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Role of Al_2O_3 nano additive in GSOBiodiesel on the working characteristics of a CI engine

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The role of combustion, performance and emission characteristics of a diesel engine using when alumina oxide nano additive blended with grape seed methyl ester (GSOME) as a fuel has been studied. Biodiesels are produced from grape seed oil by transesterification process. The fuel properties of D80B20 (80% Diesel + 20% GSOME), D80B20$Al_2O_3$50 (80% Diesel + 20% GSOME + 50ppm Al_2O_3 nano particles) and D80B20 $Al_2O_3$100 (80% Diesel + 20% GSOME + 100ppm Al_2O_3 nano particles) have been studied and compared according to ASTM standard test methods for biodiesel. The acquired data are studied for various parameters, such as brake power, breakthermal efficiency, brake specific fuel consumption, exhaust gas temperature, and exhaust emission of carbon monoxide, hydrocarbon and oxides of nitrogen gases.

Keywords: Alumina oxide nanoparticles, Combustion, Grape seed oil, Methyl ester, Ultrasonicator

Modern diesel engine capability has forwarded to the point where the disadvantages of biofuel usage are becoming much lesser than the advantages. Recent diesel engines produce less noise, vibrations or smoke and they are additional fuel-efficient than older model engines. Biodiesel fuels achieve just as well as regular diesel fuels. In 1998, Department of Energy, Govt. of India, approved that using low blends of biodiesel causes increase in fuel economy. Road tests, as well aslaboratory tests, have confirmed that biodiesel fuels have the equal horsepower and torque as regularpetrodiesel engines. Biodiesel is more ecofriendly than petroleum diesel because it is prepared from renewable resources and has lower emissions. The disadvantages of biodiesel properties are higher viscosity, lower oxidation stability, lower volatility, higher pour point and lower calorific value[1]. Researchers also modified diesel fuel to decrease these dangerous emissions without affecting the physical and chemical properties of the fuel[2-4]. Some recent studies on the diesel fuel reformulation have been conducted on adding the possible metal nanoparticles. Metal based additives have been working as combustion catalyst to help the combustion and to reduce emissions and fuel consumption for hydrocarbon fuels. These metal based additives include manganese, barium, calcium, cerium, cerium–iron, platinum, platinum–cerium, iron and copper[5]. The use of platinum based additive on diesel engine revealed improved brake specific fuel consumption and reduced unburned hydrocarbon, carbon monoxide and emission[6]. An experimental investigation carried out in a diesel engine using ceria nanoparticles (25 ppm) dosed with biodiesel-ethanol blends showed a slight improvement in brake thermal efficiency and a significant reduction in the heat release rate, ignition delay and harmful emissions[7]. The effect of cerium oxide on the size distribution and work of diesel particulate matter has also been studied, which indicated a decrease in the accumulation mode, but an increase in ultrafine[8]. The effects of alumina nanoparticles on the working characteristics of a compression ignition engine using 5% of water content in the liquid fuel blended with alumina nanoparticles showed a major improvement in brake thermal efficiency and reduced harmful pollutants[9]. Recently, engineers and scientists have applied nanotechnology to human lives in a wide variety of subjects such as computer, biomedical, material and fuel engineering fields. Addition of metallic powder to normal fossil fuel typically

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increases the combustion stability and improves combustion efficiency. Adding of aluminum nanopowder to a rocket's solid fuel can improve combustion efficiency and increase combustion speed by an order of magnitude[10]. Aluminum nanopowder has a very high activity and can react with water at temperatures from 400 - 660°C to generate hydrogen and improve fuel combustion[11]. An experiment conducted in a single cylinder horizontal diesel engine using aluminium nanoparticles blended diesel fuel with varying water percentage showed a significant improvement in the brake specific fuel consumption and reduced harmful pollutants such as smoke and NOx. In addition, they have stated that additives in the form of metal oxide in the water/diesel emulsion will act as a catalyst to activate the molecular bonding and to attain better performance and reduced emissions from the diesel engine[12]. The performance, combustion and emission characteristics of compression ignition engines improved due to the presence of combination of alumina nanoparticles in the jatropha biodiesel fuels, leading to reduced ignition delay and peak pressure[13]. The addition of nanoparticles to the diesel improves ignition temperature, shorten ignition delay and radiative/mass transfer properties[14]. However, the effects of alumina oxide nano-additives with GSOME blends need to be investigated. Henceforth, the current investigation is focused to provide a physical pathway to incorporate the potential alumina nanoparticles in blended fuel and study the performance, emission, and combustion characteristics of a direct injection single cylinder diesel engine.

Experimental Procedure

In the present investigation, the tests were conducted on a single cylinder, four stroke, air cooled direct injection diesel. The performance, combustion and emission characteristics were observed for various loads at constant speed of 1500 rpm. The cylinder pressure was measured by mounting a quartz transducer with an inbuilt charge amplifier (0–100 bar) into the cylinder head. The heat release rate was measured by first law analysis of twenty cycles of pressure crank angle data. The cylinder gas pressure data were logged as an average of 20 cycles with a resolution of 0.5°CA using a data acquisition system. The power output is tested after the operating temperature is reached up to 80°C. The loading is by means of an eddy current dynamometer. The cylinder compression ratio of all the tests was 17.5:1 and the results were noted under steady state conditions. The emissions were measured using an AVL five gas analyzer. CO and CO_2 were measured as percentage volumes but total hydrocarbon was measured as n-hexane equivalent in ppm. NO was calculated in ppm Smoke was measured in terms of percentage opacity using an AVL smoke meter. The technical specifications are shown in Table 1. The fuel tank is connected with standard burette to measure the quantity of fuel consumed in unit time. The GSO was supplied by International Pvt Ltd, Chennai, India. The alumina oxide nanoparticles of average size of less than 50 nm were supplied by the Manufacturer M/s. Sigma-Aldrich, USA. The detailed specifications are listed in the Table 2. The nanoparticles were weighed by Digital balance (0.001g accuracy) Shimadzu make, Model BL220H, 220g capacity. The mixing of alumina oxide in biodiesel was done using a neat diesel placed in an ultrasonicator set at a frequency of 40 kHz and 120 W for 60 min. The properties of alumina oxide - GSOME blends were tested according to ASTM standard. The fuel properties of D80B20, D80B20$Al_2O_3$50 and D80B20$Al_2O_3$100 are determined in Syed Ammal Engineering College, Ramanathapuram, Tamilnadu, India (Table 3).

Results and Discussion

Fuel properties

The results obtained are compared in order to study the effect of nanoparticle and its dosing level on the fuel properties. No significant differences are

Table 1—Technical specifications of experimental engine

Make	: Kirloskar
Engine type	: Single cylinder vertical air cooled diesel engine
No. of strokes per cycle	: 4
Rated speed	: Constant speed (1500 rpm)
Stroke	: 110 mm
Compression ratio	: 17.5:1
Orifice diameter	: 13.6 mm
Loading type	: Eddy current dynamometer
Rated power	: 4.4 kW

Table 2—Detail of alumina nanoparticle

Parameter	Specification
Manufacturer	: M/s. Alfa Aesar, USA
Chemical name	: Aluminium oxide (Al_2O_3)
Average size of particle	: < 50 nm
Specific surface area	: > 40 m^2/g
Appearance	: White

observed in the density, kinematic viscosity, pour points and cetane number due to the addition of alumina oxide nanoparticles in the blends. The alumina oxide nano additive blends show an improvement in flash point compared to D80B20. The higher flash point temperatures are desirable for safe handling of the fuel[15]. The calorific value of the alumina oxide nano additive blends is higher than that of B20. The higher calorific value clearly indicates the better thermal efficiency and lower fuel consumption[16,17].

Combustion characteristics

The heat release rate and cylinder gas pressure of different blends fuel are shown in the Figs 1 and 2. The heat release rate is negative during the ignition delay period. The negative heat release rate values of the blend fuels after the ignition are mainly due to the cooling effect caused by heat losses and fuel vaporization from the engine cylinder walls[18]. It is observed that the heat release rate and cylinder gas pressure are lower for the alumina oxide nanoparticles blended fuels compared to B20. This could be due to the improved surface area–volume ratio and enhanced ignition properties of nanoparticles which initiate the early combustion, leading to reduced peak pressure compared to that of B20 (ref.19).

Performance characteristics

The variation in brake thermal efficiency (BTE) with bmep (brake mean effective pressure) of all test fuels is shown in the Fig. 3. The brake thermal efficiency of the engine is developed by the addition of alumina oxide in the blends. The alumina oxide nanoparticles present in the blend promote longer and more complete combustion and also acts as an oxygen buffer, thus increasing the efficiency. It has also been identified that the improvement in the efficiency

Table 3—Properties of test fuels

Parameters	D80B20	D80B20 $Al_2O_3$50	D80B20 $Al_2O_3$100
Density at 20°C, kg/cm^3	0.841	0.852	0.864
Kinematic viscosity at 40°C, mm^2/s	5.7	5.8	5.8
Flash point, °C	39	65	69
Pour point,°C	< -13	< -15	< -15
Cetane number	46	48	49
Calorific value, kJ/kg	37018	38656	39577

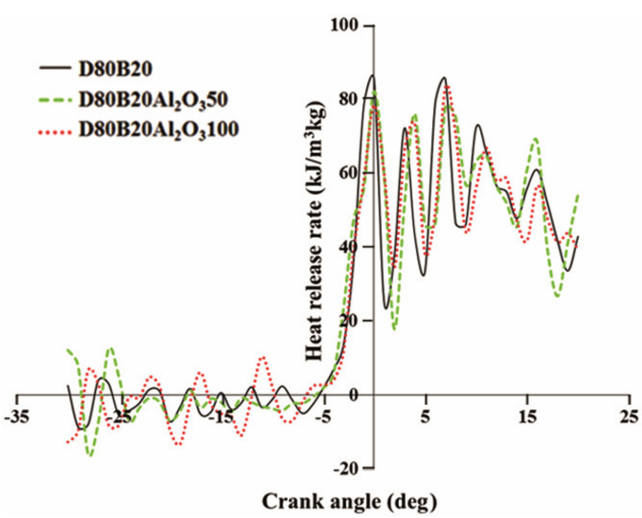

Fig. 1—Variation in heat release rate with crank angle at full load

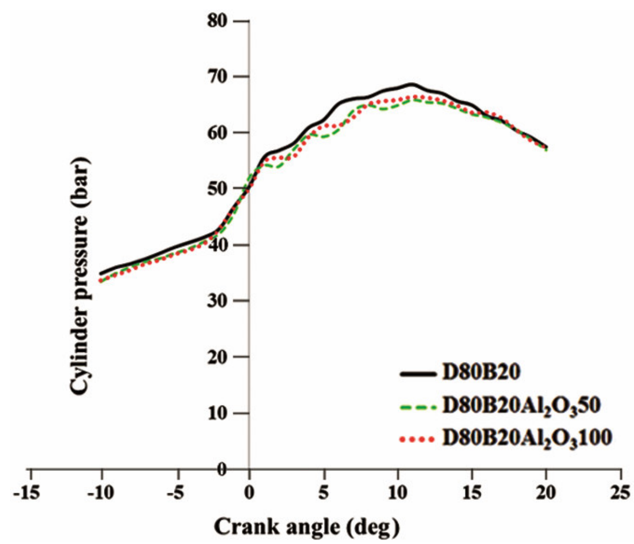

Fig. 2—Variation in cylinder gas pressure with crank angle at full load

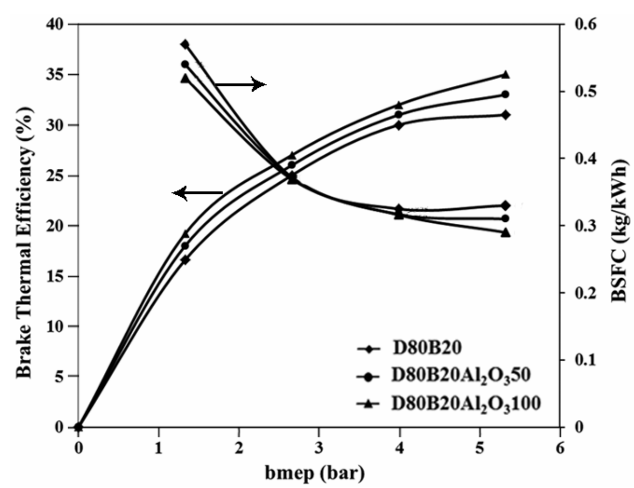

Fig. 3—Variation in brake thermal efficiency and BSFC with bmep

generally increases with the dosing level of nanoparticles[15]. This could be possibly attributed to improved combustion characteristics of nanoparticles, such as advanced surfacearea volume ratio, which, in turn, allows more amount of fuel to react with the air leading to improvement in the brake thermal efficiency[19]. The variation of Brake Specific Fuel Consumption (BSFC) with bmep of all test blends is shown in the Fig. 3. The BSFC reduces with an increase in the dosing level of nanoparticles. It is observed that more quantity of fuel has been consumed to maintain the engine speed constant[20]. This could be possibly attributed to the presence of nanoparticles in the blend as it possess enhanced surface area–volume ratio for better the catalytic effect and less fuel consumption during the combustion in the engine cylinder[19]. The exhaust gas temperatures (EGT) for all blends with respect to bmep are shown in Fig. 4. It is observed that the EGT for alumina oxide nanoparticles blends is lower than that of B20. It is due to rapid evaporation, which in turn, results in reduced cylinder average temperature[21].

Emission characteristics

The variation in hydrocarbon (HC) and carbon monoxide (CO) emissions with bmep for all blends is shown in Fig. 5. CO emission critically depends on the air-to-fuel ratio relative to stoichiometries proportions[22]. HC and CO are found to be considerably reduced on the addition of the alumina oxide additive. This could be possibly attributed to the short ignition delay and the enriched ignition characteristics of alumina nanoparticles, leading to high catalytic activity due to their higher surface-volume ratio and improved fuel air mixing in the combustion chamber[15]. The variation in NOx emissions with bmep for D80B20, D80B20$Al_2O_3$50 and D80B20 $Al_2O_3$100 blends is shown in Fig. 6. The NOx formation is highly dependent on the combustion temperature[23]. According to the Zeldovich mechanism, the formation of NOx depends on temperature, residence time and O_2 concentration. The NOx emission is found to be mostly reduced on the addition of alumina oxide nanoparticles to blends. This is due to the shortened ignition delay and less fuel is added during the combustion, which, in turn, leads to decrease in NOx emissions[19]. The variation in smoke opacity with bmep for D80B20, D80B20$Al_2O_3$50 and D80B20 $Al_2O_3$100 blends is shown in Fig. 6. This is due to the shortened ignition delay, quick evaporation rate and improved ignition characteristics of alumina nanoparticles resulting in lower smoke emissions compared to that of D80B20[19].

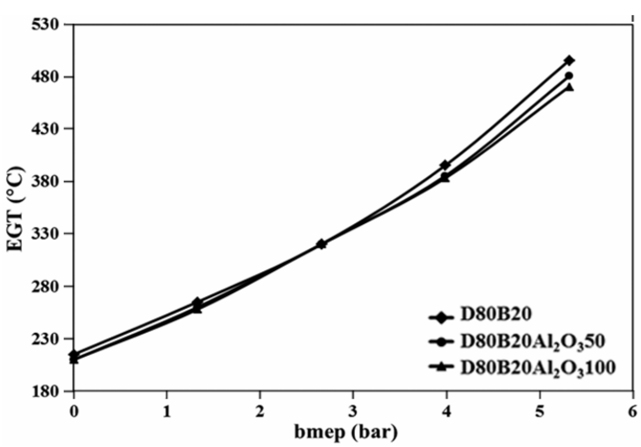

Fig. 4—Variation in exhaust gas temperature with bmep

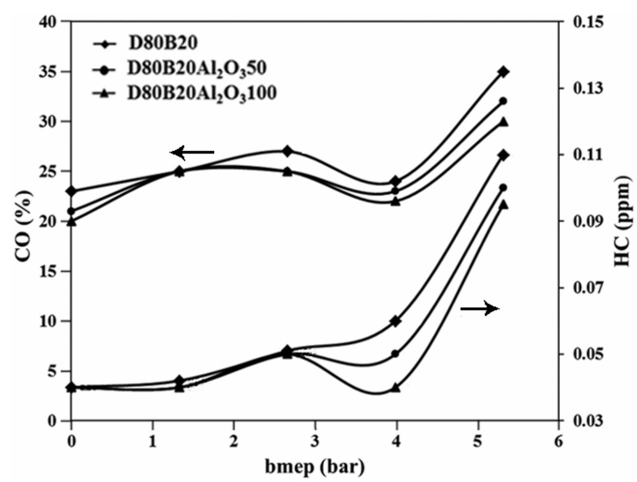

Fig. 5—Variation in CO and HC with bmep

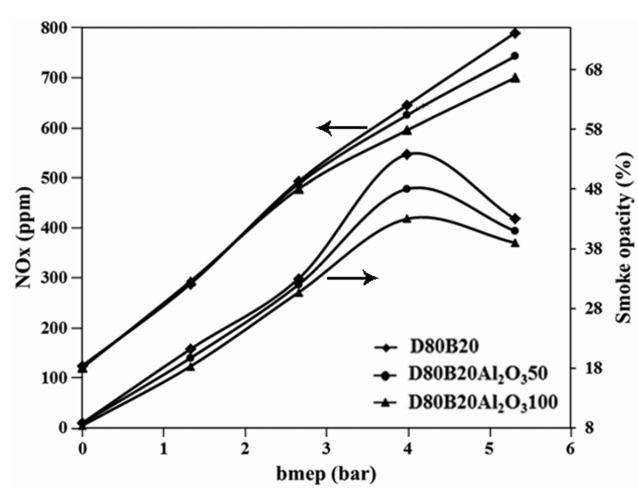

Fig. 6—Variation in NOx and smoke opacity with bmep

Conclusion

Based on the study the following conclusions are drawn :

(i) The flash point and calorific value increase with the dosing level of Al_2O_3 nanoparticles in blends.

(ii) The heat release rate decreases with an addition of Al_2O_3 nanoparticles, leading to the rapid combustion in the premixed phase and to reduced peak pressure.

(iii) Considerable improvement in brake thermal efficiency is observed with Al_2O_3 added blends compared to that with B20 at full load operating condition.

(iv) Compared with B20, emission of CO and HC reduces in the case of Al_2O_3 added blends.

(v) NOx emission and smoke opacity are found to be the least for Al_2O_3added blends.

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