Influence of Aluminium Oxide Nanoparticles in a Compression Ignition Engine with Simarouba Biodiesel

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Abstract
The current study reports outcome of aluminium oxide nanoparticles blend biodiesel fuel on the performance and emission distinctiveness of a compression ignition engine. The biodiesel is formed from Simarouba oil by transesterification method and blended with 50ppm Aluminium oxide nanoparticles. The entire analysis is carried out in invariable speed CI engines with four phase’s pure diesel, diesel+50pppm Aluminium oxide nanoparticles, blended biodiesel (S20) and S20+50pppm Aluminium oxide nanoparticles. The outcome revealed a significant improvement in brake thermal efficiency and reduction in brake specific fuel consumption, carbon monoxide (CO), unburnt Hydrocarbons (UHC). But there is also small percentage increase in oxides of nitrogen emissions.

Keywords: nanoparticles, biodiesel, aluminium oxide, Simarouba, performance, Emission

Abbreviation

| ANP                  | Aluminium Oxide Nanoparticles |
|----------------------|-------------------------------|
| S20                  | Simarouba Biodiesel 20% blend with diesel |
| BTE                  | Brake Thermal Efficiency      |
| BSFC                 | Brake Specific Fuel Consumption |
| CO                   | Carbon Monoxide               |
| UHC                  | Unburnt Hydrocarbons          |
| NOX                  | Oxides of Nitrogen            |
| BP                   | Brake Power                   |

1. Introduction

The growing Industrialization and modernization of the globe have lead to an immense climb in the requirement and consumption for gasoline fuel. These have resulted in depletion of oil resources, environmental pollution, and stringent emission norms, and thus increase in fuel price. The transport
segment universal is totally reliant on petroleum-resultant fuels. One-fifth of worldwide CO2 emissions are created by the transport sector. Hence in this existing universal circumstances there is an distinguished demand for alternative sources to replace the fossil fuels in the automotive engines. Diesel engines are widely used in automobiles as they have a higher thermal efficiency than other engines [1]. However diesel engines are one of the major contributors to the emissions such as hydrocarbons, particulates, nitrogen oxides, and soot. These emissions are responsible for environmental pollution and they pose a health hazard to human beings. Thus wide use of diesel engines leads to harmful threat of nitrogen oxide and hydrocarbon emissions.

Various vegetable oils together edible and non-edible can be considered as substitute sources of fuel for compression ignition engines. The available options for non-edible biodiesel feedstock are honge, Jathropa curcas, simarouba rubber seed etc. However the major difficulty of vegetable oils is their viscosity, which is very much higher than the diesel. The fuel injection systems in diesel engines are exceptionally much responsive to the viscosity changes. High viscosity of the vegetable oils leads to reduced atomization, which in turn may lead to poor combustion, ring sticking, injector coking, injector deposits, injector pump failure and lubricating oil dilution by crank case polymerization [2-4]. By reducing viscosity of vegetable oil the engine performance can be improved. There are many methods to reduce viscosity used by researchers such as blend and heating. By blending viscosity of oil was decreased and volatility improved. Experiments conducted with various methyl ester have discovered that blends upto 40% by volume with diesel provide good engine performance and reduced some harmful emissions [5-7]. From transesterification process vegetable oils can be converted has biodiesel. Biodiesel refers long chain triglycerides. Biodiesel is produced by two step process when free fatty acid value is more than 10. If free fatty acid value is less than 10, biodiesel can be produced in single step [8]. A single step base transesterification process is adopted for the production of biodiesel. Biodiesel can be used alone, or blended with diesel in any proportions. According to our country biodiesel policy edible oil for production of biodiesel is restricted. The biodiesel produced from non-edible oil was largely supported. The non edible sources in India are simarouba, Jathropa curcas, honge etc.

The vegetable oil transesterification reduces its viscosity; the biodiesel fuel properties is based on the feed stock i.e. process technologies and vegetable oils used [9]. The nanofluids having high surface to volume ratio which will contribute in better and complete combustion [10].

2. Experimental setup and procedure

The experimental setup consists of air cooled compression ignition engine cylinder with 661 cc volume connected with sensors to measure the all the values.
3. Preparation of Simarouba biodiesel sample

The biodiesel fuel is formed from the non-edible Simarouba oil by the standard transesterification process. The ASTM standards are adopted for testing the fuel properties. For finding kinematic viscosity of fuel Saybolt viscometer is used and value found at 40°C. Using a Hydrometer density of fuel blend found in
kg/m³. To flash point of simarouba biodiesel pensky martin closed cup apparatus was used. The calorific value of the tested fuels is determined as per the ASTM D240 standards. For finding calorific value Bomb Calorimeter was used. The ASTM test method D613 is used for the determination of cetane number of the fuel blends [11]. The properties of the tested fuels are listed in the Table 1.

| Property                        | ASTM | Diesel | S100 | S20  | Diesel+50ppm ANP | S20+50ppm ANP |
|--------------------------------|------|--------|------|------|----------------|---------------|
| Density at 25°C (kg/m³)        | D1298| 810    | 865  | 829  | 820            | 846           |
| Kinematic viscosity at 40°C (centistoke) | D 445| 2.2    | 5.2  | 2.9  | 2.6            | 3.4           |
| Calorific value (kJ/kg)        | D 240| 42500  | 37500| 41500| 42900          | 41850         |
| Flash point and Fire point (°C) | D 93 | 51     | 160  | 69   | 68             | 50            |
| Cetane number                   | D 613| 48     | 53   | 49   | 50             | 51            |

3.1 Preparation of nanoparticles blended Simarouba biodiesel fuels

Al₂O₃ (Aluminium dioxide) nanoparticles is blended with Simarouba biodiesel fuel with the use of a bath type Ultrasonicator to prepare the blended biodiesel fuel with metal additives. Aluminium oxide nanoparticles in an average of size 51 nm are supplied by Sigma Aldrich, Bangalore. Using digital balance meter 50 mg of aluminium oxide nanoparticles accurately weighed and uniformly dispersed in Simarouba biodiesel using a bath type Ultrasonicator to prepare the nanoparticles blended Simarouba Biodiesel fuel (S20+50 ppm ANP) Similar procedure is repeated with diesel fuel to get diesel and nanoparticles blend (Diesel+50ppm ANP). The stability characteristic study is conducted and observed that it is stable for 5 days.

4. Results and discussions

The performance and emission characteristics of diesel, diesel+50ppm ANP, S20 and S20+50 ppm ANP are investigated.

4.1 Performance characteristics

The variations of brake thermal efficiency and brake specific fuel consumption of fuel with respect load is plotted and shown in Fig.2 and 3.

It is experimental that the brake thermal efficiency of the nanoparticles blended Simarouba biodiesel fuels is high compare to that of diesel,S20 and diesel+50ppmp ANP at all the loads. This may be because of better combustion due to nanoparticles (high surface to volume ratio) which have influenced added amount of fuel to react with the air leading to enrichment in the brake thermal efficiency [12, 13]. The maximum brake thermal efficiency is observed for S20+50ppm ANP at 80% load is 26.05%. The energetic aluminium oxide nanoparticles increases combustion rate, which will in turn increase the efficiency of compression ignition engines.
The similar observation is done for brake specific fuel consumption that for S20+50ppm ANP there lowest value is 0.271kg/kwh at 80% load. This could be possibly due to the presence of aluminium oxide nanoparticles.

4.2 Emission characteristics

It is observed that at all loads S20+50ppm ANP produces more oxides of nitrogen emission compare to diesel, S20, diesel+50ppm ANP as shown in Fig.4. This is because more complete combustion in case of
S20+50ppm ANP due to presence of more oxygen [14]. Also nanoparticles combustion increases temperature inside the cylinder which is in turn increases oxides of nitrogen. To produce oxides of nitrogen two major causes are high temperature and availability of excess air in the combustion. At maximum load oxides of nitrogen for S20+50ppm ANP is 37.5% more than diesel.

It is also observed from Fig.5 and Fig.6 that unburnt hydrocarbons decrease considerably because excess oxygen in S20+50ppm ANP [15]. At maximum load unburnt hydrocarbons decreases by 25% for S20+50ppm ANP compare to diesel.
The magnitude of carbon monoxide emission 0.002% volume at maximum load S20+50ppm ANP. This may be because enhanced ignition characteristics of nanoparticles leading to high catalytic motion.

![CO Vs Load](image)

**Fig.6 CO Vs Load**

5. Conclusions

The performance and emission characteristics of Simarouba biodiesel fuel and nanoparticles blended Simarouba biodiesel fuels are investigated for a single cylinder constant speed compression ignition engine. The conclusions of investigations are as follows:

- The brake thermal efficiency of nanoparticles blended Simarouba biodiesel fuels are significantly improved compared to diesel. The maximum thermal efficiency at 80% load S20+50ppm ANP is 26.05%.
- The brake specific fuel consumption is 0.027 kg/kwh at 80% load for S20+50ppm ANP.
- At maximum load oxides of nitrogen emission increased by 37.5% compared to diesel.
- Unburnt hydrocarbon emission is decreased by 25% at maximum load compared to diesel.

REFERENCES

[1] Gaurav Dwivedi, Siddharth Jain, M.P. Sharma, ‘Diesel engine performance and emission analysis using biodiesel from various oil sources – Review’, J. Mater. Environ. Sci. 2013, 4, pp 434-447.
[2] Barnwal B K and Sharma M P., ‘Prospects of Biodiesel Production from Vegetable oil in India.’ Renewable and Sustainable Energy Reviews, 2005, 9, pp363-378.
[3] Avinash Kumar Agarwal, “Biofuels (alcohols and biodiesels) applications as fuels for internal combustion engines”, Progress in Energy and Combustion Science, 2007, pp: 233–271.

[4] Murugesan A, Umarani R, Subramanian R, “Bio-diesel as an alternate fuel for diesel engines-A review”, Journal of Renewable and sustainable energy reviews, 2009, pp: 653-662.

[5] I.M. Rizwanul Fattah, H.H.Masjuki, A.M.Liaquat, RahizarRamli, M.A. Kalam, V.N.Riazuddin, ‘Impact of various biodiesel fuels obtained from edible and non-edible oils on engine exhaust gas and noise emissions’, Journal of Renewable and Sustainable Energy Reviews, 2013, pp 552–567.

[6] Md. NurunNabi, Md. MustafizurRahman, Md. ShamimAkhter, ‘Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions’, Applied Thermal Engineering, 2009, 29, pp2265–2270

[7] T. VenkateshwaraRao, G. prabhakarrao, K. Hema Chandra reddy. ‘Experimental investigation of pongamia, Jatropha, Neem methyl esters as biodiesel in CI engine’. JMJIE. 2008, 2, pp117-122.

[8] A.E. Atabani, A.S.Silitonga, H.C.Ong, T.M.I.Mahlia, H.H.Masjuki, IrfanAnjumBadruddin, H.Fayaz, ‘Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production, Renewable and Sustainable Energy Reviews’, 2013, 18, pp 211–245

[9] Rao et al, G. L. K. . Relationships among the physical properties of biodiesel and engine fuel system design requirement. International Journal of Energy And Environment,2010, Vol. 1, Issue. 5, pp. 919-926.

[10] Ganesh, G. Gowrishankar, ‘Effect of Nano-fuel additive on emission reduction in a Biodiesel fuelled CI engine’,2011, IEEE, DOI: 10.1109/ICECENG.2011.6058240

[11] J. Sadhik Basha, R. B. Anand, “ The influence of nano additive blended biodiesel fuels on the working characteristics of a diesel engine” Braz. Soc. Mech. Sci. Eng.,2013, 35:257–264

[12] Sadhik Basha J, Anand RB ‘Performance and emission characteristics of a DI compression ignition engine using carbon nanotubes blended diesel’. Int J Adv Ther Sci Eng,2010, 1:67–76

[13] DeLuca LT, Galletti L, Severini F ‘Combustion of composite solid propellants with nanosized aluminium’. Combust Explos Shock Waves,2010, 41:680–692

[14] Suppes GJ, Goff M, Burkhart ML, Bockwinkel K ‘Multifunctional diesel fuel additives from triglycerides’. Energy Fuels,2001,15:151–157

[15] M.N. Nabi, S.M.N. Hoque, M.S. Akhter, ‘Karanja (Pongamia Pinnata) biodiesel production in Bangladesh, characterization of Karanja biodiesel and its effect on diesel emissions’, Fuel Process. Technol. 90 (2009) 1080–1086.