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Performance and Emission Test in CI Engine using Magnetic Fuel Conditioning with Nano Additives

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***Abstract:** An Experimental investigation was carried out to find out combustion performance and emissions characteristics of diesel engine using nano-aluminum oxide (n-Al_2O_3) mixed diesel. The n-Al_2O_3 of size 50 nm was mixed into diesel fuel at the rate of 0.5g/l and 1g/l for formulation of new alternate fuels. The n-Al_2O_3 was dispersed by means of an ultrasonic sonificator in order to produce uniform dispersion of n-Al_2O_3 in the diesel fuel. Nano-Al_2O_3 possesses better combustion characteristics and enhanced surface-area-to-volume ratio and hence allows more amount of diesel to react with the oxygen which in turn enhances the burning efficiency of the test fuels. This also enhanced using neodymium magnets which separates the molecules of the clustered hydrocarbon. The magnets are fitted across the fuel line to give best magnetic field for the fuel to flow through. The diesel fuel with and without n-Al_2O_3 additive were tested in a variable compression diesel engine at different load conditions and the results revealed that a considerable amount of enhancement in the brake thermal efficiency and substantial reduction in content of NOx and unburnt hydrocarbon (UBHC) at all the loads compared to neat diesel were observed due to nano Al_2O_3's better combustion characteristics and improved degree of mixing with air.*

***Keywords:** Fuel additive, Nano-aluminum oxide, Diesel engine, Diesel, Neodymium magnets, Performance, Emissions.*

I. INTRODUCTION

I.C. engines convert heat energy into mechanical energy by burning the fuel in its combustion chamber called engine cylinder. During combustion, oxygen combines with hydrogen to form water (H_2O), carbon monoxide (CO) and carbon dioxide (CO_2). The nitrogen in the fuel combines with oxygen and forms nitrogen oxide (NO_2). Researchers showed that nanodiesels have a potential for use as alternate fuels in the internal combustion engines due to enhanced properties [1, 4]. The application of magnetic field in the fuel line can change the fuel state and reduce the clustering of fuel particles. The fuel atoms will be changed into parallel spin from opposite spin towards each other [3]. There is big scope for research on compatibility of nanomaterial and how these fuel blends to overcome the emission regulation.

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Studies about environment can be made to reveal a total picture on impact of using nanoparticle blended fuels [4]. Some researchers used 1g/l and 1.5g/l of aluminium oxide for the production of test fuels. The aluminium oxide nanoparticle is mixed with diesel fuel using ultrasonic vibrator at frequency of 24 kHz in order to obtain stable mixture [6]. The NOx emissions are lower in additive added fuels combustion compared to base fuel combustion at all loads. 1.5g/l mixture results lower NOx emission compared to 1g/l mixture at all loads. It is because of the difference of combustion temperature, oxygen content and the reaction time between two mixtures [6]. The results of the performance test show that, ignition delay period and BSFC reduced with Al_2O_3 when added to neat diesel. BTE and peak cylinder pressure values were raised with the addition of Al_2O_3 nanoparticle in plain diesel [7]. In this research, the performance and emission characteristics of the diesel engine using diesel as fuel are taken as the benchmark reading and nano Al_2O_3 was mixed with the diesel and the performance and emission characteristics of diesel engine were compared.

II. NANO-Al_2O_3 –DIESEL BLENDSPREPARATION

Nano additives of 50nm size aluminium oxide is used to blend with the diesel fuel. 0.5g & 1g of n-Al_2O_3 were mixed into one litre of diesel fuel separately for preparing two test fuels. Sonicator at frequency of 40 kHz, a power of 200Wis used to concuss the mixture for 30 minutes to produce a uniform suspension of the experimental test fuels [1]. The test fuels with additives were quoted as D+0.5g and D+1g. The density, fire point, flash Point and calorific value of test fuels were measured using ASTM teststandards and the properties of the fuel blend are given in the Table 1. Immediately, the fuel blends were used to conduct test on diesel engine after preparation in order to avoid any settling or sedimentation to occur.

Table I Properties of the fuel blends

Properties	Diesel	Diesel + 0.5g	Diesel + 1g
Density, kg/m^3	832	842	844
Flash point, ^{0}C	52	50.8	48.4
Fire point, ^{0}C	55.8	52.2	51.4
Calorific Value, kJ/kg	44820	43250	41530

III. EXPERIMENTAL PROCEDURE

Fig 1 shows the photograph of the test engine. The fuel performance and emission tests are done using a dual engine which can run on diesel and gasoline fuels.

It is a variable compression engine with the feature of compression change for required fuel as per specifications and requirements. The load is given by eddy current dynamometer. The coolant used in the engine is water and its rate of flow is measured using roto meter. The additive fuel mixture is kept in a separate fuel tank with fuel indicator in order to analyse the specific fuel consumption. The air flow at inlet is indicated by manometer. The complete engine specifications are provided in Table 2. The instrumentation set up mainly comprises of data acquisition system software called 'Engine soft'. The data and all wanted information regarding the performance and emission of the engine is acquired from this software. An AVL combustion emission bench II is used to measure all major gaseous emissions from the engine in every test.

Fig 1 Photograph of the engine test rig.

Table II Specification of the engine test rig

Engine Type	Single Cylinder 4-Stroke Multi Fuel VCR Engine With Eddy Current Dynamometer
Bore & Stroke	87.5mm & 110mm
Fuel	Diesel
Power	3.5 kW
Speed	1500 RPM
Compression Ratio Range	12:1 – 18:1
Injection Variation	0-25^0 before TDC

IV. RESULTS AND DISCUSSION

The performance and emission characteristics of the diesel engine with test fuels were tested using the experimental setup described above. The observed values are brake thermal efficiency (BTE), specific fuel consumption (SFC), and emission concentrations of HC, NO_X, CO and CO_2 with various values of load at 1500 rpm.The variation of specific fuel consumption with engine load for different fuel mixtures (with and without magnetic fuel conditioning) has been shown in fig 2. The results show that the BSFC is lower for Al_2O_3 nanofuel than neat diesel at all engine loads. It is resulted that by the application of magnetic field around fuel inlet lines, the internal energy of a fuel to cause specific changes at a molecular level which obtained easier combustion of the fuel. At maximum load the 0.5g additive with magnetic conditioning shows 13% reduction of SFC compared to the diesel fuel. The 1g fuel with magnetic fuel conditioning shows 7% reduction of SFC. The mixtures without magnetic fuel conditioning shows slightly lower specific fuel consumption at all loads compared to diesel.More oxygen and the positive effects of aluminium nanoparticles on physical properties of diesel fuel causes to increase in combustion efficiency, and this reduces BSFC. This is due to the addition of aluminium oxide nanoparticle which supplied extra oxygen for complete combustion.

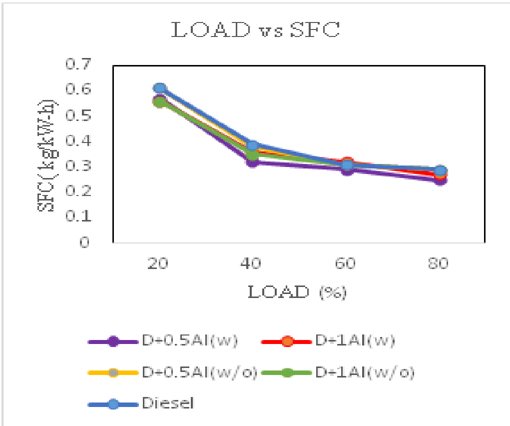

Fig 2 Variation of SFC with Engine load

Fig. 3 represents the variation of brake thermal efficiency with applied load. There is some improvements in brake thermal efficiency is observed for blended test fuels than neat diesel. Because nano Al_2O_3 additive reduces the evaporation time of the test fuel and hence it reduces the physical delay. Thus, the fuels were completely burnt and effectively utilized in the combustion chamber. Nano Al_2O_3 react with water vapour formed during combustion at high temperature generates hydrogen and improves the fuel combustion. At maximum load the 0.5g mixture and 1g mixture with the magnetic fuel conditioning shows 14% and 9% improvement over pure diesel respectively.

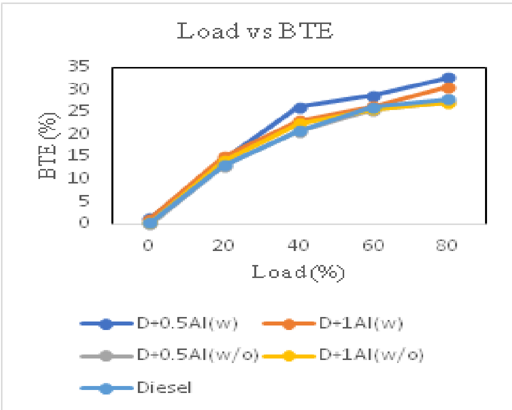

Fig 3 Variation of BTE with Engine Load

The aluminium oxide in different blends with diesel is tested in the variable compression engine with a constant compression ratio of 18:1. In the results the diesel causes higher cylinder pressure than any other blends. The mixtures of 0.5 g and 1g without magnetic conditioning shows higher cylinder pressure than the other blends with magnetic fuel conditioning. The magnetic conditioned fuels will burn quickly and completely in the combustion chamber it reduces the need of high cylinder pressure.

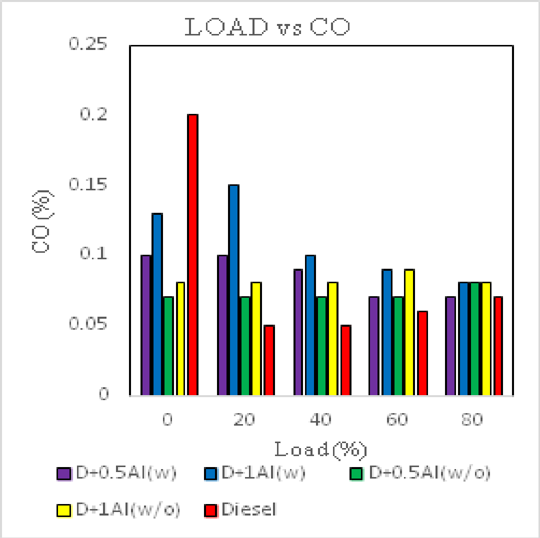

Fig 4 Variation of Cylinder pressure with Crank angle

The variation of hydrocarbon emission with load is shown in Fig. 5. The nano Al_2O_3 present in the test fuels decreases the HC emission when comparing with base fuel. Aluminum oxide acts as a catalyst and lowers thecombustion activation temperature of carbon and thus enhances oxidation of hydrocarbon and promoting complete fuel combustion. The research shows that the 0.5g and 1g mixture with magnetic fuel conditioning shows 22% and 52% reduction of HC over the diesel at maximum load and the 0.5g and 1g fuels without magnetic fuel conditioning shows about 19% and 22% of reduction over diesel fuel.

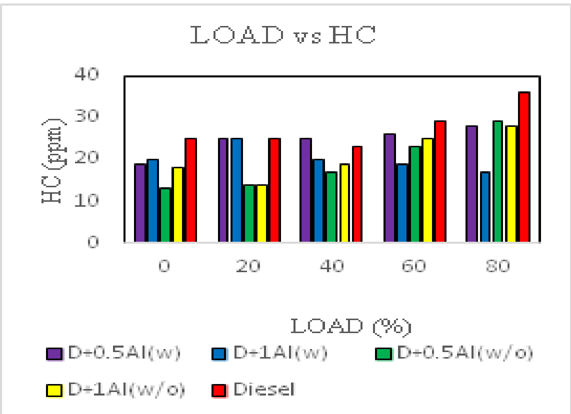

Fig 5 Variation of HC with the Engine load

The CO emission of diesel fuel and test fuels with the applied load is given in the Fig. 6. The carbon monoxide emission for diesel fuel is higher compared to nano Al_2O_3 blended fuels due to its lower thermal efficiency resulting in incomplete combustion of fuel. The greater catalytic and improved combustion characteristics of nano Al_2O_3 blended fuels leading to improved combustion of fuel could be the reason for this reduction of CO emission in fuel blends operations. At no load conditions the diesel results much higher CO emissions than the blended nano fuels. At maximum load 0.5 g and 1g of the both magnetic conditioned and non-magnetic conditioned fuels show about the same CO emission as the diesel fuel.

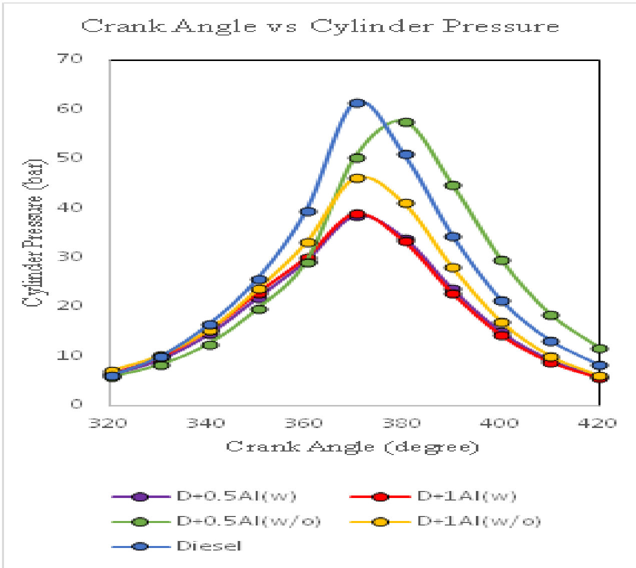

Fig 6 Variation of Carbon monoxide with the Engine load

Fig 7 shows that the emissions test for aluminium oxide nanofuel with and without magneticfuelconditioning observed that there is a reduction of up to 52% and 57% of CO_2 emission for 0.5g and 1g fuels with magnetic conditioning respectively, compared to diesel at maximum load.

The CO_2 emission of 0.5g and 1g blend fuels both show reduction of 20% at maximum load compared to diesel fuel. The aluminium oxide nanoadditive also acts as an oxygen donating catalyst, and providesoxygen for the oxidation of CO, or absorbs oxygen for the reductionof CO_2.

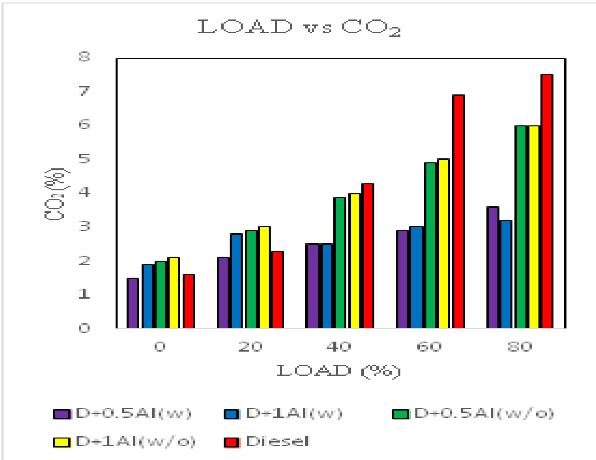

Fig 7 Variation of CO_2 with the Engine load

The NO_X concentration of diesel fuel and test fuels with engine load is shown in Fig. 8. The nitrogen oxide emission for blends is lower than that of diesel fuel at some loads. It was observed that at maximum load operation, reduction is about 14% and 27% for of 0.5g and 1g blend with magnetic fuel conditioning respectively.

The 0.5g blend with magnetic fuel conditioning shows an improved reduction in NO_X emission at all load when compared with 1g blend with magnetic fuel conditioning. A detailed flame analysis could possibly show the exact reasons behind the NO_Xformation as the behavior could be due to a complex interaction among factors such as oxygen content, combustion temperature and the reactiontime.

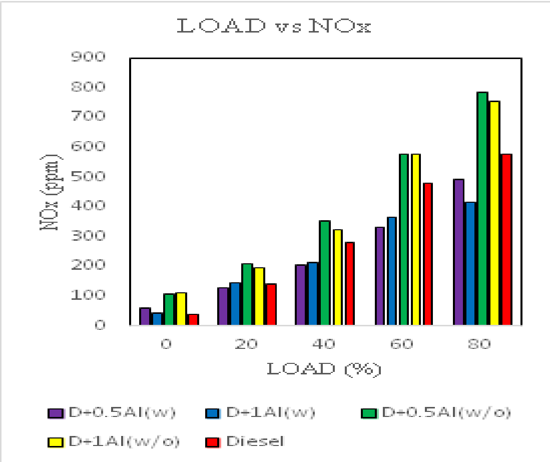

Fig 8 Variation of Nitrous Oxide with the Engine load

CONCLUSIONS

Experiments were carried out at different dosing levels of the nanoparticles to study the effects of nano Al_2O_3 blend with diesel on engine performance and its emissions. The important observations and inferences are givenbelow.

- ❖ Among the fuel blends with or without the presence of magnetic field and the pure diesel the 0.5g fuel additive blend with the presence of magnetic field results the lower fuel consumption of about 13% compared to the diesel.1g fuel blend shows 7% reduction in SFC compared to diesel. It shows this blend will give better fuel efficiency among all fuel blends.
- ❖ The fuel blend of 0.5g fuel additive with the presence of magnetic field is shows about 14% higher brake thermal efficiency compared to pure diesel. 1g fuel blend with magnetic fuel conditioning shows about 9% improvement over the diesel. The fuel blends without the presence of magnetic field have lower brake thermal efficiency.
- ❖ The 0.5 g and 1g fuel additive blends without the presence of magnetic field have lesser hydrocarbon emissions overall than fuel blends with magnetic field and pure diesel in lower load conditions. 0.5g and 1g fuel additive blends shows about 22% and 52% reduction of HC at maximum load over diesel respectively.
- ❖ The fuel additive blend with the magnetic field shows similar carbon monoxide emission as the blends without magnetic conditioning. The diesel releases lower amount of carbon monoxide than other fuel additive blends.
- ❖ The 0.5g and 1g fuel additive blends with the presence of magnetic field results about 52% and 57% reduction of CO_2 compared to diesel. The fuel blend without the presence of magnetic field and diesel have higher carbon dioxide emissions than the fuel with magnetic conditioning.
- ❖ The 0.5g and 1g fuel additive blends with the presence of magnetic field shows about 14% and 27% reduction of nitrous oxide compared to diesel. The fuel blends without the magnetic conditioning results higher nitrous oxide than diesel fuel.
- ❖ Among the various fuel additive blends 0.5g fuel additive with magnetic conditioning in diesel engine produces overall better results than other blends. It has better performance characteristics and reduced emission on diesel engine than otherblends.

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