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Combustion analysis of CuO_2 nanoparticles addition with neochloris oleoabundans algae biodiesel on CI engine

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ABSTRACT

An experimental research is performed to determine the performance, combustion as well as emission qualities of a variable compression engine at constant speed using Copper Oxide nanoparticles as being fuel-borne additives in diesel–biodiesel blend. In this research, the effects of adding CuO2 nanoparticles to neochloris oleoabundans methyl ester-diesel blended (B20) fuel on compression-ignition engine had been experimentally investigated. The B20 with 25, 50, 75, and 100 ppm dosage of CuO2 nanoparticles were examined at various engine loads and constant engine speed. The fuel blends were labelled as B20, B20 + 25 ppm, B20 + 50 ppm, B20 + 75 ppm and B20 + 100 ppm. Moreover, even without the any engine alterations, the combustion properties of those fuel blend samples were investigated through the experimentally measured standards like viscosity, density, cloud point, calorific value and pour point while the engine combustion has also been examined through the factors like cylinder pressure, net heat release as well as rate of pressure rise. The experimental outcomes show that the use of biodiesel blend along with CuO2 nano particles in diesel fuelled engine has revealed better combustion than B20 fuel.

1. Introduction

Rapid growth in number of automobile industries has developed the exhaust emissions together with health problems and global ecological degradation. The quality of air destroys significantly with raising vehicular emissions like hydrocarbon, carbon monoxide, nitrogen oxides as well as smoke emissions that the transportation sector is highly responsible [1]. In this situation, vegetable oils are observed to be a possible energy resource which can replace fossil fuels. The oil have been gathering popularity as a substitute fuel for the diesel fueled engines since its characteristics are nearly the same as those of diesel fuel [2]. A lot of experimental investigations were described with a huge variety of metals as fuel ingredients to increase the fuel characteristics and thus the engine combustion, as well as to decrease the engine emissions. The oxides of metals like copper, calcium, cerium, iron, barium, cobalt, and nickel were commonly used as fuel additives [3]. It is discovered that a lot of experimental works had been focused mainly on biodiesel and also its blend with ordinary diesel in different ratios for optimization. Only a few works had been founded on biodiesel blended with nano particles to increase the combustion in single-cylinder four stroke compression ignition engine at different loads [4]. The influence of aluminium oxide nano additives in biodiesel-diesel blends improved diesel fuel engine combustion as well as performance when compared with diesel. To ensure that we have performed this with RuO_2 nano particles in neochloris oleoabundans algae oil methyl ester and we have found that there is an enhancement in fuel consumption as well as an improved performance in combustion and emission properties. Moreover, attention will be given to the operating parameters as well as design parameters of the engine to revert the difficulties of the biodiesel fuels [5].

2. Materials and methods

2.1. Fuel property test

The test fuel standards are kinematic viscosity, density, flash point, calorific value, cloud point and pour point for B20 and its blends B20 + 25 ppm, B20 + 50 ppm, B20 + 75 ppm, B20 + 100 ppm are described in Table 1. Apart from calorific value, the remaining characteristics like flash point, kinematic viscosity,

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Table 1
The specifications measured based on ASTM standard for B20 and Al_2O_3 blend fuels.

Properties	ASTM	B20	B20 + 25 (CuO_2)ppm	B20 + 50 (CuO_2)ppm	B20 + 75 (CuO_2)ppm	B20 + 100 (CuO_2)ppm
Density (g/cm^3)	D-4052	0.830	0.831	0.8317	0.8318	0.8319
Kinematic viscosity at 40 °C (mm^2/s)	D-445	4.73	5.1875	5.6449	5.6671	5.6894
Flashpoint (min °C)	D-92	176	176.5	177	177.5	178
Cloud point (°C)	D-2500	−1	−4	−4	−4	−4
Pour point (°C)	D-97	−4	−4	−4	−4	−4
Calorific value (kJ/kg)	D-240	43,540	44511.5	45,483	45,501	45,519
Cetane index	D-613	58	54.75	51.5	51.75	52
Water and sediment (% vol.)	D-2709	0.05	0.05	0.05	0.05	0.05

density, pour point and cloud point values are higher than the diesel fuel as we are required and also seen that the standards of all the above fuel properties increases since the blend level increases. The benefits of increasing flash point in biodiesel consist of greater safety, which makes it easier to transport when compared to diesel fuel; less fire risk, more safer to storage as well as limited chances of uncontrolled explosion. This will lead to enhanced operation heat, greater losses, higher pressures and temperatures and also decreased overall cycle efficiency. However, rise in density of biodiesel in a fuel sample decreases its calorific. It causes greater fuel consumption [6].

2.2. Preparation of nano blends

The nano blends are prepared separately through B20 extracted from neochloris oleoabundans algae methyl ester with the CuO_2 nano particle, added to every blend B20, at the dosages of 25, 50, 75, as well as 100 ppm with the aid of an ultrasonicator. The ultrasonication technique is best suitable way to scatter the nanoparticles in a base fluid, since it allows potential agglomerate nanoparticles returning to the nanometer range. The CuO_2 nanoparticles at average size of 50 to 100 nm are supplied by M/s. Alfa Aesar, USA. The properties of CuO_2 nanoparticles are described in Table 2. The nano particles were weighed to a quantity of 25 ppm and also distributed in all biodiesel blends with the help of ultrasonicator set at a power as well as frequency of 110 W and 35 kHz, correspondingly, for 30 min, to generate the nanoparticles mixed biodiesel fuel (B20 + 25 ppm). A similar process is tried for the mass portions of 50, 75 and 100 ppm to the CuO_2 nanoparticles added biodiesel fuels placed in test tubes in stable conditions for evaluating the stability properties. Through the characterization tests, it was found which they were stable for more than a month [7].

2.3. Experimental setup

A Kirloskar single cylinder, four-stroke diesel engine with load arrangement of eddy current dynamometer had been used to carry out the different experimental researches for the combustion, performance as well as emission. For this analysis, Kirloskar engine is recommended as test engine, because it can also not be difficult to carry out the necessary modifications. AVL 444DI gas analyzer as well as AVL 437C smoke meter had been employed for testing the emissions from the test engine. The engine specifications are indicated in Table 3. The fuel consumption had been calculated with the burette for various loading through the eddy current dynamometer. All the testing measurements were done after enabling the engine to perform for specific period without including load for warm-up and also to achieve the steady operating condition. All the test readings had been taken at a constant speed of 1500 rpm to make the various analyses [4].

Table 2
Properties of CuO_2 nano particles.

Item	Specifications
Manufacturer	M/s. Alfa Aesar, USA
Chemical name	Copper oxide (CuO_2)
Average particle size	<50 nm
Specific surface area	>40 m^2/g
Appearance	White colour

3. Result and discussion

3.1. Combustion analysis

3.1.1. Cylinder pressure

Fig. 1 shows that the variation of cylinder pressure for various biodiesel fuel blends at different crank angle. The addition of nanoparticles with biodiesel blends shows significant improvement in cylinder pressure as well as ignition delay. The peak combustion pressure demonstrates an opposite relation with compression pressure as well as thermal conductivity. From the above figure, it can be observed that the neat B20 has lesser cylinder pressure when compared with all other test fuels because of its higher magnitude of density as well as viscosity and those characteristics of fuel result to very poor evaporation rate which will results in poor combustion. B20 with CuO_2 nanoparticle added fuel blends exhibits higher cylinder pressure when compared with neat B20 because of the presence of oxygen contents in the fuel, which will leads to lower values of cetane number and longer period of ignition delay [8].

3.1.2. Net heat release

Fig. 2 indicates that the change of net heat release with different crank angles for the various test fuel blends. The net heat release is poor through the time of ignition delay for all the tested fuel

Table 3
Technical specifications of the test engine.

Engine specifications	
Make	Kirloskar
Number of cylinders	One
Stroke	110 mm
Cycle	Four stroke
Displacement volume	661 cc
Bore	87.5 mm
Type of cooling	Water cooling
Injection timing	23°BTDC
Rated power	5.2 KW @ 1500 RPM
Nozzle opening pressure	210 bar
Compression ratio	16.5:1
Lubrication system	Splash system
Type of governor	Mechanical centrifugal type
Valve timing	
Inlet valve opening	12° before TDC
Inlet valve closing	33° after BDC
Exhaust valve opening	38° before BTC
Exhaust valve closing	3° after TDC

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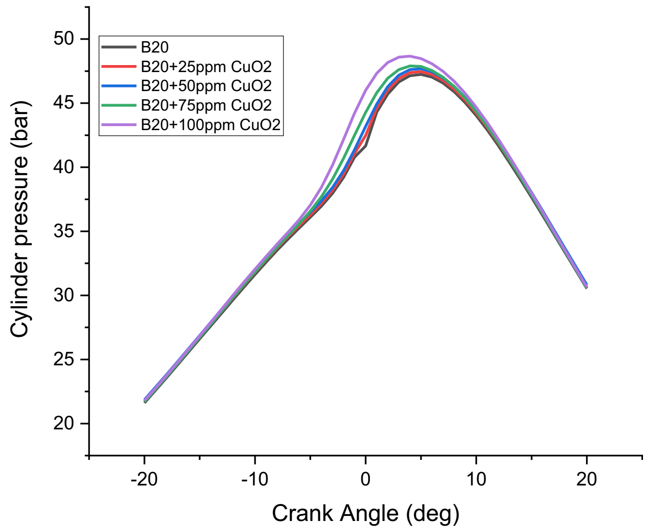

Fig. 1. Variation of cylinder pressure with crank angle.

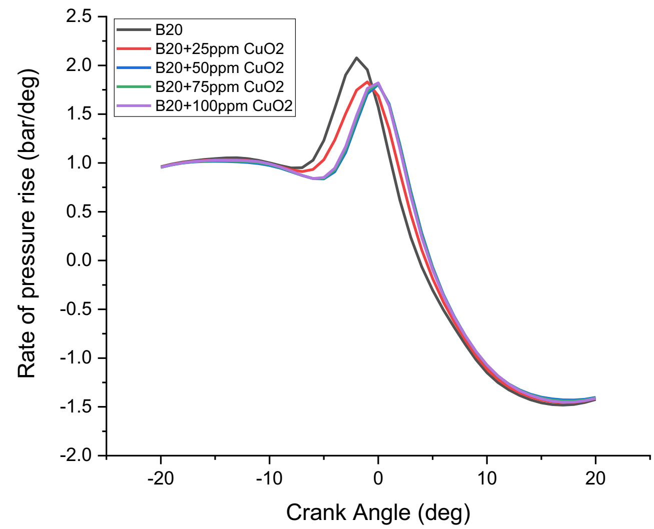

Fig. 3. Variation of rate of pressure rise with crank angle.

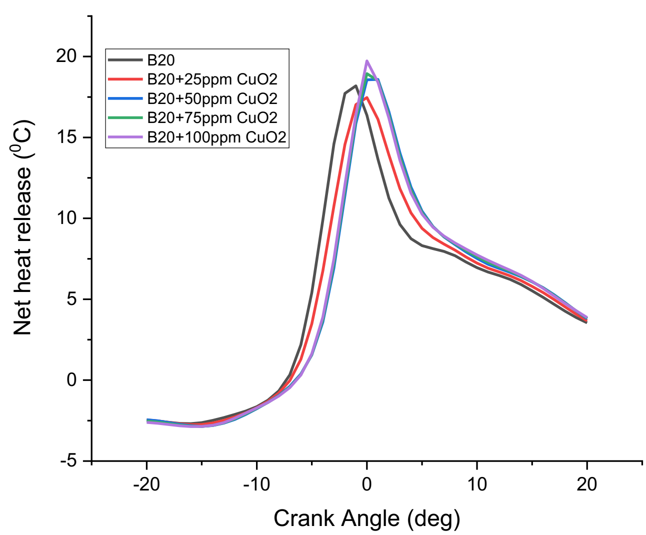

Fig. 2. Variation of Net heat release with crank angle.

blends. This returns to the fuel vaporization in which the fuel provides the heat from the warm air during compression stroke. After combustion begins, the obvious net heat release grows rapidly and achieves the peak value of the premixed fuel and air. The long ignition delay improves the mixing between fuel and air causing rapid burning rate in the premixed combustion stage and also a higher net heat release in premixed phase. The addition of CuO_2 nanoparticles to B20 blends achieves shorter ignition with higher net heat release when compared to B20 fuel at premixed combustion. These results shows that the oxygenated CuO_2 nanoparticle additives presented the combustion as well as net heat release at the phase of premixed combustion [9].

3.1.3. Rate of pressure rise

Fig. 3 indicates that the change of rate of pressure rise at different crank angle for various fuel blends with full load condition. The rate of pressure rise is slightly lower for the neat B20 blend when compared with other fuel variants examined. A greater rate of pressure rise is actually noticed for the B20 + 100 ppm CuO_2 nano particle added fuel sample because of their improving heat release rate in the premixed combustion level. An addition on CuO_2 nano particles with B20 fuel blends illustrates a better rate of pressure rise in comparison with neat B20 fuel. In the case of neat B20 blend, the premixed combustion stage keeps going during the power stroke, however it doesn't provided for the pressure rise as the piston is moving in direction of bottom dead centre leading to a lower pressure rise [10].

4. Conclusion

Experimental investigation of CuO2 nanoparticle additives burning in diesel fuel engine had been performed at different dosage of the nanoparticle. The fuel properties of all test fuel blends met the ASTM specifications. The fuel classification data revealed some similarities as well as differences with regards to B20 and also B20 along with CuO_2 nano additives. Nanoparticles added fuel blends had greater BTE, EGT and lesser BSFC than B20. B20 along with CuO_2 added fuel blends showed high peak cylinder pressure, rate of pressure rise and also lesser net heat release when compared with B20. As a result of this research, the CuO_2 nanoparticles at 100 ppm quantity can be used as a fuel additives for the biodiesel to increase the performance and combustion properties and also to reduce the exhaust emissions when used in diesel engines.

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