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Influence of Iron (II, III) Oxide Nanoparticles Fuel Additive on Exhaust Emissions and Combustion Characteristics of CRDI System Assisted Diesel Engine

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Abstract—
This paper presents the results of investigations carried on CRDI system assisted diesel engine using diesel blended with Iron (II, III) Oxide nanoparticles. The iron (II, III) Oxide nanoparticles was mixed with diesel in mass fraction of 25 and 50 ppm with the help of mechanical homogenizer and an ultrasonicator. The experiment was carried out with the aim of obtaining comparative measures of combustion and emission parameters to evaluate the behavior of the CRDI diesel engine running on the diesel and iron (II, III) Oxide nanoparticles blended modified diesel. It was observed that iron (II, III) Oxide nanoparticles blended diesel exhibit a significant reduction in specific fuel consumption and exhaust emission at all operating loads. The results also showed a significant enhancement in brake thermal efficiency and heat release rate due to influence of iron (II, III) Oxide nanoparticles addition in diesel.
Keywords: Iron (II, III) Oxide Nano particles (IONP), mechanical Homogenizer, ultrasonicator, combustion, emissions.

I. INTRODUCTION

One of the most critical challenges ahead of the diesel engine is to meet future emissions regulations whilst improving performance and fuel economy with a minimal cost penalty. The current and emerging after treatment technologies give encouraging results, but their cost and complexity threaten the competitiveness of the diesel engine package. Conversely, over the past decade, research on diesel homogeneous charge combustion has highlighted an alternative approach for significant engine out reductions of nitrogen oxides (NOx) and Particulate Matter (PM) emissions [1-3]. Diesel fuel is one of the prime focus areas of research for the scientists in order to improve the properties of fuel as per the standard specifications. In the present scenario, the scientists and environmentalists are concerned with ecofriendly fuels worldwide for industrial development brought with its prosperity environmental pollution. Transportation vehicles with hydrocarbon fuel contribute significantly to air pollution through the emission of SOx and NOx from IC engines [4]. The overall calorific value of the diesel fuel increases due to high energy density of metal oxide particles, and improving the performance of the engine by increasing power output [5]. Nanoparticles blended fuels exhibit considerably enhanced thermal and physical properties when compared to base fuels. At nanometer scale the surface-area-to-volume ratio of the nanoparticles increases and this create a larger contact surface area during the rapid oxidation process [6]. Lenin et al. [7] investigated in his study is based on the effect of nano metal oxide additives like manganese oxide and copper oxide to diesel fuel. Metal oxide additive are doped with diesel fuel. The changes in diesel fuel properties due to the introduction of nano metal oxide additive were observed. The diesel fuel with nano metal oxide additive presented a marginal increase in performance. The exhaust emissions of the diesel fuel with nano metal oxide additive showed significant decrease in level emissions. Sajith et al. [8] conducted an experiment in diesel engine by dosing cerium nanoparticles to biodiesel and found a significant reduction in NOx and HC levels, and enhancement in the brake thermal efficiency. For example, due to size related properties, energetic materials containing nanoparticles can discharge more than double the energy of even the finest molecular explosives [9]. Aluminum nanoparticles blended with water-diesel emulsion fuel, reacts with water at higher temperatures and generate hydrogen which promotes complete combustion in engine chamber. Addition of aqueous aluminum nanofluid to diesel fuel will increase the total combustion heat, while the concentration of nitrogen oxides and smoke in the exhaust emission from the engine will decrease [10]. There are many advantages of incorporating nano materials into fuels, such as shorter ignition delay and shorter burning times. Furthermore,

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nanoparticles can be diffuse into high temperature zones for rapid energy release, oxidation reaction, and enhanced propulsive performance with increased density impulse. Many researchers have been also done to investigate the effect of adding nanoparticles to fluids. It has been reported that adding nanoparticles to a
fluid can enhance its physical properties such as thermal conductivity, mass diffusivity, and radiative heat transfer [12–14]. In this experiment Iron (II, III) Oxide nanoparticles was added to diesel in different proportions and investigate the performance, combustion and emission of the CRDI system assisted diesel engine.

II. PROPERTIES OF IRON (II, III) OXIDE NANOPARTICLES

Scanning electron microscopy provides direct examination of nanotube alignment and size [15]. The morphology of nanoparticles was investigated by field emission scanning electron microscopy (FE-SEM). The FE-SEM images showed that most of the nanoparticles obtained from all the ablated laser energies have spherical shape with a particle size of less than 100 nm. Furthermore, it was observed that the particle size increased with increasing the laser energy [16]. SEM of Iron (ii, iii) Oxide nanoparticles is shown in Figure 1. Surface and morphological characterization of Iron (ii, iii) Oxide nanoparticles were carried out using scanning electron microscopy. Nanosized spherical shaped Iron (ii, iii) Oxide nanoparticles obtained was confirmed. The diameter distribution of the nanoparticles varies from 24-65nm.

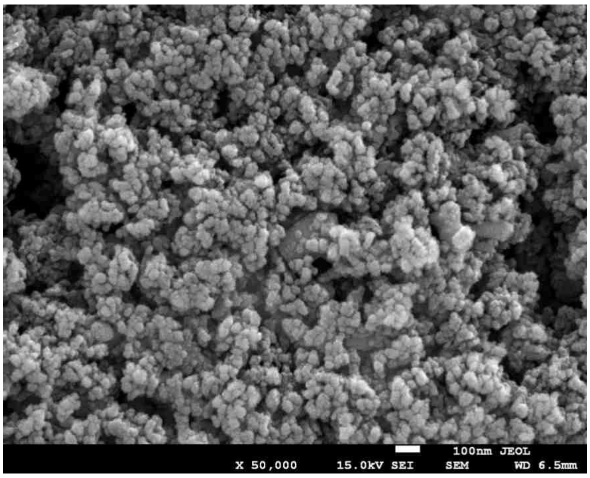

***Figure 1** SEM of Iron (II, III) Oxide Nanoparticles*

III. PREPARATION OF FUEL BLEND

For the blending of Iron (II, III) Oxide nanoparticles in diesel, take samples of diesel say 1 litre and then 0.025g of Iron (II, III) Oxide nanoparticles is added to make the dosing level of 25 ppm. Subsequently to increase the dosing level of 50 ppm, we have to increase to 0.05g/lit respectively. After addition of Iron (II, III) Oxide nanoparticles it is shaking well. And then it is poured into apparatus where it is agitated for about 30 minutes in an ultrasonic shaker for making uniform suspension. It should be shaken well before use, as excess of nanoparticles settle down on solution.The important physical and chemical properties of diesel and IONP blended diesel were determined by standard methods and shown in table 1.

Table 1 Properties of diesel - IONP blend samples

Description	Density @ 15°C, (Kg/m3)	Flash Point, °C	Net Calorific Value, (kJ / kg)	Cetane Number
Diesel fuel	815	58	42,000	47
Diesel fuel with 25 ppm IONP	819	63	42,342	48.4
Diesel fuel with 50 ppm IONP	823	67	42,657	49.6

IV. EXPERIMENTAL SETUP AND TEST PROCEDURE

Experiments were conducted on Kirloskar TV1, four stroke, single cylinder, air cooled diesel engine. The rated power of the engine was 5.2 kW at 1500 rpm. The engine was operated at a constant speed of 1500 rpm and a standard injection pressure of 300 bar. Details of the engine specification are given in Table 2. The fuel flow rate is obtained by the gravimetric basis and the airflow rate is obtained on the volumetric basis. The AVL smoke meter is used to measure the smoke density. AVL five-gas analyzer is used to measure the rest of the pollutants. A burette is used to measure the fuel consumption for a specified time interval. During this interval of time, how much fuel the engine consumes is measured, with the help of a stopwatch. The experimental setup is indicated in Figure 2.

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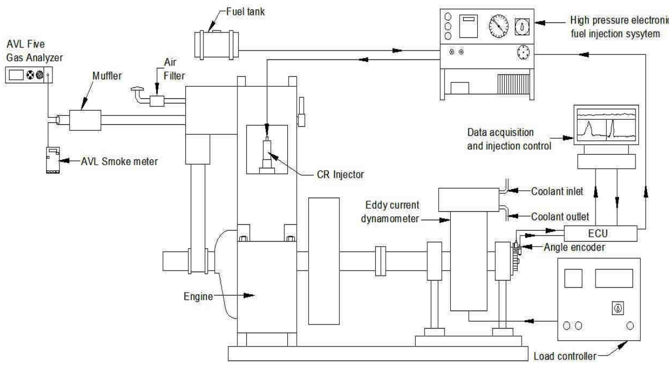

Figure 2 *Experimental Setup*

Table 2 Engine Specification

Type	:	Vertical, water cooled, four stroke
Number of cylinders	:	One
Bore	:	80 mm
Stroke	:	110 mm
Compression ratio	:	17.5:1
Maximum power	:	5.2 kW
Speed	:	1500 rev/min
Dynamometer	:	Eddy current
Injection timing	:	23 (before TDC)
Injection pressure	:	250 kgf/cm^2

V. RESULTS AND DISCUSSION

The operation of the engine was found to be very smooth throughout the rated load, without any operational problems for the iron (II, III) Oxide nanoparticles blended diesel fuel blends. In the present section, based on the combustion data, cylinder pressure and heat release rate are plotted against crank angle. The performance attributes such as brake thermal efficiency, specific fuel consumption, and the emission parameteres such as CO, HC NO_x, and smoke opacity are plotted against brake power.

5.1 Engine Performance

5.1.1 Brake Specific Fuel Consumption (BSFC)

The performance tests were conducted on a CRDI diesel engine with diesel and modified diesel. Brake specific fuel consumption, which depends on the engine power as well as density and viscosity of the fuel. The variations of brake specific fuel consumption for the neat diesel and the Iron (II, III) Oxide nanoparticles blended diesel at various loads have been depicted in Figure 3. It is observed that the BSFC values of neat diesel fuel and 25ppm IONP fuel are nearly same, while the 50ppm IONP fuel shows a considerable decrease of about 9% in comparison with the other cases.

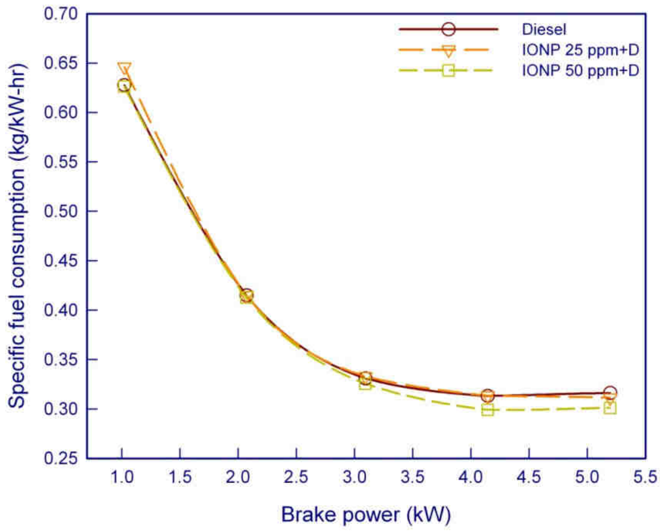

Figure 3 *Specific Fuel Consumption Against Brake Power*

5.1.2 Brake Thermal Efficiency (BTE)

Figure 4 shows the variation of brake thermal efficiency with increasing load for two different concentrations of Iron (II, III) Oxide nanoparticles. The brake thermal efficiency was increased by about 2% with the addition of 50ppm IONP in diesel. This behavior can be explained based on the viscosity increase of the diesel with an increase in the nanoparticles concentration. Although the high surface area and, subsequently, great chemical reactivity of the nanoparticles lead to increase the combustion efficiency of the nanoparticle blended diesel fuel.

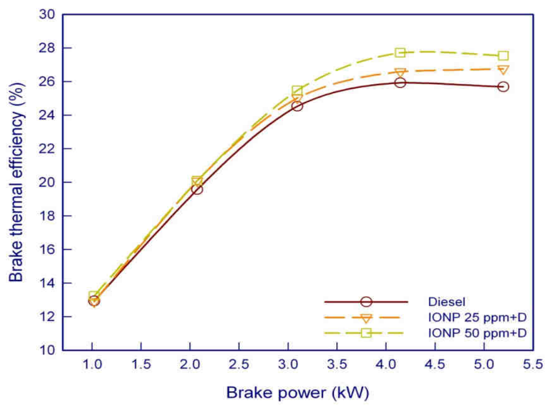

Figure 4 *Brake Thermal Efficiency Against Brake Power*

5.2 Emission Parameters

5.2.1 Carbon Monoxide Emissions (CO)

The variation of carbon monoxide with brake power is shown in Figure 5. The carbon monoxide emission decreases with the addition of Iron (II, III) Oxide nanoparticles with the diesel fuel. Generally, the CO emission is caused due to the poor mixing of air and fuel, and incomplete combustion of fuel. The IONP present in the fuel promotes longer and more complete combustion, as compared to the base fuel, as IONP acts as an oxygen buffer, releasing oxygen depends upon the partial pressure of oxygen. The CO emission is marginal up to the brake power of 4.2 kW and then increases rapidly with higher load. CO is to be found considerably reduced with the addition of Iron (II, III) Oxide nanoparticles with the diesel. The CO emission decrements are about 48% and 52% of the cases of 25ppm IONP and 50ppm IONP fuels, respectively, at the full load of the engine.

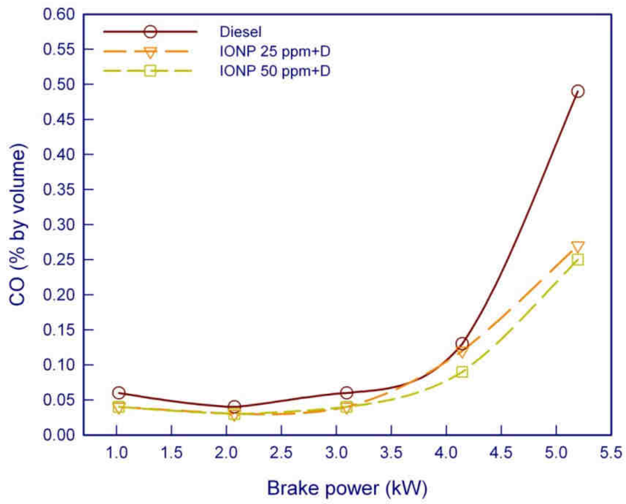

Figure 5 *CO Against Brake Power*

5.2.2 Hydrocarbon Emissions (HC)

The variation of hydrocarbon emission with brake power is shown in Figure 6. The addition of Iron (II, III) Oxide nanoparticles reduces the HC emission when compared with neat diesel. The Iron (II, III) Oxide nanoparticles acts as an oxidation catalyst and lowers the carbon combustion activation temperature, thus enhances the hydrocarbon oxidation. The least HC emission is observed as 55ppm for the 50ppm IONP blended diesel fuel at the brake power of 5.3kW. This is due to the higher cetane number, and high oxygen content present in the IONP blended diesel.

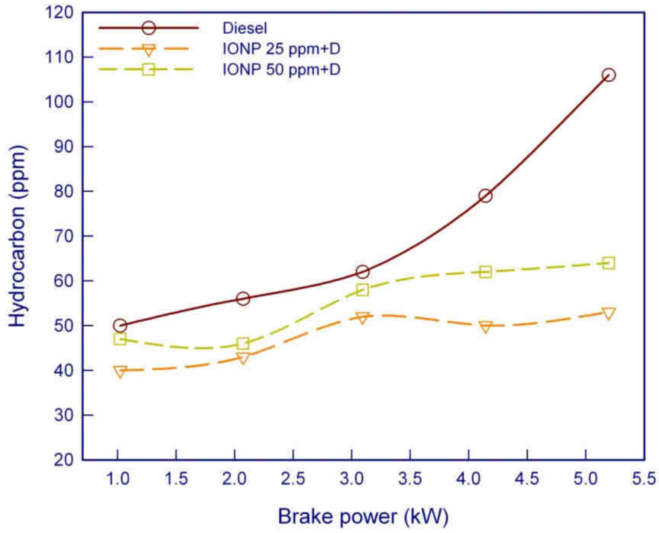

Figure 6 *Hydrocarbon Against Brake Power*

5.2.3 Oxides Of Nitrogen (NOx)

The NOx emissions of the engine at different nanoparticles concentrations and the engine loads have been shown in figure 7. It is clear that, the NOx emission dramatically increases, by means of IONP nanoparticle additives. This is because of the reduced ignition delay that resulted in the higher peak temperatures and higher pre mixed combustion fraction observed with IONP-diesel blends. The NOx emission from 50ppm IONP blended diesel is 990 ppm, whereas it is 910ppm for 25ppm IONP blended diesel, compared to 890ppm for neat diesel, at the full load respectively.

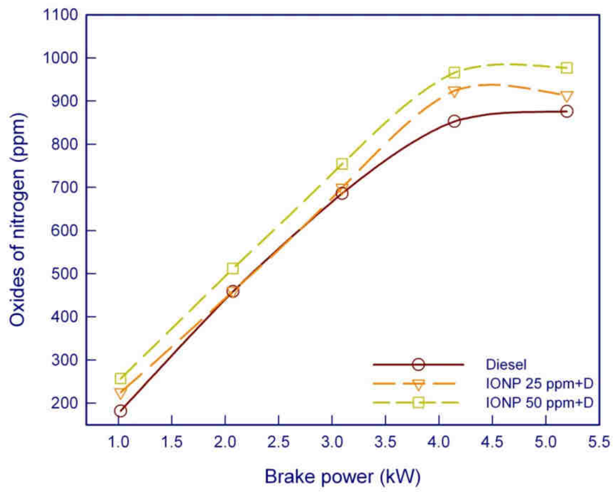

Figure 7 *Oxides Of Nitrogen Against Brake Power*

5.2.4 Smoke Opacity

Figure 8 shows the smoke opacity percentage of diesel and modified diesel fuel at different brake power. Reduced smoke opacity is observed in the case of 50ppm IONP blended diesel fuel. This could be attributed due to shorter ignition delay and better combustion characteristics of IONP blended diesel fuel. The smoke opacity for 50ppm IONP blended diesel fuel is 51HSU, whereas it is 73HSU for sole diesel fuel at full load.

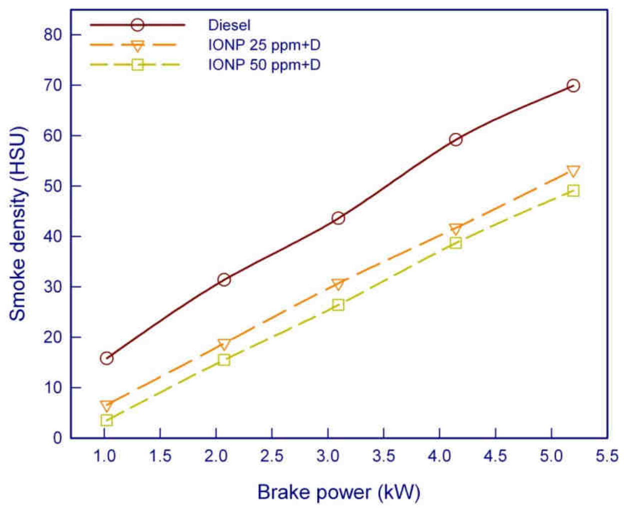

Figure 8 *Smoke Density Against Brake Power*

5.3 Combustion Characteristics

5.3.1 Cylinder Pressure

Figure 9 shows that the in-cylinder pressure within the combustion chamber of the CRDI diesel engine running with iron (II, III) Oxide blended diesel and sole diesel at a constant speed of 1500 rpm. From the figure it is seen that the pressure starts increasing significantly from 7° before TDC for 50ppm IONP blended diesel and 5° for neat diesel. The initial increase in pressure observed in the case of 50ppm IONP blended diesel fuel compared to the neat diesel fuel. The peak pressure is 73.70 bar in the case of 50ppm IONP blended diesel, whereas for neat diesel the peak pressure is 68.04 bar at full load as shown in Figure 6.8. This is due to high surface areas of nanoparticles, which increases their chemical reactivity which in turn reduces the ignition delay.

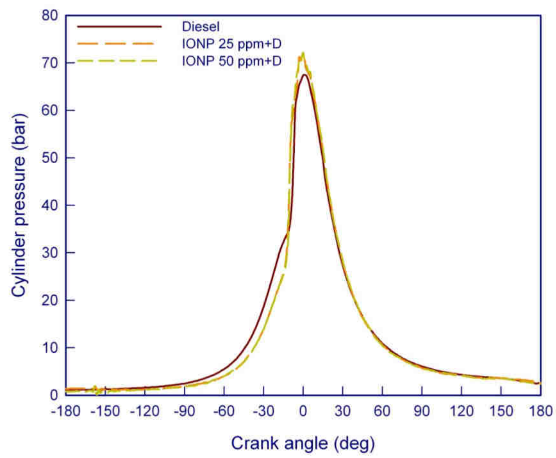

Figure 9 Cylinder Pressure Against Crank Angle

5.3.2 Heat Release Rate

The variation of heat release rate with crank angle is shown in Figure 10.The results show that the heat release rate was found to be generally increased with the addition of IONP to diesel. This is due to premixed and uncontrolled combustion phase. The amount of heat release rate is 123.587, 149.328 and 168.468 kJ/m^{3}deg for diesel, CMNT25 and CMNT50, respectively. This is due to the nanoparticle blended fuels showed accelerated combustion due to the shortened ignition delay. Due to shortened ignition delay, the degree of fuel-air mixing and uniform burning could have improved

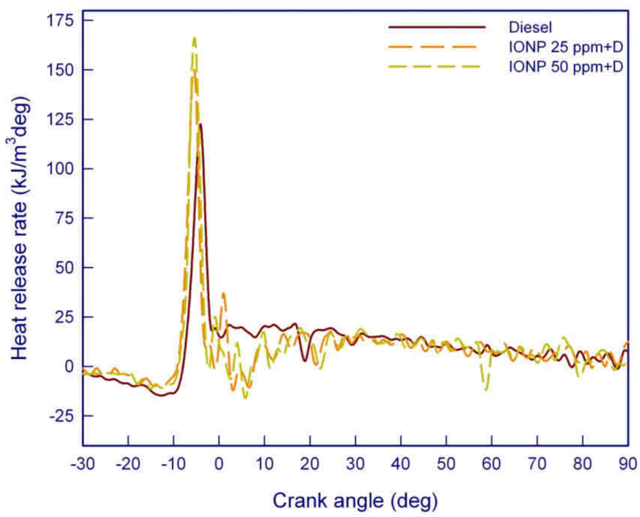

Figure 10 *Heat Release Rate Against Crank Angle*

VI. CONCLUSION

In the present investigation CRDI engine performance, emission and combustion characteristics by using iron (II, III) Oxide nanoparticles blended diesel are studied and based on the experiment the following conclusion are,

- A marginal enhancement in brake thermal efficiency was observed with the use of iron (II, III) Oxide nanoparticles.
- The reduction in HC emission by using iron (II, III) Oxide nanoparticles blended with diesel. IONP blended diesel showing 52% reduction in HC compare with neat diesel fuel.
- IONP fuel additive reduce CO emission is up to 52% compare with neat diesel, because IONP act as an oxygen buffer and donates surface lattice oxygen.
- NOx Emission slightly increases by using IONP blended diesel fuel compare to neat diesel fuel.
- The decrease in the emissions is proportional to the dosing level of IONP nanoparticles in the diesel and optimum dosing level of 50 ppm of catalytic nanoparticles was observed.

Hence, iron (II, III) Oxide nanoparticles is efficient in improving performance, combustion and reducing the exhaust harmful pollutants from the CRDI system assisted diesel engine.

Nomenclature

bmep	Brake mean effective pressure, MPa
SFC	Specific fuel consumption, kg/kWh
BP	Brake power, kW
CO	Carbon monoxide, %
HC	Hydrocarbon, ppm
NO	Nitrogen oxide, ppm
CRDI	Common rail direct injection
IONP25	Iron (II, III) Oxide nanoparticles of 25ppm blend with diesel
IONP50	Iron (II, III) Oxide nanoparticles of 50 ppm blend with diesel
rpm	Revolution per minute
TDC	Top Dead Centre

REFERENCES

[1] Takeda Y, Keiichi Na, Keiichi Ni, (1996), Emission Characteristics of Premixed Lean Diesel Combustion with Extremely Early Staged Fuel Injection, SAE Paper 961163.

[2] Aoyama T, Hattori Y, Mizuta J, Sato Y. (1996), An Experimental Study on Premixed-Charge Compression Ignition Gasoline Engine, SAE Paper 960081.

[3] Yanagihara H, Sato Y, Mizuta J. A Study of DI Diesel Combustion Under Uniform Higher-Dispersed Mixture Formation, JSAE Review, July 1997, pp. 247-254.

[4] Heywood JB. Internal combustion engine fundamentals. New York: McGraw- Hill; 1988.

[5] Mu-Jung Kao, Chen-Ching Ting, Bai-Fu Lin, and Tsing-TshihTsung, Aqueous Aluminum Nanofluid Combustion in Diesel Fuel, Journal of Testing and Evaluation, Vol. 36, No. 2 Paper ID JTE100579.

[6] Arul MozhiSelvan V, Anand R.B, and Udayakumar M, 2009, Effects of cerium oxide nanoparticle addition in diesel and diesel-biodiesel-ethanol blends on the performance and emission characteristics of a CI engine, ARPN J. Of Eng. And applied sciences, 4, 1-6.

[7] M.A. Lenin, M.R. Swaminathan and G. Kumaresan (2013), Performance and emission characteristics of a DI diesel engine with a nanofuel additive, Fuel 109:109 362–365.

[8] V. Sajith, C. B. Sobhan, and G. P. Peterson. Experimental Investigations on the Effects of Cerium Oxide Nano particle Fuel Additives on Biodiesel" research article, Advances in Mechanical Engineering, Volume 2010, Article ID 581407, 6 pages.

[9] Sun J, Simon SL. The melting behavior of aluminum nanoparticles. Thermochimica Acta 2007, 463:32-40.

[10] Kao MJ, Ting CC, Lin BF, Tsung TT. Aqueous aluminum nanofluid combustion in diesel fuel. J Test Eval 2008;36:186-90.

[11] Hsin-Yi Huang, Yeong-Tarng Shieh, Chao-Ming Shih, Yawo-Kuo Twu, Magnetic chitosan/iron (II, III) oxide nanoparticles prepared by spray-drying, Carbohydrate Polymers 81 (2010) 906-910

[12] R. Prasher, P. Bhattacharya, and P. E. Phelan, "Brownian motion- based convective-conductive model for the effective thermal conductivity of nanofluids," Journal of Heat Transfer, vol. 128, no. 6, pp. 588-595, 2006.

[13] S. Krishnamurthy, P. Bhattacharya, P. E. Phelan, and R. S. Prasher, "Enhanced mass transport in nanofluids," Nano Letters, vol. 6, no. 3, pp. 419-423, 2006.

[14] H. Tyagi, P. Phelan, and R. Prasher, "Predicted efficiency of a nanofluid-based direct absorption solar receiver," in Energy Sustainability Conference, pp. 729-736, June 2007, ES 2007- 36139.

[15] Metin Guru, Ugur Karakaya, Duran Altıparmak, Ahmet Alıcılar, Improvement of Diesel fuel properties by using additives, Energy Conversion and Management 43 (2002) 1021-1025.

[16] Veeradate Piriyawong, Voranuch Thongpool, Piyapong AsanithI, Pichet Limsuwan, Preparation and Characterization of Alumina Nanoparticles in DeionizedWater Using Laser Ablation Technique, Journal of Nanomaterials, Volume 2012, Article ID 819403, 6 pages.

[17] Valentin N. Popov, Carbon nanotubes: properties and application, Materials Science and Engineering R 43 (2004) 61-102.