An Experimental Analysis on Synergetic Effect of Multiple Nanoparticle Blended Diesel Fuel on CI Engine

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Abstract

Although the Compression Ignition Engines are a significant source of power, their detrimental emissions initiated the searches for alternative fuels that are renewable, safe and non-polluting. Even many researchers have put valid efforts in fuel modification, the current work describes the role of multiple nanofuel additives in diesel fuel. In this context, Aluminium oxide and Cobalt oxide nanoparticles are incorporated with the diesel fuel to investigate the performance, emission and combustion characteristics of a four stroke, single cylinder diesel engine. Experiments were carried out using five different additive combinations, neat diesel and diesel with some commercial additive for comparison. The experimental outcome revealed a substantial enhancement in brake thermal efficiency and a marginal reduction in harmful pollutants such as NOX, CO and smoke, for a particular nano additive proportion compared to that of neat diesel and commercial additive incorporated diesel.
Keywords: Alumina, Cobalt Oxide, Combustion, Emission, Nanoparticles, Pollutants

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I. INTRODUCTION

Due to growth of population, high energy consumption and global warming concerns, it is having great importance for the green engineering sector. In this regard, even automobiles being one of the prior reasons for the environmental pollution and energy consumption, the design and improvement in engines have received substantial attention. Compression Ignition engines are considered as the prime mover not only in automobiles but also in power plants, industrial sectors and marine sector due to its reliable operation. So it is required in the present scenario to implement design and improvement of high energy efficient, low energy consumption and low hazardous emission diesel engines in automobiles. Government has also implemented stringent rules to engine manufactures and customers to follow emission norms to save the environment from the harmful emission.

In this regard, various techniques have been employed such as fuel modification, engine design alteration and exhaust gas treatment and various researches have put their valid efforts to improve performance while reducing the pollutants in the compression ignition engines. Fuel modification techniques are widely adopted since it doesn’t require any major hardware modifications. Most of such fuel modification techniques are materialized by adding some fuel additives. Nanoparticle employs as one of the critical diesel additives due to its unique property which improve the fuel properties, combustion and reduce the level of deleterious pollutants. Nanoparticles are simplest form of structures of the order of nanometers. Nanoparticles are said to have amazing properties due to its smaller size and greater surface area to volume ratio. For the reason itself it has found various applications in the field of research and industries. Currently researches are accelerated in the field of automobiles with application of nanoparticles. The present work is an advancement with the application of multiple nano additives in diesel fuels.

The objective of the present investigation is to study the synergetic effect of multiple nanoparticle additives in a CI Engine in order to enhance the combustion characteristics, Improve the performance of engine, reduce the harmful emissions.

Global environmental and economic scenario itself clearly defines the scope of our present work. Due to the increased pollution and energy (fossil fuel) depletion it requires, less fuel consumption and more power along with the reduction of harmful emission from automobiles.

By incorporating some combination of nanoparticles, it can bring out the requirements at low cost itself. When compared with the advantages obtained the cost is negligible and it could satisfy the impending emission regulations.

II. THEORY

A. Nanoparticles:

Nanoparticles are simplest form of structures of the order of nanometers ranging up to a size where they lose their unique properties. They can be available in different forms such as metals, metal oxides, and carbon nanotubes.. The current investigation is being proceeded with the desirable properties of the selected Alumina and Cobalt Oxide nanoparticles as a fuel additive.

Thermal conductivity is the most important parameter in the enhancement of thermal efficiency of an engine. Since alumina can bring out more uniform temperature distribution, it can bring about significant change emission levels.

The unique property for the Alumina nanoparticles in bringing out desirable outcomes as a fuel additive is its ability to produce micro explosions in the cylinder, which in turn reduces the peak temperature.

Cobalt Oxide acts as the better oxygen buffer in the role of a fuel additive. Thus the Oxygen atoms can moderate the combustion reaction so as to produce a cleaner combustion.As the temperature increases, the mobility of active oxygen atoms increases and the oxidation of CO become easier. The lattice oxygen on CO_3O_4 is more active than active oxygen and form bidentate carbonate which can oxidise CO to produce CO_2.

The present investigation is on the synergetic effect which the Alumina supported cobalt oxide could give as a potential fuel additive.

III. EXPERIMENTAL METHODOLOGY

The investigation is carried out in an experimental setup as shown in figure 1. The set up consist of a single cylinder, four stroke, direct injection diesel engine coupled to an AC alternator for loading and an instrumentation system. The engine cooling was done by normal air cooling.

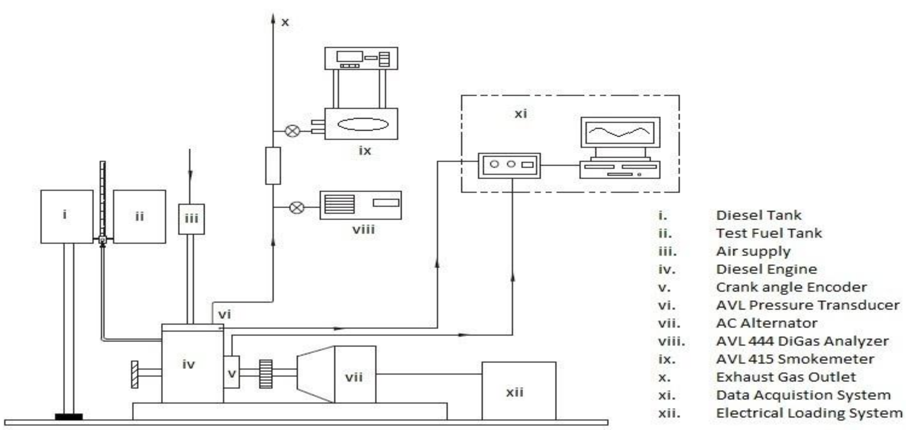

Fig. 1: Experimental Setup

The instrumentation system includes AVL 444 Di-gas analyzer, AVL 415 smoke meter, Data acquisition system consisting of AVL pressure transducer (model: GH14D/H01) and AVL365C angle encoder. The AVL 444 Di-gas analyzer measures the exhaust emission such as NO_X, CO, CO_2, O_2 and unburned HC. While the smoke opacity and soot concentration is measured by the AVL smoke meter. The details of engine technical specification and instruments are listed in table 1.

Table – 1
Engine Specifications

Make & Model	*Kirloskar, TAF 1*
Type	*Single cylinder, four stroke, air cooled, direct injection*
Bore x Stroke	*87.5 x 110 mm*
Compression Ratio	*17.5:1*
Swept volume	*661cc*
Combustion Chamber	*Open hemispherical*
Nozzle holes	*3 holes*

Spray hole diameter	*0.25mm*
Cone angle	*110 degree*
Rated output	*4.4kW,1500 rpm*
Injection timing	*23^oBtdc*
Injection pressure	*200 bar*

A. Preparation of Blended Fuel:

The diesel fuel was obtained from an approved dealer of Indian Oil Corporation Limited. The Alumina nanoparticles (40nm) were supplied by the manufacture M/s Plasma Chem, Berlin, Germany and CO_3O_4 nanoparticles (50nm) were supplied by M/s Sigma Aldrich, USA. The details specification of the particles are listed in table 2.

Table – 2:
Particles Specifications

Particle	*Al_2O_3*	*CO_3O_4*
Manufacturer	*Plasma Chem*	*Sigma Aldrich*
Shape	*Spherical*	*Spherical*
Average size	*40 nm*	*< 50 nm*
Full range	*5-150 nm*	*10-150 nm*
Purity	*>99.8%*	*99.5%*
Appearance	*White*	*Black*

In general the nanoparticles possess excellent dispersion in all fluids such as water, ethylene glycol and oil to form stable suspensions for long periods, weeks or months. Hence for the present work ultrasonication technique was adopted to disperse both the particles in diesel fuel. This would help in preventing the agglomeration of particles. Both the particles were weighted separately in a predefined mass fraction and dispersed in the neat diesel with the aid of an ultrasonicator for 30 minutes .Thus the different nanoparticles blended diesel fuel (D5000, D0050, D3515, D2525, D1535) was prepared. Moreover the prepared samples were kept undisturbed and found to be stable for more than a week.

IV. RESULTS AND DISCUSSIONS

This section describes the combustion, performance and emission attribute of the diesel engine using virgin diesel, 5 blended samples namely D5000, D0050, D3515, D2525, D1535 and the sample with commercial diesel additive. The combustion characteristics are presented as heat release rate and cylinder pressure plotted against crank angle. The performance characteristics are plotted as brake thermal efficiency and specific fuel consumption against brake mean effective pressure. The emission parameters are plotted against load.

A. Combustion Characteristic:

The variation of cylinder pressure and heat release rate was plotted with reference to crank angle for the tested fuels from no load to full load. Among the various test samples D3515 was found to have higher peak pressure. It was found that for the sample with Al_2O_3 and Co_3O_4 particles in equal proportion (D2525) shows a lesser value of peak pressure when compared with other fuel samples. At higher loads, the peak pressure was found to be higher for commercially available additive doped fuel than that of D2525. When compared with neat diesel, D2525 was showing similar and lesser trends in peak pressure. The figure 2 shows variation of cylinder pressure for the fuel samples at full load.

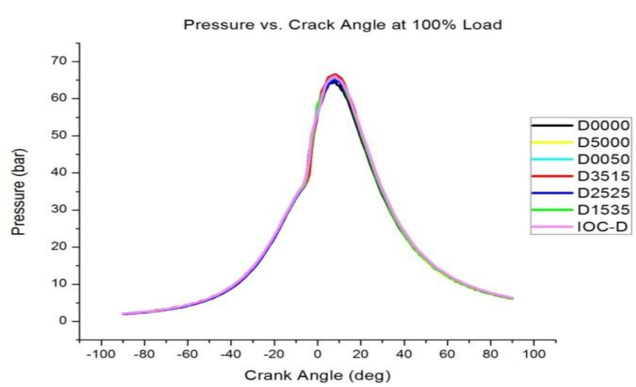

Fig. 2: Variation of Pressure with Crank Angle

Similar results were obtained when the heat release rate was plotted against the crank angle for the test fuels. Figure 3 shows the heat release rate Vs crank angle at half load and full load for the fuel samples. It was found that heat release rate for the sample with equal proportion of both the particles was lesser when compared with other samples and commercial additive. At higher loads sample D2525 have similar and better results with neat diesel.

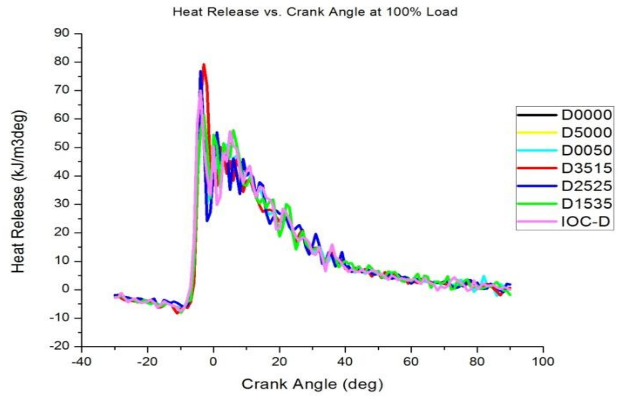

Fig. 3: Variation of Heat Release with Crank Angle

This could be due to the improved ignition which has accelerated the combustion. This leads to better catalytic activity. Thus the pressure of nano sized particles in the diesel has enhanced the ignition and produced low heat release rate when compared with other sample and especially the commercial additive. Due to the greater surface area- volume ratio, the nanoparticles could have improved the fuel- air mixing and leading to shorter ignition delay.

B. Performance Characteristic:

The variation of brake thermal efficiency with respect to break mean effective pressure is shown in figure 4. It is observed that brake thermal efficiency of samples with particle additives show significant increase in brake mean effective pressure. The samples especially D2525 shows a constantly higher brake thermal efficiency in all loads, particularly at higher loads.

This could be due to the better combustion characteristics which allowed more fuel to interact with air. Even the Co_3O_4 particles which supplied sufficient active oxygen helps in enhancing the efficiency.

Similar trend was obtained in case of specific fuel consumption. Figure 5 shows the change in brake specific fuel consumption with respect to bmep. The specific fuel consumption was found to be decreasing at medium loads. This could be due to proper mixing of air with fuel and shortened ignition delay effort. It means that at medium loads, a lesser amount of fuel was consumed for producing a same amount of work when compared to the neat diesel.

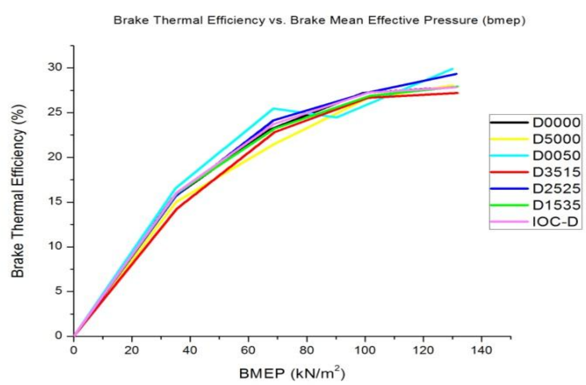

Fig. 4: Brake Thermal Efficiency vs BMEP

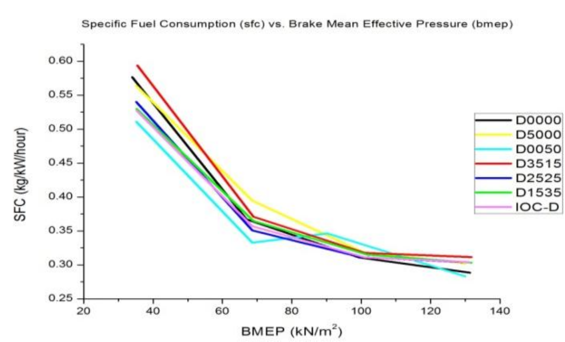

Fig. 5: Specific Fuel Consumption vs BMEP

C. Emission Characteristics:

For a compression ignition engine, the major emission consists of oxides of nitrogen, carbon monoxide, unburned hydrocarbons and smoke.

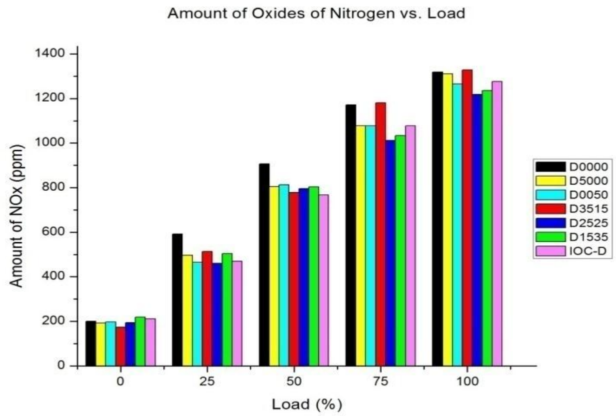

Fig. 6: Variation of NO_X with load

The variation of NO_X with respect to load is shown in figure 6. At higher loads NO_X emissions show a marginal decrease with sample D2525. The better combustion characters associated with sample, such as lower heat released caused the reduction in oxides of nitrogen. Also it is noticeable that at every load; NO_X emissions produced by sample D2525 are lower compared to neat diesel and commercial additive.

The variation of HC emissions for the particle doped diesel fuels, neat diesel and commercial additive added fuel is depicted in figure 7. It can be inferred from the figure that, even at medium and higher loads, the HC emissions showed a significant reduction with nanoparticles. Especially the sample with equal amount of both particles, D2525 showed an almost constant emission rates at lower to higher loads. This is because Al_2O_3 helps in lower loads while CO_3O_4 helps in higher loads.

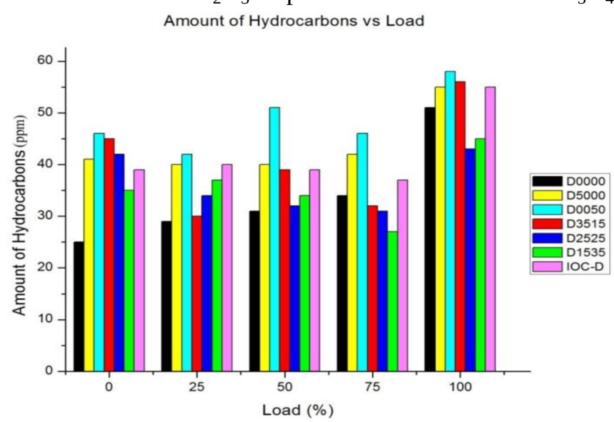

Fig. 7: Variation of Hydrocarbons with load

It is a serious concern to note the percentage of carbon monoxide. It is shown in figure 8 that the CO emission marginally decreases with D2525 sample and possess a great extent of difference with neat diesel and commercial additive doped diesel.

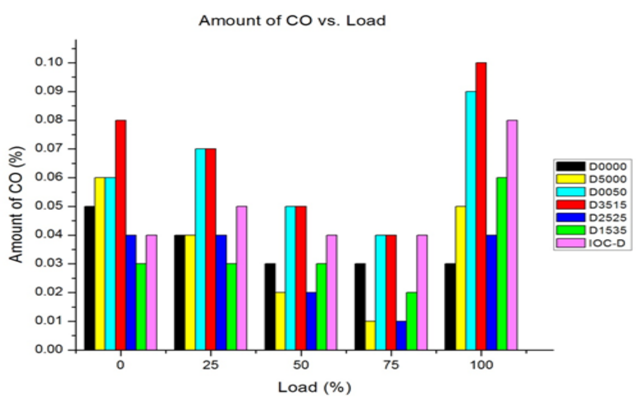

Fig. 8: Variation of Carbon Monoxide with load

There was a slight reduction in smoke opacity level for D2525 sample at all loads and particularly at higher loads. This could be due to better fuel- air mixing in presence of Al_2O_3 and CO_3O_4 nanoparticle which have led to improved combustion.

The variation of smoke opacity for the neat diesel, particle blended diesel and additive samples are illustrated in figure 9.

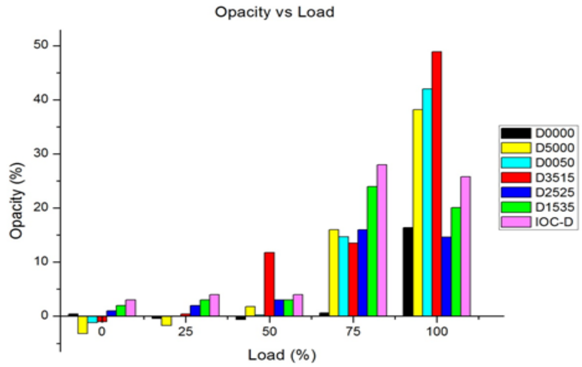

Fig. 9: Variation of Smoke Opacity with load

V. CONCLUSIONS

The present work was an experimental investigation of performance, combustion and emission characteristics of a single cylinder four stroke direct injection diesel engine using Al_2O_3 - CO_3O_4 nanoparticles blended diesel fuel. The fuel samples were made with five different proportions of additives. The combustion, performance and emission characteristics of these samples were studied and compared with that of neat diesel and diesel which is doped with commercial diesel additive. The results were in supportive with application of nanotechnology in the area of internal combustion engines for improving performance and reducing emission.

The conclusions of investigations are as follows:

1) The alumina- cobalt oxide nanoparticles blended diesel fuel was stable for more than a week under idle conditions.
2) Due to the shortened ignition delay effect of nanoparticles blended diesel fuel the peak pressure and peak heat release rate was reduced.
3) There was a noticeable improvement in the brake thermal efficiency of the particle blended sample. Especially when the Al_2O_3 and CO_3O_4 nanoparticles where blended in equal ratio, the results were satisfactory. There was a reduction in specific fuel consumption when compared to neat diesel.
4) There was a marginal reduction of NO_X, HC, CO and smoke emissions for D2525 sample. HC emissions were found to have 15-20% reduction when compared with neat diesel and 20-25% reduction with commercial additive additive doped diesel at full load. The CO emission kept above 20% marginal decrease than neat diesel in lower and medium loads. NO_X emissions were also found to be lesser when compared at all loads conditions. The smoke opacity and soot concentration were also satisfactory for the sample.

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