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Emission Characteristics study on Variable Compression Ratio Engine using Nanoparticle blended diesel fuel

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***Abstract*—** In the current scenario, vehicular emission contributes to major pollution source. Thus, it becomes necessary to reduce emission by improving the performance of the engines. Fuel borne catalyst proves to be a promising solution to reduce emission before combustion due to its ease of implementation without much modification of the existing engine design. The combined effect of Aluminum oxide (Al_2O_3) and cerium oxide (CeO_2) nanoparticles, blended with diesel on the emission characteristics of a Variable Compression ratio (VCR) engine was carried out in the present study. The effect of various mass proportions of nanoparticles on the emission characteristics was determined. The net particle mass loading rate ranged between 0.5% to 1%. The nanoparticles were mixed in diesel with the aid of the ultrasonication process. The results showed that for the nanoparticle blended diesel, a good deal of reduction was achieved in the emission characteristics with Unburnt Hydrocarbon (UBHC), carbon monoxide (CO), and NOx got reduced by 34%, 25%, and 5% compared to pure diesel. The enhanced emission characteristics were due to the improved surface area to volume ratio and heat conduction properties of the metal oxide nanoparticles.

***Keywords*—** Vehicular emission, Ultrasonication process, Pure diesel, Emission characteristics. etc

I. Introduction

In the current scenario, vehicular emission contributes to major pollution source. Thus, it becomes necessary to reduce emission by improving the performance of the engines. Several processes such as post-treatment of exhaust gases with a catalytic converter, modification of the combustion chamber and piston geometry to improve combustion efficiency and water- fuel emulsion injection into the combustion chamber to reduce combustion[11] chamber temperature are deeply researched. The above mentioned processes involve huge cost and greater design changes in engine geometry.

Fuel borne catalysts prove to be a promising solution since it involves altering the fuel properties through the addition of additives in the form of nanoparticles which will enhance the fuel properties for the clean combustion process. J.Sadhik Basha and R.B. Anand [1] investigated the effects of Aluminum oxide nanoparticle and Carbon Nano Tubes blended biodiesel.

They observed that the Break Thermal Heat Efficiency (BTHE) of the engine increased by 28.9% compared to pure biodiesel. Yanan Gan and Li Qias [2] experimented on the combustion characteristics of the fuel droplets with nano and micro-sized aluminium oxide particles and observed that nano-sized particle suspension can remain stable for a longer time. This is due to the higher surface area to volume ratio which leads to interaction between the particle surface and surrounding fuel that is strong enough to overcome density differences. Janet M. Dowding et al. [3] observed the scavenging nature of cerium oxide nanoparticle on nitric oxide radicle.

They observed that CeO_2 (+3/+4) valence states react with nitric oxide leading to the reduction of the NOx formation due to potent redox reaction. X.Shi et al. [5] observed through experimentation that for oxygenated contents in fuel, the particulate matter emission of Compressed Ignition (CI) engine decreased whereas nitrogen oxide emission increased. V.Arul Mozhi Selvan et al. [4] investigated the effects of cerium oxide (CeO_2) nanoparticle addition in diesel and diesel-biodiesel-ethanol blends in a VCR engine and observed that the ignition delay was less leading to low Unburnt Hydrocarbon (UBHC) emission whereas the NOx emission increased for the nanoparticle-fuel mixture.Philip M.Gueririe et al. [8] have studied the droplet combustion of microparticle aggregates of oxygen-containing nanoparticles and observed that nanoparticle laden fuel's burning rate increased by 44% when compared to neat diesel.

Dilip Srinivas Sundaram et al. [9] have studied the ignition and combustion of micro and Nanosized aluminium particle [12] and concluded that the compression ratio plays a vital role in the ignition and complete combustion of Nanoparticle aluminium. V.Prabakaran et al. [10] studied the performance and emission characteristics of DI diesel engine with diesel-blended biodiesel with the addition of copper oxide nanoparticles were investigated. The following conclusion was drawn the experimental result.

The brake thermal efficiency was increased in B20CuO75ppm at all loads than neat diesel. The specific fuel consumption is higher for the B20CuO75ppm than neat diesel at the entire load comparing with the different dosing level of blends. V.Krishnan et al. [11] studied the results of experimental investigations on the influence of the addition of cerium oxide in nanoparticle form on the major

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physiochemical properties and the performance of diesel. The fuel is modified by dispersing the catalytic nanoparticle by ultrasonic agitation. Cerium Oxide Nanoparticles reduced HC, CO and smoke efficiency up to50.33%, 33%, and 12.5% compared with a biodiesel blend

Thus, Aluminum oxide (Al2O3) and Cerium oxide (CeO2) nanoparticles prove to be promising fuel borne catalysts to improve the emission characteristics of the Compressed Ignition (CI) engine.[13] The effect of various mass proportions of nanoparticles on the engine emission characteristics is carried out in the present work.

II. EXPERIMENTAL SETUP

Table 1: Properties of Nanoparticle blended Diesel Fuel samples

Nanoparticle Proportion	Representation	Density (Kg/m³)	Kinematic Viscosity @40ºC	Flash Point (ºC)	Fire Point (ºC)	Cetane Number	Calorific Value (KJ/Kg)	
Al2O3 (PPM)	CeO2 (PPM)							
25	25	A25C25	830.5	12.8	52	58	43	32901.7208
25	50	A25C50	854.4	10.8	63	67	52	35435.09096
25	75	A25C75	869.9	11.3	69	74	58	39858.0392
50	25	A50C25	831.4	11.3	56	59	48	33317.6104
50	50	A50C50	862.7	10.5	65	72	56	36962.62752
75	25	A25C75	842.9	11	58	62	51	34573.52168

Table 2: Specification of Variable Compression Ratio Engine

Specification	Description
Type	Single Cylinder, Direct Fuel Injection
Bore X Stroke	110 X 87.5 mm
Swept Volume	661 CC
Injection Timing	23ºbTDC
Compression Ratio Range	12-18
Temperature Sensor	Type RTD, PT100 and Thermocouple, Type K
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse
Data acquisition device	NI USB-6210, 16-bit, 250kS/s

The Aluminum oxide and Cerium oxide nanoparticles were weighed at fixed proportions by mass and mixed in diesel fuel with the aid of an ultrasonicator[15] for 60 minutes. The nanoparticle mixed diesel fuel sample properties are presented in **table 1.** The experiment was carried out immediately after the sonication process of each fuel blend to avoid settling down by aggregation of the nanoparticles in the fuel samples. The experiment was carried out in a 4-stroke, Direct Injection, single-cylinder VCR engine with 3.5KW@1500rpm power. The VCR engine specification is described in **table 2.** Each fuel sample was tested in the engine[13] for 30 minutes followed by a cooling down period of 60 minutes and a clean diesel-run for 30 minutes. This was to avoid the interference of the effect of one fuel blend sample over the other.

III. RESULT AND DISCUSSION

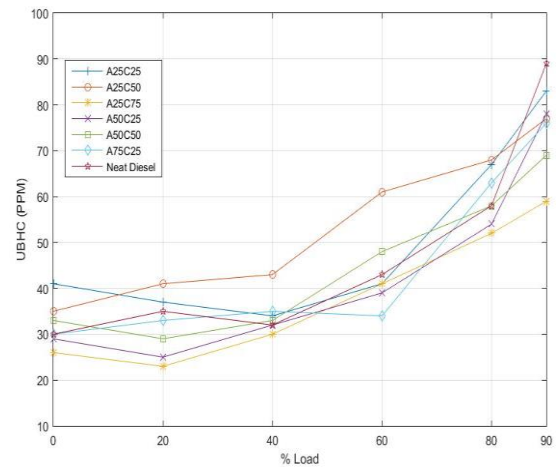

Figure 1: Comparison of UBHC emission of Nanoparticle blended Diesel Fuel with Neat Diesel

The comparison of UBHC, CO and NOx for various nanoparticle mass loading rate is discussed in this section. From **Figure 1** it is observed that the UBHC emission[14] is significantly less for nanoparticle blended diesel fuel when compared to pure diesel. This is due to the increased surface area to volume ratio [1, 2, 6]. The UBHC emission reduction occurred for A25C75 with a 34% reduction when compared to neat diesel. The ranking of nanoparticle mixed diesel fuel samples based on the reduction in the emission of UBHC indicates that the UBHC [14] reduction primarily depends on the proportion of cerium oxide nanoparticle in the fuel sample.

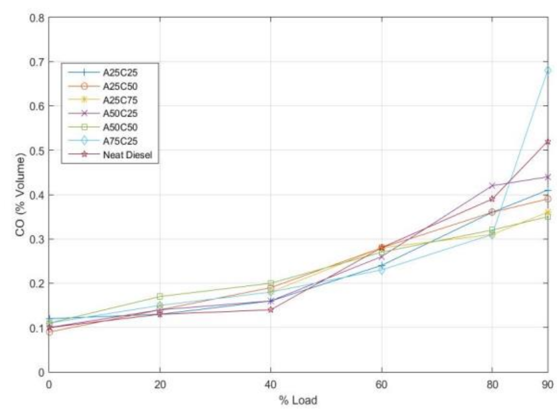

Figure 2: Comparison of CO emission of Nanoparticle blended Diesel Fuel with Neat Diesel

From **Figure2,** it is evident that the CO emission of nanoparticle blended diesel fuel samples is significantly less than that of pure diesel fuel. This is due to the active catalytic property of nanoparticles which reduces the ignition delay and improves the combustion process [7]. The maximum reduction in CO occurred for A50C50 with a 25% reduction of CO emission.

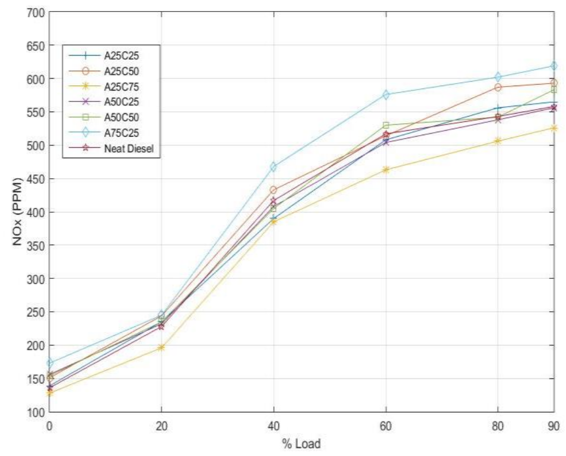

Figure 3: Comparison of CO emission of Nanoparticle blended Diesel Fuel with Neat Diesel

From Figure 3, it can be observed that the NOx emission increases for nanoparticle blended diesel fuel samples when compared to pure diesel. The NOx emission is reduced for A25C75[16] by 5% at peak load. This is due to the scavenging property of cerium oxide nanoparticle on nitric oxide particle [6]. For all the other nanoparticle mixed diesel fuel samples, it can be seen that the NOx emission is slightly higher than that of pure diesel. This is primarily due to the oxygen contribution of nanoparticle at elevated temperature [4]. From the NOx emission pattern[15], it can be inferred that the NOx emission increases with the increase in the proportion of aluminium oxide nanoparticle [16] in the fuel blend.

IV. Conclusion

The emission characteristics of nanoparticle blended diesel fuel at different nanoparticle mass loading rates have been experimentally investigated with the aid of a Variable Compression Ratio engine. The effects of nanoparticle proportion on the engine emission parameters were investigated and the key findings are documented as follows

i. The emission of UBHC shows that it decreases with an increase in the proportion of cerium oxide nanoparticles. Thus, the reduction of UBHC emission depends primarily on the proportion of cerium oxide nanoparticles.

ii. The CO emission of nanoparticle blended diesel fuel emission is significantly less for nanoparticle blended diesel fuel due to the active catalytic nature of the constituent nanoparticles.

iii. The nanoparticle blended diesel fuel has higher NOx emission due to the active contribution of oxygen by the nanoparticle and the NOx emission depends on the proportion of aluminium oxide nanoparticle in the diesel fuel.

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