emission as the engine was not loaded. It also concluded that blended fuel emission of CO is like that of pure diesel.

### 3.5. Variation of Load with CO\textsubscript{2}

The various Carbon Dioxide levels for varying blends were shown in figure 5. From the readings, it is inferred that emission of Carbon dioxide is like that of pure diesel. The CO emission can be reduced by
providing surplus oxygen into the combustion chamber. Therefore converting CO into CO₂ this is possible by complete combustion.

![LOAD VS CO₂](image)

**Figure. 5**: Variation of CO₂ with engine loads

Carbon dioxide will appear in the exhaust of the diesel engine at full load condition. From the results of emission characteristics, it was observed that the Carbon dioxide emission for all blended ratio of blended fuel was more likely compared to diesel performance at all load conditions.

3.6. Variation of Load with UHC

The various hydrocarbon emissions for different blends were shown in figure 6. Excluding at higher loads the hydrocarbon emissions are little lower than diesel.

![LOAD VS UHC](image)

**Figure. 6**: Variation of UHC with engine loads

At different load conditions, the unburned hydrocarbon emission was lower for the diesel fuel with respect to the blends E5 to E15. This is because of the higher calorific value of diesel and due to which less amount of fuel was injected when compared to plastic oil blends. This builds the engine to function at leaner state. Because of oxygen enrich environment, combustion is complete. Hence lower unburned hydrocarbon emission was observed with diesel fuel.
4. Conclusion
Alternative fuels should be available at ease and at low cost, should be environment friendly and provide energy security needs without reducing engine’s operational performance. Waste to energy is the trend in the selection of alternate fuels. Plastics waste has become a significant element in resourceful waste. In this work, Waste Plastic oil Ethanol, Diesel blend with Cetane additive has been attempted as an alternative fuel. The experiments were conducted without any modification on the engine. CI engine performance tests were conducted with various blend ratios of diesel-WPPO-ethanol with cetane additive and the best combination of blends and additives were studied. Based on the engine performance and emission characteristic test of the Waste Plastic Pyrolysis oil, Ethanol, Diesel and Cetane Improver blend symbolize a admirable substitute fuel which gives better performance and similar emission characteristics results compared with base pure diesel. From this study, blend of diesel 90%; waste plastic pyrolysis oil 5%; ethanol 5% with cetane additivewas performance better when compared to other blends.

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