EXPERIMENTAL ANALYSIS OF INFLUENCE OF INJECTION PRESSURE ON COMPRESSION IGNITION ENGINE WITH BIODIESEL AND NANOPARTICLES BLEND

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Abstract
The scarcity of conventional fuel and stringent emission norms made researchers to look after alternative fuels to run an internal combustion engine. One of the possible alternatives for the Compression Ignition engine is biodiesel. Although there are some challenges such as high viscosity, low calorific value, carbon deposit on the injector nozzle, etc. To overcome these challenges nanoparticles are added which will bring most properties near to virgin diesel. Simarouba a non-edible biodiesel feedstock used and aluminum oxide nanoparticles are added with 50 nm size. Using a probe-type Ultrasonication process nano-biodiesel blend is prepared. To improve stability SDS surfactants are added. The characterization of nanoparticles studied using SEM image. The performance of the engine tested for different dosage levels of nanoparticles mainly 25 ppm, 50 ppm, and 75 ppm. The injection timing, injector pressure, and speed kept constant, whereas injection pressure is varied 200 bar, 225 bar, and 250 bar. There is found a 5.2% increase in brake thermal efficiency for nanoparticles added blend biodiesel at 250 bar compare to 200 bar pressure. For the same thing brake specific fuel consumption decreased by 9%. Most of emissions such as Carbon monoxide, unburnt hydrocarbons decreased, whereas there is a significant amount of increase in oxides of nitrogen emission found.

Keywords: Biodiesel, nanoparticles, transesterification, stability

Notations
CI- Compression Ignition
SEM-Scanning Electronic Image
SDS- Sodium Dodecyl Sulfate
BTE-Brake Thermal Efficiency
BSFC-Brake Specific Fuel Consumption
B20-Diesel(80%)+Simarouba(20%)

1. Introduction
To travel people or to take goods from one place to transportation is required. For transportation most of the vehicles use chemical energy in the form fuel. There are different types of fuels are used to run the engines. High octane number fuels are used in Spark Ignition engines, whereas high Cetane number fuels are used in Compression Ignition engines. Due to many reasons in India, most of the heavy vehicles use Compression Ignition Engines. Due to rapid depletion of fuel it is the need of the hour to shift from conventional fuels to alternative fuels. One of the possible alternatives for diesel is biodiesel because it has most of the properties identical to diesel. The major disadvantage in biodiesel is its low calorific value and high viscosity to overcome this challenge biodiesel is used as blend with diesel[1]. Injector deposit is another major challenge to overcome. Injector deposit is another major challenge to overcome. Endurance test on engine after using biodiesel shows in SEM image there is a greasy type of deposition. The higher level of carbon deposits observed at the injector tip after usage of biodiesel without much modification[2]. The biodiesel has prospective to replace conventional diesel fuel[3].

With recent development of nanotechnology, a lot of researchers is using nanoparticles in different applications. The usage of nanoparticles in diesel engines in biodiesel tends to reduce toxicity, improves stability. Application nanoparticles tend to improve performance characteristics and decrease the major pollutions[4]. The major challenge in nanoparticles characterization is in relevance with physical conditions[5].

Simarouba one of the non-edible oil feedstock used to produce biodiesel from transesterification process. The brake thermal efficiency is found to be increased by 9.14% for biodiesel nanoparticles blend SME2040 (20% biodiesel+40 PPM nanoparticles), this is because graphene nanoparticles having higher thermal conductivity increases combustion efficiency which in turn increases heat transfer coefficient. As a heat transfer coefficient increases, it has directly related with convection heat transfer. As the load increased, there will be an increase in smoke because fuel to air ratio becomes lean to richer. But with the addition of surfactant, smoke is decreasing because there will be an increase in atomization. Also with the addition of surfactant carbon
monoxide will decrease because there decrease in viscosity. The unburnt hydrocarbon is more for simarouba biodiesel compare to diesel because of poor atomization. But unburnt hydrocarbon decreased with the addition of graphene nanoparticles to biodiesel. The higher peak pressure and heat release rate were obtained for SME2040[6]. The three chief components of biodiesel are oleic acid, linolic acid and palmitic acid. To increase specific gravity and Cetane number, the better molar ratio between methanol and acid is used. The transesterification process plays important role in determine the fuel properties of biodiesel[7].

2. Biodiesel and nanoparticles blend preparation

The biodiesel used for current experimental work is non-edible oil Simarouba. The main reason using Simarouba seeds for production biodiesel are higher free unsaturated fatty acid which leads to long term stability[8]. The properties of Aqueous Aluminium oxide nanoparticles are shown in Table 1. The properties of diesel, simarouba biodiesel and B20 (Diesel 80%+ simarouba 20%) is shown in Table 2. Properties are found using apparatus in lab where Cetane value is taken from literature. One of issue will arise is aggregation of nanoparticles in fuel after some time. This is related to stability of nanoparticles. It may be overcome by different processes like Ultrasonication process, adding surfactants to the mixture. The anionic surfactants having better thermal conductivity compare to cationic surfactants[6]. Fig 1 shows the characterization of Nanoparticles.

Table 1 Properties of Aqueous Aluminium Oxide Nanoparticles

| Parameter              | Property         |
|------------------------|------------------|
| Manufacturer           | PLATONIC NANOTECH|
| Average particle size  | 30-50 nm         |
| Surface area           | 120-140 m²/g     |
| Purity                 | 99.90%           |
| Density                | 3.97 g/cc        |
| Molecular weight       | 101.96 g/mol     |
| Melting point          | 2055°C           |
| Morphology             | Spherical        |

Fig 1 SEM Analysis of Aqueous Aluminium Oxide Nanoparticles

Table 2 Fuel Properties of Diesel, Simarouba biodiesel and B20

| Properties                    | Unit   | Simarouba | Diesel | B20 | ASTM | Apparatus used         |
|-------------------------------|--------|-----------|--------|-----|------|------------------------|
| Kinematic viscosity at 40°C   | cSt    | 4.68      | 2.5    | 2.83| D 445| Redwood Viscometer     |
| Calorific Value               | KJ/kg  | 37950     | 43000  | 41900| D 240| Bomb calorimeter        |
| Density                       | Kg/m³  | 880       | 840    | 848 | D 1298| Hydrometer              |
The probe type Ultrasonication is the best method of preparation of biodiesel-nanoparticles blend. The simarouba biodiesel blend is taken in the ratio of 80% pure diesel and 20% simarouba biodiesel, which makes B20. The dosing level of Aqueous Aluminum Oxide is added to blend B20 by 25 ppm (by weight) and goes an increment of 25 ppm. Sodium Dodecyl Sulfate (SDS) is used as surfactant[9].

3. Engine specification and test procedure
The engine test was carried out in single cylinder four stroke diesel engine with water cooled. The engine specification is given in Table 3. Initially diesel fuel used, performance, emission and smoke is measured. Subsequently B20, B20+25 ppm Al₂O₃, B20+50 ppm Al₂O₃ and B20+75 ppm Al₂O₃ used and taken readings. During the experiment, Injection timing (23°bTDC) and Compression Ratio (CR) kept same where Injection Pressure is varied has 200 bar, 225 bar and 250 bar. The experiment was conducted at constant speed 1500 RPM. To change injection pressure, different injector nozzles are used.

| Type                          | Single cylinder four stroke diesel engine |
|-------------------------------|------------------------------------------|
| Rated power                   | 5.2 KW                                   |
| Cooling                       | Water cooled                             |
| Compression ratio             | 17.5:1                                   |
| Stroke                        | 110 mm                                   |
| Bore                          | 87.5 mm                                  |
| Capacity                      | 661 cc                                   |
| Dynamometer                   | Eddy current supply 230 V AC             |

4. Uncertainty analysis of the experimental data
There will be always measurements errors. By taking 5 trails reading uncertainty of any measured reading was found. The Table 4 shows uncertainties in measured values. The values are obtained by average of 5 readings.

| Measured variable             | Accuracy (±)   |
|-------------------------------|----------------|
| Load                          | 0.1            |
| Fuel consumption in g         | 0.1            |
| HC                            | ±1.3           |
| CO                            | ±2.8           |
| NOₓ                           | ±2.2           |
| Smoke                         | ±2.2           |

5. Results and discussion
5.1 Brake thermal efficiency & Brake Specific Fuel consumption
The variation of BTE and BSFC for the test fuel for different loads is shown in fig 2, 3, 4, 5, 6, 7 at Injection pressure 200 bar, 225 bar and 250 bar. Due to high viscosity and lower calorific value there is the decrease in brake thermal efficiency whereas adding nanoparticles increases with dosage 75 ppm with injection pressure increases the Brake thermal efficiency 5.2% whereas brake specific fuel consumption decreases by 9%. There is clearly seen significant increase in brake thermal efficiency and decrease the brake specific fuel consumption when increase of pressure and dosage of nanoparticles.
Fig 2 Brake Thermal Efficiency Vs Load at 200 bar Injection Pressure and 23°bTDC Injection Timing

Fig 3 Brake Thermal Efficiency Vs Load at 225 bar Injection Pressure and 23°bTDC Injection Timing

Fig 4 Brake Thermal Efficiency Vs Load at 250 bar Injection Pressure and 23°bTDC Injection Timing
5.2 Emissions

The variation of emissions Vs load is shown in fig 8, 9, 10, 11, 12, 13, 14, 15 and 16. It is clear from graph that addition of nanoparticles with simarouba biodiesel decreases the formation of unburnt hydrocarbon emission because metallic nanoparticles increase the rate heat release rate. Also it can be seen increase in injection
pressure decreases the formation hydrocarbon emission because more complete combustion. High injection pressure uses nanoparticles in better way.

Fig 8 Hydrocarbons Vs Load at 200 bar Injection Pressure and 23°bTDC Injection Timing

Fig 9 Hydrocarbons Vs Load at 225 bar Injection Pressure and 23°bTDC Injection Timing

Fig 10 Hydrocarbons Vs Load at 250 bar Injection Pressure and 23°bTDC Injection Timing
The same trend of decrease in Carbon Monoxide emission can be observed with increase in dosage level of aqueous aluminium oxide nanoparticles. But at injection pressure 250 bar there is rapid increase in carbon monoxide is observed for B20+75 ppm Al₂O₃, it may be due to availability less oxygen produces more carbon monoxide in place of carbon dioxide.

The variation between NOₓ emissions Vs Load is seen in graph fig 14,15 and 16. It is observed there is almost linear increase in oxide of nitrogen in most of cases. Highest oxides of nitrogen emission are observed at 250 bar pressure for B20+75 ppm Al₂O₃, it is may be due to high temperature inside the combustion chamber during combustion.
6. Conclusions
The current study experimentally investigates the influence of injection pressure on CI engine with Aqueous Aluminium Oxide nanoparticles with Simarouba biodiesel. Based on the results obtained following conclusions are made

- The viscosity of simarouba biodiesel found decreasing with addition of aqueous aluminium oxide nanoparticles.
- Engine performance is improved with increase in dosage level of Nanoparticles. But increase in the dosage of nanoparticles above 75 ppm causes problem with stability.
Carbon monoxide and hydrocarbon emissions are decreased with addition nanoparticles and also with increase in injection pressure.

The oxides of nitrogen emission are increased for higher injection pressure.

The simarouba biodiesel can be used with 20% blend with aqueous aluminium oxide nanoparticles with 75 ppm with injection pressure 250 bar. But need to study about nanoparticles in emission as well as stability of nanoparticles for long term.

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