Role of non metallic Nano additive in the behavior of a diesel engine fueled with blends of Waste plastic oil

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This study analyze about the efficiency improvement and emission reduction of a 4 stroke mono cylinder diesel engine fueled by 20 % by volume mixture of Waste Plastic Oil (WPO) blended with 80 % diesel and different proportion of non metallic nano additive. WPO was extracted through the pyrolysis process using plastic wastes collected from near by areas. Nano additives made from rice husk was blended @ 25ppm, 50ppm, 75ppm and 100ppm. The fuel mixture was tested for its stability and later used in diesel engine for performance, emission and combustion characters. Result indicate that for W20 mixture without additives revealed 3.5 % drop in brake thermal efficiency (BTE) and Brake specific fuel consumption (BSFC) increased by 5.7 % at a full load condition when equated with diesel. With the blending of Non metallic Nano additives (NA), the BTE increased by 2.6 % and fuel consumption reduces by 3.1% for the W20NA75 blend when compared to other blends. Emissions parameters like hydrocarbon (HC), carbonmonoxide (CO) and smoke opacity reduced by 15.3%, 7%, and 20.4% respectively with rise in oxides of nitrogen (NOx) emission by 14.1% when equated to diesel at maximum load condition. It can be concluded that 75ppm rice husk nanoparticles added with W20 blend helped to rise the efficiency characters and reduces engine out pollutants of a CI engine.

1. Introduction

Diesel vehicles are broadly employed in road transport and agriculture sector. Mahua vegetable oil was utilized in a single-cylinder diesel power train
and it was found that due to the larger viscosity and mass per unit volume, the efficiency of the engine dropped significantly [1]. Three ratios (10%, 20%, and 30%) of Bioethanol got from Eichhornia Crassipes were added with base fuel and 30% blend offered utmost emission drop [2]. Methyl ester of Neem oil at higher injection pressure was tried in a diesel engine for performance and emission study. It was observed that fuel injection pressure will be proportional to Thermal efficiency, NOx, in Cylinder Pressure and HRR and inversely proportional to Specific Energy Consumption, Hydrocarbon, Carbonmonoxide and Smoke[3].

Fuel additives were blended to modify the property of main fuel by using 4 different oxygenated additives like Propylene glycol, Dimethyl carbonate, Ethylene glycol, and 2-Butoxyethanol with Jatropha methylester and the results reveal that BSFC reduced with BTE rise for biodiesel added with nano additive[4]. Borassusflabellifer oil with L-ascorbic acid was tried in a mono-cylinder diesel engine. The results reveal that the efficiency parameters improved and emission factors reduces to a significant values [5]. Liquid additives are found to improve performance and emission to some extent, but not to a significant level [6]. Al$_2$O$_3$ nano additives with pongamia biodiesel revealed significant rise in Brake Thermal Efficiency and reduction of Hydrocarbon, Carbonmonoxide and smoke emissions. In terms of fuel usage and NOx emission the oil and additive does not produced a significant results[7].

The authors analyzed the characters of biodiesel blend with CeO$_2$ and Al$_2$O$_3$ as Nano Particles. It mentions the drop in CO, NO, and HC emission of about 44%, 30%, 60% respectively[8]. Attempt was made by adding ZnO Nano additive to methyl ester of Soya bean biofuel and it was found that biodiesel helped in improving the output of the engine when blended at optimum situations [9]. Rubber seed oil at 1:4 ratio was mixed with diesel and aluminum oxide nano additive was blended at 3 different ratios. The output mentions that there was rise of BTE and the drop in BSFC. NOx emission raised with carbon deposits[10].

2. Materials and Methods

2.1 Pyrolysis and Distillation of waste plastic oil

Pyrolysis is the activity of heating and melting plastics of different categories in the nonattendance of oxygen. Here Plastic waste was heated in a barrel type reactor at 300 - 350°C for 1.5 hours. The gas arised out of melting of the plastics were condensed to give oil with low sulphur. The oil obtained through this process was made to undergo distillation process for making diesel grade fuel. A Distillation column was used for distillation process. A fuel like Petrol was obtained from 1st fractional level and hotness was 90 to 130°C. Diesel grade fuel was obtained from 2nd fractional level and was 250 to 285°C was the temperature range with density of 0.80 g/ml.
2.2 Nano additive

Nano additives act as a catalyst to change the property of base fuel and to enhance the efficiency and reduce emission characteristics of an engine. In general, Nano-particles have large outer surface area which will help fuel and air mixture to undergo complete combustion. In this experimental work, Rice husk Nano additive was manufactured from rice husk by utilizing ball-milling procedure. Tungsten carbide stones of 10 mm radius were employed to break the rice husk to very fine molecules. This nano additive made of Rice husk will have volatile matter of 74%, ash content of 18% and have a calorific property of 15 MJ/kg.

2.3 Uncertainty analysis

The uncertainty associated with combustion, emission, and performance characters get a proper estimate of the outcomes. The gross uncertainty is arrived by the concept of root-mean-square technique prescribed by Holman. The gross uncertainty is calculated using Equation:

\[
U = \sqrt{U_{\text{load}}^2 + U_{\text{hp}}^2 + U_{\text{bte}}^2 + U_{\text{bsfc}}^2 + U_{\text{HC}}^2 + U_{\text{CO}}^2 + U_{\text{smoke}}^2 + U_{\text{NOx}}^2}
\]

\[
= \sqrt{(0.8)^2 + (0.5)^2 + (0.8)^2 + (0.4)^2 + (0.3)^2 + (0.2)^2 + (0.2)^2 + (0.3)^2}
\]

\[
= 1.39
\]

3. Experimental setup and procedure

The research was done on a Kirloskar single cylinder 5HP naturally breathing water frozen DI diesel engine. The investigational arrangement employed here can be seen in Figure.
1. The details of the arrangement is presented in Table 1. 1500 rpm is the rated rotational speed of the power train. AVL (Germany) GH12D pressure transducer gauge the pressure of the cylinder. A 5 gas emission measuring equipment was used to gauge various emission parameters like HC, CO, CO₂, O₂ and NOx. The Heat release rate and pressure of the cylinder data will be received from Pressur-Crankangle curve. Calibration were done for all the measuring instruments as per procedures. Diesel, W20, W20NA25, W20NA50, W20NA75 and W20NA100 were the various fuels used. The engine was loaded from 25% to 100%. The BTE and BSFC can be obtained from the load test and the emission parameters was measured as mentioned above.

![Layout of the Experimental setup](image)

**Table 1 Parameters of the test engine**

| Make & Model         | Kirloskar & TV1 |
|----------------------|-----------------|
| Rated Power          | 5.2 kW @ 1500 rpm |
| No. of Cylinders     | Single          |
| Combustion chamber   | Hemispherical   |
| Piston bowl          | Shallow bowl    |
| Compression ratio    | 17:5:1          |
| Rated Speed          | 1500 rpm        |
| Bore Diameter        | 87.5 mm         |
| Stroke Length        | 110 mm          |
| Injection Pressure   | 220 bar         |
| Injection Timing     | 23 deg CA BTDC  |
| Fuel Injection type  | Direct          |
| Number of holes in nozzle | 3             |
| Spray hole diameter  | 0.25mm          |
| Spray cone angle     | 110             |
Cubic Capacity    661.45 cc
Type of loading    Electrical Load
Type of cooling    Water cooling
Type of ignition    Compression Ignition

4. Results and discussion
4.1 Performance characteristics
4.1.1 Brake thermal efficiency (BTE)

Fig. 3  Change in  Brake Thermal Efficiency

The change in BTE against BP of the power train is shown in Figure 3. The graph shows the BTE drops with the blending of WPO to diesel, but improves due to the mixing of
nonmetallic nano particle to diesel. The Nano additive has high surface to volume ratio which helps in increasing the efficiency of the blend. For diesel the BTE was noted as 28.3%, for D80W20 blend the BTE was observed as 26%, for W20NA25 blend the BTE was noted as 26.4%, for W20NA50 blend the BTE was noted as 27.2%, for W20NA75 blend the BTE was found to be 25.7% and for W20NA100 blend the BTE was found to be 27%.

4.1.2 Brake specific fuel consumption (BSFC)

![Grafik zum Change in Brake Specific Fuel Consumption](image)

Fig. 4 Change in Brake Specific Fuel Consumption

The change of fuel consumed against BP is revealed in Figure 4. It is seen that there is 1.3% increase in fuel consumption at no load for the D80W20 mixture than base fuel. This drop was further enhanced to 6.3% for D80W20 mixture at maximum load situation. For diesel fuel the fuel consumption was noticed as 0.33 kg/kW hr, for D80W20 blend the BSFC was found to be 0.37 kg/kW hr, for W20NA25 blend the BSFC was noted to be 0.36 kg/kW hr, for W20NA50 blend the BSFC was noted as 0.37 kg/kW hr, for W20NA75 blend the BSFC was noted to be 0.38 kg/kW hr and for W20NA100 blend the BSFC was noted to be 0.39 kg/kW hr.

4.2 Emission characteristics

4.2.1 Carbon-monoxide(CO) emission
The change of CO emission against BP is shown in Figure 5. Carbon particles which are not oxidized properly results in CO emissions. Nano additives assists the burning process because of the catalytic activity and assists to drop the pollution by properly dispersing and increasing the oxidation activity. Blending of waste plastic oil to diesel reduced CO emission to a marginal value. For diesel the CO emission was found to be 0.2 % by volume, for W20 blend the CO emission was observed as same as diesel without any change, for W20NA25 blend the CO emission was noticed as 0.16 % by volume, for W20NA50 blend the CO emission was noticed as 0.12 % by volume, for W20NA75 blend the CO emission was found to be 0.1 % by volume and for W20NA100 blend the CO emission was noticed as 0.11 % by volume. There was a sharp fall in CO emission with the increase in addition of non metallic nano additive to the diesel waste plastic blend.

4.2.2 Hydro carbon (HC) Emission
Figure 6 depicts the variation of HC pollutant for different BP values at same speed. It is noted that HC pollution for all mixtures with WPO was lesser than diesel and rise in nano additive still assists in the drop in HC emission. The Nano additives increase the mixing of fuel air and aids in to complete combustion which in turn leads to reduced HC pollution. For diesel the HC pollution was noted to be 57ppm, for W20 blend the HC pollution was observed as 58ppm with small change from diesel fuel, for W20NA25 blend the HC emission was noticed as 57ppm, for W20NA50 blend the HC emission was noticed as 55ppm, for W20NA75 blend the HC pollution was noted to be 51ppm and for W20NA100 blend the HC pollution was noticed as 53 ppm.

4.2.3 Oxides of Nitrogen (NOx) Emission
Figure 7 reveals change of NOx pollutant against BP. For diesel the NOx pollution was found to be 697ppm, for W20 blend the NOx emission was noticed as 678ppm, for W20NA25 blend the NOx emission was noticed as 677ppm, for W20NA50ppm blend the NOx pollution was observed to be as 697ppm, for W20NA75 blend the NOx emission was seen as 675ppm and for the final blend of W20NA100 the NOx emission was observed to be as 666ppm. It can be seen from the above graph that the NOx emission is found to be higher for W20NA750 blend where the combustion temperature is found to be high.

4.2.4 Smoke Emission

Figure 8 Variation of Smoke emission
The blending of Nano additives enhance smoke pollution by minimizing zones of fuel-rich region and by supplying extra molecules of oxygen for the burning activity. For diesel the Smoke pollution was noted to be as 27BSU, for W20 blend the smoke pollution was noticed as 33.5 BSU, for W20NA25 blend the Smoke emission was noticed as 32.7BSU, for W20NA50ppm blend the Smoke emission was observed to be as 26BSU, for W20NA75 blend the Smoke emission was seen as 26BSU and for the final blend of W20NA100 the Smoke emission was observed to be as 35.2BSU.

5. Conclusion

The results of the present investigation shows that the 80% Diesel, 20% Waste Plastic oil with 75ppm nonmetallic nano additive blend has been found to be a best blending combination in terms of improvement in performance and reduction in emissions. The results are summarized below:

- There was an improvement in BTE for the Diesel, waste plastic oil 75ppm nano additive blend.
- The nonmetallic rice husk nano additive reduces the fuel consumption for the D80W20NA75 blend which behaves as oxygen donating agent and also make the combustion complete.
- There was a remarkable drop in HC, CO and Smoke emission due to the addition of Nonmetallic nano additive with the diesel and waste plastic oil.
- The non metallic nano additive made from rice husk can be easily available from the agriculture product there is no change of increase in cost of the fuel blend.

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