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EFFECT OF CeO_2 NANO ADDITIVE ON PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE FUELLED BY NEEM OIL-BIODIESEL

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ABSTRACT

An experimental study was carried out to study the performance, emission and combustion characteristics of single cylinder, direct injection diesel engine, air cooled diesel engine, fuelled with two modified fuel blends, BN20 (Biodisel from Neem oil) and Cerium oxide blended BN20 (Diesel 80% and 20% Biodiesel from neem oil on volumetric percentage), and the results are compared with standard diesel fuel operation. The cerium oxide nano additive was mixed with BN20 using Ultrasonicator device to achieve better stability. The properties of BN20 with and without nano additive were compared with standard diesel fuel. The addition of nano additive has resulted higher BSFC and BTE when compared to standard diesel fuel. In the case of emission, NOx, Smoke, HC and CO emissions reduced considerably by the addition of nano additive in the BN20 fuel blend. It is also observed that higher cylinder pressure and heat release during the cerium oxide blended BN20 fuel mode.

Key words: Neem oil, Performance, Emission, Cerium oxide.

INTRODUCTION

Diesel engines exhibits higher thermal efficiency in automotive applications due to their better fuel economy compared to petrol engines. Generally, diesel engines are called as dirty engines due to their higher emissions levels during the combustion. The main pollutants from the diesel engines are NO_x and Smoke emissions. Most of the researches have contributed their effort to reduce the emissions from the diesel engines. The some of the effective techniques are EGR (Exhaust gas recirculation), water emulsion, modifying the engine design and treatment of the exhaust gases. One of efficient technique is fuel modification which influences the better emission reduction and higher combustion and performance characteristics of diesel engine. Sajith et al.[1] investigated the cerium oxide nano

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particles in the diesel engine and observed that better engine performance and combustion characteristics. The emissions, CO, HC and NO_x and smoke emissions reduced by the addition of nano particles. Syed Aalam et al.[2] investigated in a CRDI engine with aluminium oxide nano particles blended biodiesel. They observerd that aluminium oxide nano particles blended fuel exhibits a considerable reduction in SFC and exhaust emissions. Shaafi et al.[3] have conducted experiments in diesel engine with soybean biodiesel using alumina nano particles. They reported that cylinder pressure and heat release rate increased with a reduction of exhaust gas temperature. Furthermore, they observed that a reduction of CO, UBHC with an increase in NOx emission slightly. The similar results are reported by some other researchers for the reduction of emissions from the diesel engine using nano particles[4,10].

EXPERIMENTAL

Test fuel – Neem oil

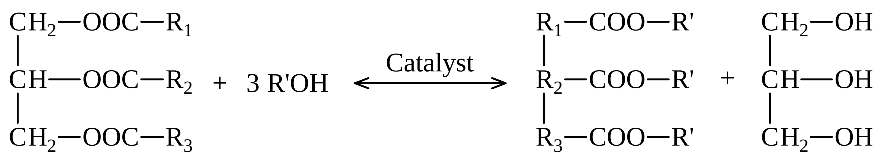
Neem oil is light to dark brown, bitter in nature. The elements of neem oil are triglycerides and triterpenoid compounds. It contains steroids of campesterol, beta-sit sterol, stigma sterol and a plethora of triterpenoids. The properties of neem oil biodiesel are compared with standard diesel fuel in Table 1. The neem oil normally contains Oleic acid as 52.8%, Stearic acid as 21.4%, Palmitic acid as 12.6% and Linoleic acid as 2.1% and other lower fatty acids as 2.3% in its chemical structures.

Table 1: Properties of diesel and neem oil and its biodiesel

Properties	Diesel	Neem oil	BN20	BN20 + CeO_2
Kinematic viscosity (Cst) at 40°C	3.12	6.77	3.74	3.71
Density (kg/m^3)	825	875	828	830
Flash Point (°C)	53	172	65	66
Calorific value (MJ/kg)	43.57	36.5	41.9	41.94
Cetane Number	45-55	31	43.5	43.7

Preparation of neem oil biodiesel

A number of methods are used to produce biodiesel from vegetable or non-edible oils. Pyrolysis, micro-emulsification, diluation and transesterification are common techniques to produce the biodiesel. The common and easy technique used to produce biodiesel is transesterication process using NaOH or KOH as catalyst. Neem oil was converted into its methyl ester by the transesterification process. The triglycerides react with methyl alcohol in the presence of NaOH catalyst and the glycerol and fatty acid ester formed. In the biodiesel process, 800 mL of neem oil, 200 mL of methanol and 2 gram of sodium hydroxide were taken in the beaker and stirred well till the formation of ester. The mixture was heated to 80°C. Then it was allowed for 12 hrs. Finally, there are two layers formation; the bottom layer contains the glycerol and the top layer of ester. BN20 was prepared in the volume ratio of80% Diesel and 20% biodiesel from neem oil. The detailed transesterification of neem oil-biodiesel was shown in the Fig. 1.



Glycerides **Alcohol** **Esters** **Glycerine**

Fig. 1: Transesterification of neem oil-biodiesel

Preparation of nanoparticle blended nem oil biodiesel

Ultrasonicator is used to mix thoroughly the nanoparticles (CeO_2) with the biodiesel from neem oil. The cerium oxide nanopartilces of an average size of 50 nm were used for this investigation. This Ultrasonicator technique is used to disperse the nano particles in the biodiesel mixture. 50 ppm cerium oxide nano particle was weighed by using electronic weighing machine with an accuracy of 0.01 mg. This nano additive added biodiesel mixture were kept in the Ultrasonicator about 30 min and ensured that there is no deposits of power at the bottom of the beaker.

Fig. 2: Cerium oxide nano-particles **Fig. 3: Ultrasonicator device**

Experimental set-up and procedure

The schematic diagram of the experimental set-up is shown in Fig. xxx. A vertical, single cylinder, air cooled direct injection diesel engine was used in this experimental study. The eddy current dynamometer was used to apply the load on the engine. The fuel consumption was calculated by measuring 10 cc of fuel consumption using stop watch. The AVL make pressure transducer and a crank angle encoder was used to measure the in-cylinder pressure and the respective crank angle positions. The heat release rate was calculated by AVL Indicom, software version 2.1 and all the details were stored in the personal computer for further calculation.

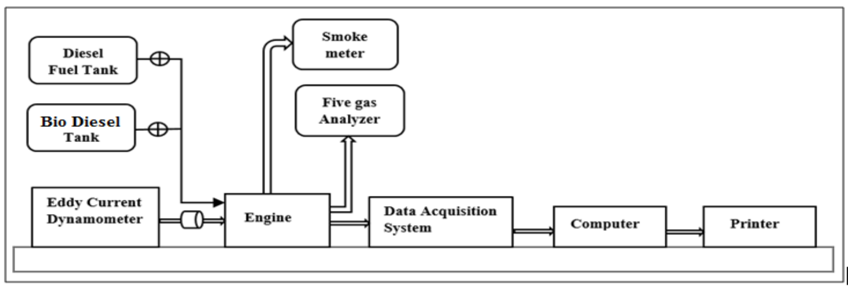


Fig. 4: Schematic diagram of Experimental setup

Table 2: Test engine specifications

Parameters	Description
Make	Kirloskar TAF1
Type	Single cylinder, 4-stroke, direct injection,
Power	5.2 kW
Bore & stroke	87.5 & 110 mm
Compression ratio	17.5
Rated speed	1500 rpm
Cooling type	Air cooling
No. of holes	3
Nozzle hole diameter	0.25 mm
Fuel injection timing	23˚ bTDC
Fuel injection pressure	200 r

A k-type thermocouple was used to measure the exhaust gas temperature from the engine. The AVL Di-gas was used to measure the emission parameters such as, NOx, CO, CO_2, HC and O_2. The AVL 437C smoke meter was used to measure the smoke opacity from the engine. The engine was operated initially for 20 min to attain the steady state. The engine was fuelled with diesel as a base fuel. Then blends of neem oil-biodiesel and nano additive blend were used and corresponding results were stored in a personal computer. The detailed engine specifications were tabulated in the Table.xxx. The standard injection pressure of 200 bar and injection timing of 23° bTDC were set for entire engine operation.

RESULTS AND DISCUSSION

Performance characteristics

Brake specific fuel consumption (BSFC)

Fig. 5 shows the variation of brake specific fuel consumption with brake power. BSFC for BN20 fuel blend increases than diesel fuel. The reason is that lower calorific value of BN20 than diesel fuel. Moreover, BSFC for cerium oxide added BN20 increases than BN20 fuel mode. It is mainly due to the lower caloric value of biodiesel blends and also to maintain the constant engine speed, more quantity of fuel is consumed.

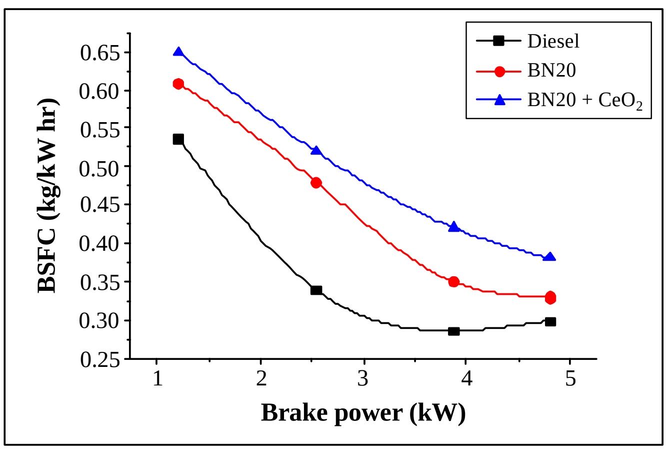


Fig. 5: Variation of BSFC with brake power

Brake thermal efficiency (BTE)

Fig. 6 shows the variation of brake thermal efficiency with the brake power. The results show that the BTE for nano additive added BN20 increases than BN20. The lower BTE for BN20 is observed when compared to diesel fuel. It is mainly due to the higher viscosity and lower calorific value of the biodiesel blend. BTE for BN20 decreases by 3.4% than standard diesel fuel. Furthermore, BTE for cerium oxide added BN20 increases by 2.8% than BN20. The cerium oxide nanoparticles act as an oxygen buffer and thus improve the brake thermal efficiency[1].

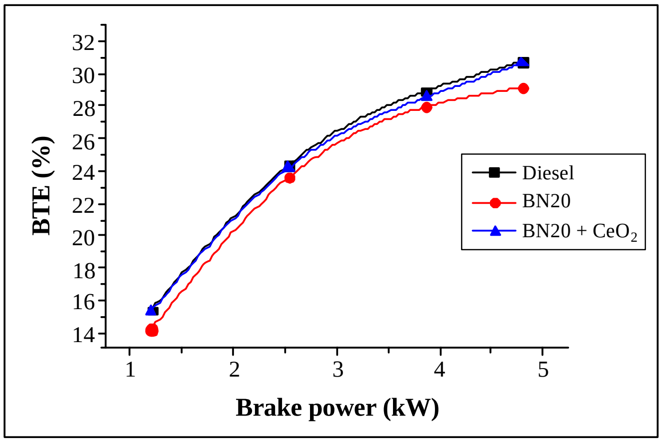


Fig. 6: Variation of BTE with brake power

Combustion characteristics

Cylinder pressure

Fig. 7 shows the variation of cylinder pressure with different crank angle position. It was observed that the peak pressure increased with the addition of cerium oxide nano additive in the BN20 blend.

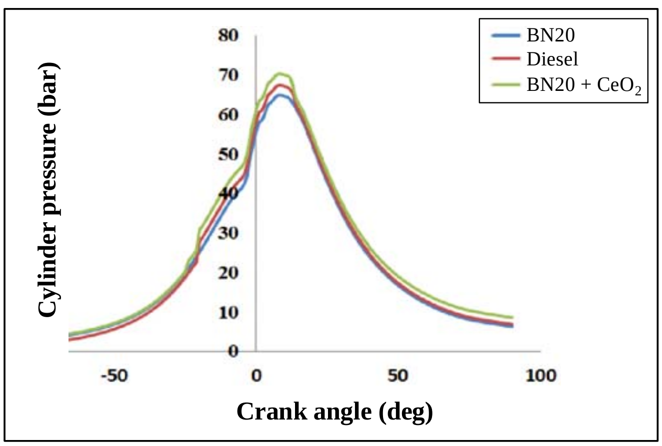


Fig. 7: Variation of cylinder pressure with crank angle

The BN20 exhibits a longer ignition delay than diesel fuel. It was found that the cylinder pressure was 70.1 bar, 67.3 bar and 64.8 bar for BN20 + CeO_2, diesel and BN20 fuel blends respectively. The cerium oxide nano additive accelerated the early start of combustion and the ignition delay decreased[14]. In addition, the more accumulation of the fuel in the premixed combustion phase and this would have been the reason for rapid combustion, which resulted in the higher peak pressure.

Heat release rate

The variation of heat release rate with different crank angle positions for different blends is shown in Fig. 8. The heat release rate for BN20 reduces than standard diesel fuel. The addition of nano particles influences the faster combustion rate for BN20 blend. The maximum heat release rates are observed as 55.123 kJ/m^{3}deg, 48.195 kJ/m^{3}deg and 56.89 kJ/m^{3}deg for diesel, BN20 and BN20 + CeO_2 blends respectively. The cerium oxide additive helps to increase fuel atomization and reducing cyclic dispersions and resulting in increased combustion rate[11].

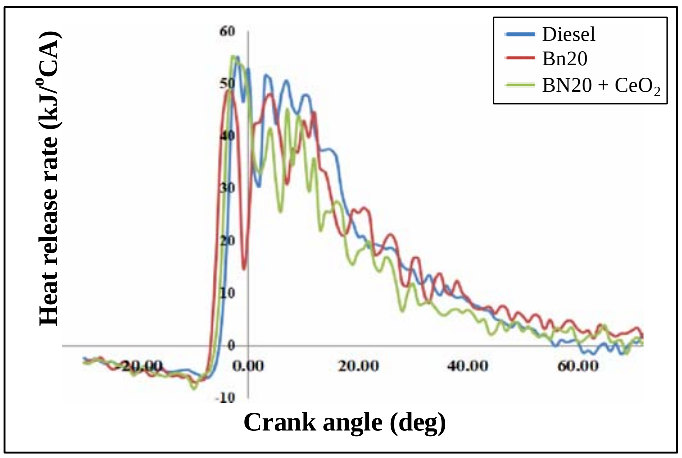


Fig. 8: Variation of heat release rate with crank angle

Emission characteristics

CO Emission

Fig. 9 shows the variation of CO emission with brake power. CO emission reduces for all the blends of biodiesel from neem oil. The CO emission reduces by 3.4% for CeO_2 added biodiesel than BN20. The CeO_2 additive helps to improve the combustion process due to the reduced ignition delay characteristics[11]. This improved combustion process resulted the lower CO emission than other modes of fuel operation.

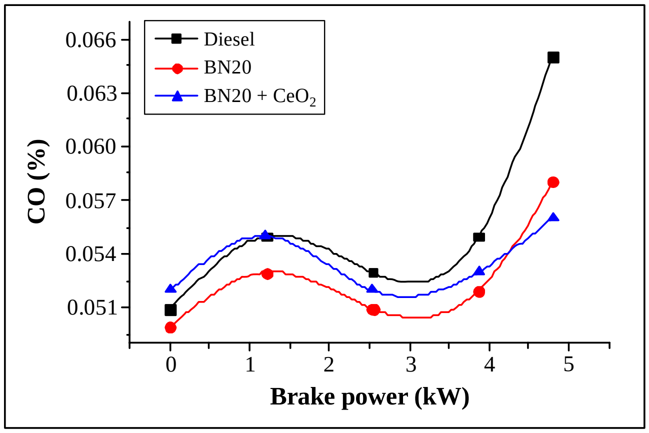


Fig. 9: Variation of CO emission with brake power

HC Emission

Fig. 10 depicts the variation of HC emission with brake power. The HC emission decreases for BN20 fuel blend. This is due to the complete combustion and sufficient oxygen availability during the combustion process. The HC emission for cerium oxide nano particle added biodiesel decreases by 2.7% than BN20. The reason is that cerium oxide is an oxidation catalyst which lowers the carbon combustion activation temperature. This leads to a more complete combustion[12].

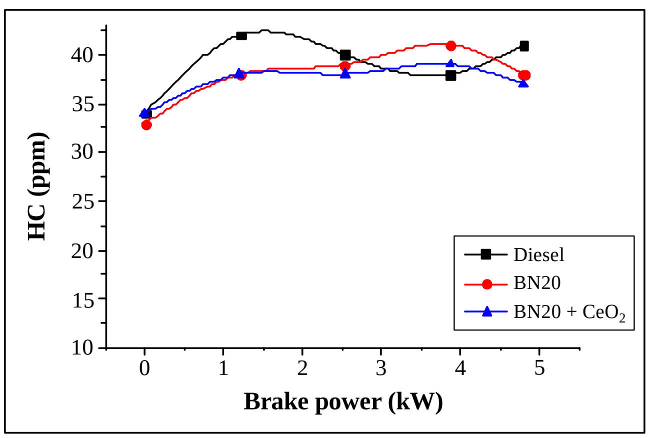


Fig. 10: Variation of HC emission with brake power

NO_x Emission

The two main pollutants from the diesel engines are NO_x and PM emissions. The NO_x generation depends mainly on the compression ratio, combustion geometry, inlet pressure and temperature and nature of the fuel[13]. Fig. 11 shows the NO_x emission increases for biodiesel from neem oil operated mode. It is due to the presence of oxygen content in the biodiesel. The addition of cerium oxide nano particles helps to reduce NO_x emission by 8.4% than BN20 blend. The cerium oxide nano particles obsorbs oxygen that leads to decreased production of NO_x emission[14].

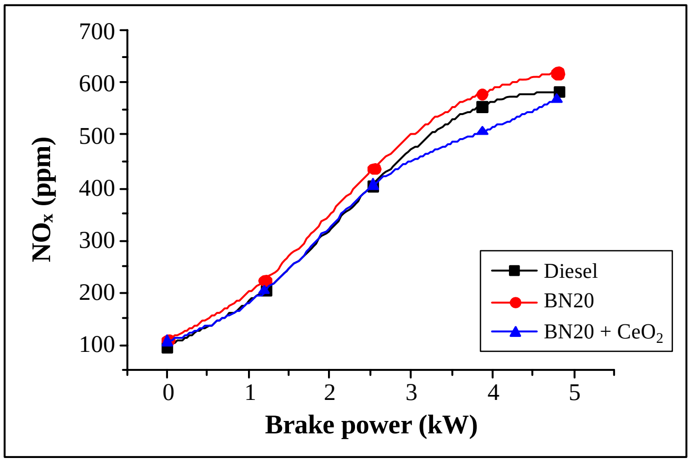


Fig. 11: Variation of NOx emission with brake power

Smoke emission

Smoke formation occurs at extreme shortage of air during the combustion of A/F mixture. If the air-fuel ratio decreases, smoke formation increases[15].

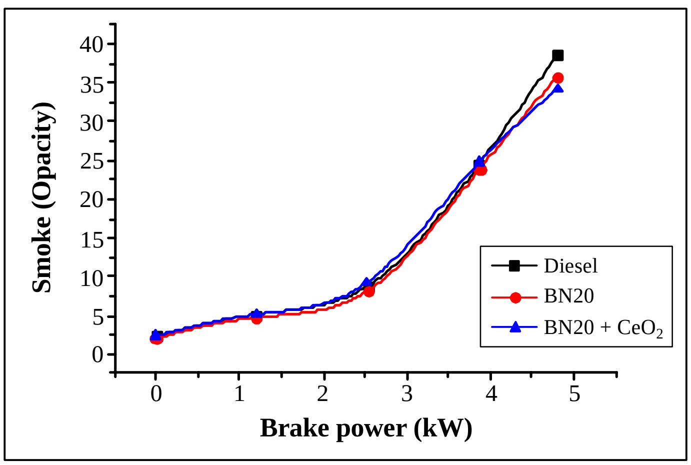


Fig. 12: Variation of smoke emission with brake power

From the Fig. 12, it is observed that smoke emission is less in the biodiesel from neem oil operated mode. It may be due to the availability of oxygen contained in the biodiesel molecules that influences the carbon oxidation in the fuel rich zones[16]. One can observe from the figure that smoke emission decreases for cerium oxide operated biodiesel fuel blend. Smoke emission decreases by 4.4% than BN20 blend. The reason may be due to the presence of cerium oxide nano particles in the biodiesel, which initiates the early combustion and yields increased area/volume ratio, and improved ignition characteristics[1].

CONCLUSION

The performance, emission and combustion characteristics of single cylinder direct injection diesel engine using Neem oil biodiesel with nano additive CeO2 were analysed. Based on the experimental investigations, the following conclusions are drawn.

- The specific fuel consumption is higher for BN20+CeO_2 fuel blend than diesel and BN20 fuel blends. This is mainly due to the lower calorific value of the fuel blend.
- The brake thermal efficiency for nano particles blended BN20 is higher than that of BN20 and diesel fuels respectively.
- The harmful gases like, CO, HC, smoke and NOx emissions reduce significantly due to the addition of nano additive in the BN20 fuel blend.
- The cerium oxide additive influences the better combustion process which yields the peak pressure and heat release rate than BN20 and diesel fuel blends. The nano additive accelerates earlier initiation of combustion and cause for the higher heat release rate when compared with BN20.
- Overall, it is evident that the addition of cerium oxide nano particles in the neem oil biodiesel blend is more efficient for improving the performance, emission and combustion characteristics.

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