Effect of aluminium oxide hydroxide Nano fluid in castor oil biodiesel fuelled diesel engine

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Abstract. This investigation deals with understanding the effect of adding Aluminium oxide hydroxide nanoparticles along with water with a motive to improve the operational characteristics of a CI engine. Castor biodiesel was prepared using methanol in transesterification process and nanoparticles were available. X-ray diffraction studies were carried out to understand the particle size, structure and its morphology. Three different levels of concentration such as 50, 100 and 200 ppm were preferred to blend in emulsified biodiesel. 20% blend of Castor biodiesel was chosen and 5%, 10% water for emulsion were used. 1% of Span 80 and Tween 80 surfactants each helps in obtaining stable mixture of the fuels. The performance, combustion, and emission characteristics were studied for a CI engine. Performance parameters and emission values reveal that the thermal efficiency is slightly lower than neat diesel. NOx emissions for castor biodiesel B20 were 10% higher than neat diesel. Nanoparticles enabled better air fuel mixing and 18.6% reduction in NOx was obtained by using 200 ppm nanoparticles.

Keywords: castor oil, biodiesel, emissions, performance.

1. Introduction

In automobile sectors, a gap constantly exists between demand and energy source. This search for alternative fuels other than fossil fuels has been bridging this gap. Large variety of biodiesels are available. They are extracted from different feedstock sources and economically cheap [1, 2, and 3]. The properties of non-edible oil are corrected closer to diesel fuel by the transesterification process. It is a feasible and common technique [4]. Among the all non-edible plants such as Pongamia, Jatropha, Mahua etc., Castor is chosen as the feedstock due to abundant presence and easy growth under adverse conditions. Valente et al [5] worked on Castor biodiesel and found that the BSFC showed an increasing trend from 3.3 to 7% as the blend increased to B35. A significant increase was noted in UBHC and CO emissions, despite the oxygen content of Castor biodiesel. Dasari et al [6] investigated three different blends of Castor methyl ester such as B5, B10 and B15. It was concluded that BTE was maximum for B10 blend. Also, HC and CO emissions were the least for B15.
Poor oxidation stability and unsaturated fatty acid content are the major drawbacks of biodiesel. Hence various metal nano additives, metal oxide nano additives, CNT additives and mixed nano additives have been used to achieve the desired fuel properties, in turn to improve the performance and satisfy the stringent emission norms [7, 8]. Risha et al [9] studied the effect of CeO$_2$ nanoparticles in the size of 10 to 20 nm on a single cylinder CI engine. A significant increase in Brake thermal efficiency was observed with addition of nanoparticles. Also, viscosity and volatility were found to increase with addition of CeO$_2$ nanoparticle. The effect of ZnO nanoparticles at 250 and 500 ppm concentration was studied by Selvaganapathy et al [10] and found that brake thermal efficiency increased by 2% by adding ZnO nanoparticles when compared to diesel. Bash et al [11] studied the CNT effect of blending with biodiesel and Al blended biodiesel and reported a shorter ignition delay. This was attributed to the increased surface to volume ratio and thermal conductivity property of the fuel. Prabakaran et al [12] studied the effect of ZnO nanoparticle addition to diesel- biodiesel- ethanol blends and found that Brake thermal efficiency reduced by 9% and fuel consumption increased by 14% when compared to diesel.

Hence, this work investigated the effect of AlO(OH) nanofluid at different concentrations on, combustion, performance and emission characteristics of a CI engine. AlO(OH) nanoparticles at 50, 100 and 200 ppm were dispersed with Castor oil methyl ester using a mechanical stirrer and an ultrasonicator. 20% Castor oil methyl ester (CME) dozed with AlO(OH) nanofluid at 50, 100 and 200 ppm are called as CMEA150, CMEA100 and CMEA200. The results of the prepared blends are compared with diesel and castor methyl ester fuel.

## 2. Preparation Methods and Materials

### 2.1 Biodiesel Preparation

Pure Castor oil is added to methoxide solution at a molar ration of 9:1. The methoxide solution comprises of 110 ml of methanol and 1% v/v of Sodium hydroxide. The reaction temperature is maintained between 55-60°C for 90 min. This optimum condition was arrived by trial and error method from data based on literature. After removal of glycerine, the product from alkali transesterification process is heated above 75°C to remove the excess methanol content in the oil. The yield was around 80% of Castor biodiesel through this transesterification process. Also the approximate cost of production of Castor biodiesel was 3.5 times higher than the conventional fuel price. Figure 1. Shows the photography of Castor oil methyl ester.
2.2 AlO(OH) Nanofluid preparation

AlO(OH) nanoparticles are utilized for preparation of nanoemulsion. The crystalline structure of aluminium oxide hydroxide nanoparticles is understood by the X-ray diffraction method. The SEM image of AlO(OH) taken at a magnification of 15,000 times reveals that Al nanofluid are spherical shaped with a particle size of 15nm. There will not be any obstacle for the fuel to flow through the nozzle since the nanoparticles sizes are very less than the nozzle diameter. The properties of nanofluids are listed in Table 1.

| Item          | Specification                  |
|---------------|--------------------------------|
| Chemical Name | Aluminium oxide hydroxide      |
| Manufacturer  | Sigma Aldrich                  |
| Density       | 810 g/l                        |
| Size          | 12 to 16 nm                    |
| Purity        | 98%                            |

2.3 Emulsion preparation

AlO(OH) acts as a source of oxygen content during combustion. Owing to huge surface volume ratio of nanofluid, high surface energy is produced and this speeds up the combustion process. Nanoparticles are mixed with distilled water using an ultrasonicator operating at 50 – 60 kHz for 45 min duration. Three samples with 3 different concentrations of 50, 100 and 200 ppm were chosen and Castor oil methyl ester emulsions were obtained. The prepared samples appeared to be pale white in color. To reduce the surface tension between the base fuel and the nanofluid, 1% of Span 80 was used. The stability of the prepared samples was checked after 5 days and no phase separation was detected. The properties like viscosity, density, lower calorific value and cetane index as per ASTM standard test procedure were found and they were closer to the base fuel. They are listed in table 2.

| Properties | Diesel | CME 20 | CME Al 50 | CME 100 | CME Al 200 | Al  | CME Al 200 |
|------------|--------|--------|-----------|---------|------------|-----|------------|
| Density Kg/m³ | 830    | 851    | 863       | 872     | 877        |     |            |
Viscosity at 40°C cst | 2.45 | 5.24 | 5.45 | 6.25 | 6.52  
Flash point °C  | 53    | 62.2 | 69   | 72   | 74    
Cetane number   | 47    | 49.6 | 49.4 | 49.2 | 48.1  
Calorific value MJ/kg | 42.35 | 36.8 | 37.51 | 37.8 | 38.1  

Table 3. Engine details

| Point              | Specification       |
|--------------------|---------------------|
| Model              | Kirloskar TV 1      |
| Cylinder Bore      | 87.5                |
| Stroke             | 110                 |
| Compression ratio  | 17.5                |
| Rated output       | 5.2 kW              |
| Speed              | 1500 rpm            |
| Pressure transducer range | 0-345.5 bar        |
| Load cell range    | 0-50 kg             |
Figure 2. Experimental setup

Table 4. Uncertainty of various instruments used

| Instrument              | Range            | Uncertainty |
|-------------------------|------------------|-------------|
| AVL digas analyzer      | CO 0-10% vol     | ±0.2        |
|                         | HC 0-20000 ppm   | ±0.3        |
|                         | NOx 0-5000 ppm   | ±0.2        |
| AVL (smoke meter)       | 0-100%           | ±0.1        |
| Cylinder Pressure       | 0-100 bar        | ±0.2        |

4. Results and Discussion

Experiments have been carried using three different Nano emulsions and their effect on engine performance, combustion and emission characteristics at 1500 rpm were investigated. The results were compared with diesel and castor biodiesel fuel under similar operating conditions.

4.1 Performance characteristics

4.1.1 Brake thermal efficiency. The trend of BTE for all load conditions for neat diesel, CME20 and CME nano emulsions with 50, 100 and 200 ppm respectively is shown in Figure 3. Increase in brake power has improved the efficiency. The maximum value of efficiency for diesel, CME, CMEAl 50, CMEAl 100 and CMEAl 200 are 32.63%, 27.69%, 28.34%, 28.46% and 29.62 % at maximum brake mean effective pressure. All the three nano emulsion fuels show higher BTE compared to CME20 at all loads. This high BTE can be attributed to water part in nanoemulsion fuel which helps in fast evaporation and better mixing with air. An improvement of 1.9% was observed in CMEAl200 fuel compared to CME.
4.1.2 Brake specific fuel consumption. The trend of BSFC for all load conditions for neat diesel, CME20 and CME Nano emulsions with 50, 100 and 200 ppm respectively are shown in Fig 4. The calorific value of CME plays an important role in determining the BSFC. All three nano emulsion fuel produced BSFC lower compared to CME at all loads. The evaporation rate is accelerated by the presence of nanoparticles. This helps in near complete combustion and reduction in formation of UBHC. The BSFC of neat diesel, CME20 and CMEAl 50, CMEAl 100 and CMEAl 200 are 0.26, 0.34, 0.32, 0.31, 0.30 kg/kW-hr.

4.2 Emission Characteristics

4.2.1 Effect of AlO(OH) Nanofluid on Hydrocarbon Emission. HC emitted for different loads in case of neat diesel, CME 20 and CME nano emulsions with 50, 100 and 200 ppm respectively are shown in Fig 5. The HC emissions were 26%, 30% and 28% less than diesel. The addition of nanoparticles still lowered UBHC emissions. With their activation energy, the carbon particles inside the combustion chamber at cylinder wall temperature are burnt. The nano particles accelerate the fuel mixing process with air.
4.2.2 Effect of AlO(OH)nanofluid on CO emission. CO emitted for different loads in case of neat diesel, CME and CME nano emulsions with 50, 100 and 200 ppm respectively are shown in Fig 6. The CO emissions were 0.08, 0.06, 0.058, 0.04 and 0.03% volume. This is due to the higher oxygen content in CME20. The nanoparticles are a source of oxidation catalyst and they help in converting CO to CO$_2$ emissions. 66% decrease in CO emissions was observed in CMEAl 200 nano emulsion compared to pure diesel.

4.2.3 Effect of AlO(OH)nanofluid on NOx emission. NOx emitted for different loads in case of neat diesel, CME and CME nanoemulsions with 50, 100 and 200 ppm respectively are shown in Figure 7. The NOx emissions were 740, 750, 738,650 and 610 ppm. Emission for CMEAl200 was 18.6% lower than diesel. The reduction in NOx with addition of nanofluid is attributed to improved catalytic activity and good thermal conductivity of the fluid.
4.2.4 Effect of AlO(OH)nanofluid on smoke emission. Smoke emitted for different loads in case of neat diesel, CME and CME nano emulsions with 50, 100 and 200 ppm respectively are shown in Fig 8. The smoke emissions were 38%, 36%, 32%, 31% and 30%. Emission for CME was 2% lower than diesel. Reduction in smoke is due to increased turbulence inside the combustion chamber caused by micro level blast of water available in the emulsion fuel.

![Figure 8. Smoke emissions](image)

4.3 Combustion phenomena

4.3.1 Pressure variation. Figure 9 shows the pressure variation for every crank angle at full load. As load increases, the in cylinder pressure will also increase due to more fuel consumption. The maximum in cylinder pressure is 68 bar for diesel whereas 66 bar for CME. This is due to higher calorific value of diesel. Furthermore, the nanofluids show slight higher peak cylinder pressure, when compared to CME. This is attributed to increase in ignition delay and high latent heat of evaporation.

![Figure 9. Cylinder pressure vs crank angle](image)

4.3.2 Heat release rate. The plot of HRR against crank angle at maximum load condition is shown in Figure 10. It is evident that combustion starts earlier for CME and CME emulsions comparative to diesel. The behavior is because of high cetane index. The lower HRR noted in case of CME nano emulsion is due to shorter ignition delay.
5. Conclusion

A single cylinder, four stroke compression engine was run with different fuels like diesel, CME and CME nanoemulsions with 50, 100 and 200 ppm respectively. The effect of Al nanofluids on performance, emission and combustion characteristics was investigated and the conclusions are detailed as follows:

1. Reduction in BSFC and increase in BTE were observed for all nano fluids compared to CME. This is owing to microlevel outburst of water and catalytic outcome of nano particles.
2. UBHC and CO emissions found to be lower by 30% and 66% compared to diesel at full load conditions.
3. Slight reduction in NOx of 18% for nano emulsions compared to pure CME was observed. This is due to enhanced catalytic effect of nano particles.
4. Smoke emissions is 2% lesser than base fuel at all conditions, due to excess oxygen molecules present.
5. The engine operation with nano emulsion shows slightly high cylinder pressure and HRR when compared to CME.

From the investigation, it is concluded that CME Nano emulsions proves to be a better alternative fuel with significant reduction in emission and improved performance characteristics.

6. References

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