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Performance Measurement On Diesel and Cerium Oxide In Diesel On CI Engine

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Abstract: *The consumption of diesel fuels for its efficiency and reduced fuel consumption has a major limitation associated with the price of crude oil in stock markets. Thus improving the combustion of fuel in engines can reduce the unfavorable emissions in the environment, which is a prominent limitation in the present scenario due to climate change and global warming. The addition of fuel additives in diesel fuels is considered as an effective way to improve the properties of fuel and to reduce the emissions in the engine. This has made the researches to focus on addition of nanoparticles in the diesel fuels to reduce the consumption and to increase the efficiency with reduced emission rates. In this paper, the performance of diesel engine is tested with diesel fuel with the addition of nanoparticle blend. This includes 20, 40 and 60 ppm cerium oxide (CeO_2) is added as an additives with the diesel fuel. This proposed blend tends to increase the complete combustion of the diesel fuel with reduced emission capacity rates. The findings revealed that the CeO_2 diesel blend with 50ppm blend performed well with improved combustion quality and specifically fuel consumption of 50ppm CeO_2 diesel blend is lower than other blends and neat diesel fuel. Also, the brake thermal efficiency (BTE) of 20ppm is increased when compared with other ppm fuel blends. Moreover, the emission of CO, HC, and NOx gases from 50ppm blend is reduced than 20 ppm and 40 ppm blends.*

Keywords: Brake Thermal Efficiency; Nanoparticles; Cerium Oxide; Diesel Blends; Gases; Reduced Emission

Nomenclature

BSFC	Brake Specific Fuel Consumption
BTE	Brake Thermal Efficiency
CC	Cubic Capacity
CeO_2	Cerium Oxide
CO_2	Carbon Dioxide
CO	Carbon Monoxide
EGT	Exhaust Gas Temperate
FC	Fuel Consumption
HC	Hydrocarbons
Kw	Kilo Watt
Min.	Minutes
Ml	Milli Litre
NOx	Nitrgen Oxides
PPM	
PM	Particulate Matter
RPM	Rotation Per Minute

1. INTRODUCTION

The major limitation in the transportation sector is the increasing exhaust gaseous emission from the automobiles and the standards which are intended to save the environment fails to do so. This leads to reversal of uncomplimentary effects in the transportation sector during the events of climate change. Actually, the transportation around the world is responsible for >25% emission of greenhouse gases. Such challenges can be avoided by improving the technologies and by the use of less polluting vehicles [1].

Various researches are conducted on the emission of neat diesel and different blends of diesel, when combusted inside the diesel engine [2]. Studies claim that burning of diesel blends rather than diesel oil leads to reduced emission of unburned hydrocarbons (HC), particulate matter (PM) and carbon monoxide (CO) emission. However, the presence of critical nitrogen oxides (NOx) gas are found in diesel blend rather than pure diesel fuel [3]. The increased emission of exhaust gas is reduced using diesel-diesel blend oil with the addition of additives added to the diesel oil and this has been put to test since last decades. This astounds the deterioration of emission in NOx due to the inclusion of diesel oil [4].

The increasing emission of NOx is avoided with the help of fuel additives and this includes the use of water as diesel additives [5]. Various strategies are used for adding water, however, three strategies are considered as useful to reduce the emission. Water is used in internal combustion engine that include diesel-diesel or water-diesel emulsion, water injection in the inlet manifold and water injection directly into the cylinder [6].

Among different blends, the mixture of diesel with water addi-

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tives is of great interest due to its adaptation over wide variety of application and that can reduce the hazardous emission of gaseous substances and it does not require any further modification of diesel engines [7]. Precisely, it is documented that the combustion of diesel blends reduce effectively the emission of NOx and particulate matter simultaneously and that does not causes any significant increment in brake specific fuel consumption (bsfc) [7]. However, the combustion of diesel and nanoparticle blend can increase the HC emission due to reduction of in-cylinder temperature. This occurs because the water particles in the fuel vaporize easily due to high latent heat [8]. Further, the performance of the blended diesel oil and the characteristic of emission of diesel blends in a 4 stroke turbocharged engine is reported in [9] and it is found that, here the 15% additives in the diesel oil at full load capacity and with engine speed of 3200 rpm, reduced well the exhaustion of NOx emission with negligence bsfc and 30% reduction is observed.

It is further seen that there is an increment of 12% in bsfc when the diesel blended with 30% water [10] and there is a 7.2% increment of bsfc, when water is included at the engine speed of 2800 rpm. However, this attributed to increase in emission of CO gases and reduced emission of NOx gases, due to the presence of water as the diesel blend [11].

The various studies researched on metal based additives [12-14] as diesel fuel additives, which increases the combustion performance of the diesel engine. Such metals to improve the reduction of gaseous emission include: iron, barium, copper, manganese, cerium, platinum and calcium. This offers a better catalytic reaction during the process of combustion and this results in complete combustion of the diesel fuel. This metal based additives in the diesel fuel increases well the quality of combustion and that leads to reduction of emission from the diesel fuel and its bsfc level. Studies shows that the release of diesel fuel with nano aluminum mixture leads to higher release of heat with reduced emission of NOx than the neat diesel fuel [15]. Further, the addition of 50 ml of $ce_2 0_3$ in the diesel or diesel fuel blend improved bte and reduced the bsfc with NOx and HC emission than the neat diesel fuel [16].

It is seen earlier, the use of water as fuel blend could increase well the consumption of diesel fuel with increased emission of CO_2. Hence, the reduction of NOx in the in the diesel blends, the combination of metal based additives is added and this provides a better strategy that reduces simultaneously the emission of gaseous and heat when water is added as additives [8]. In, [17], it is explored that the addition of ce_2o_3 in diesel fuel with 20% water content provides a better performance with reduced emission of CO, HC and particulate matter than the neat desel oil. However, it is seen that the addition of water as a blend with diesel oil in the presence of metal based additives, the performance of the engine is improved due the presence of hydroxyl radicals that leads to lowering of soot oxidation temperature [18]. Finally, the addition of 50 and 100 ppm of zinc mixture blended in diesel fuel with 10% water reduced the emission of CO, HC and NOx [19].

To the best of our knowledge, it is seen that the studies with water as additives and metal based additives improved well the performance of the engine and this is limited to higher addition of water as diesel blend, which is greater than 5%. However, there is a little impact when there is an addition of nanoparticle based ce_2o_3 additives with diesel emulsion blends without water as additives. This could improve the performance of diesel engine with reduced emissions characteristics. Hence, the present study tend to investigate the performance of engine with reduced emission feature when the ce_2o_3 nanoparticle is added as an additive over a single cylinder diesel engine. In this paper, the diesel engine performance is tested with diesel fuel blended with ce_2o_3 nanoparticle of sizes 20, 40 and 60 ppm cerium oxide (CeO_2). This blend increases well the combustion of diesel with reduced emission.

The outline of the paper is presented as follows: Section 2 provides the materials and methods of the proposed method. Section 3 evaluates the diesel blend to check the performance of the oil and finally section 4 concludes the entire paper.

2. MATERIALS AND METHODS

2.1. Fuel Sample Preparation

Three different sizes of CeO_2 is added as additives and that include 20, 40 and 60 ppm levels in a one litre of diesel fuel called DX20, DX40 and DX60, respectively. The emulsification of cerium oxide in is added by including 75 ml of 1:2 ratio blended with two surfactants, namely Span 80 and Tween 80 with proper addition of metal catalyst. The emulsion is then stabilized with Polytronhomogenizer under standard room temperature over a period of 30 min. The experiments are conducted on a different diesel fuel blend with CeO_2 and the performance is noted.

The nanoparticle level during each dosing is measured with an electronic balance, which is mixed with diesel using ultrasonic shaker and a constant agitation is applied over 30 minutes. This provides uniform suspension to the diesel fuel and the modified fuel is utilized for the test, immediately after preparation and this avoids settling of the sediments.

2.2. Engine Set-up

The experiment is carried out on a 4 stroke single cylinder with direct injection and water cooled engine with a variable compression ratio. The engine taken for experimentation is an air cooled engine with direct injection of aspirate and injection start is 38 during the top dead center. The displacement of the engine is 507 cc, which is loaded with electrical dynamometer of 22 kW. The pressure sensor inside the in-cylinder is a piezoelectric transducer. The combustion pressure is analyzed with a charge amplifier, which is used as a pressure sensor and the location of the crank angle is checked with computer program. Magnetic rotary encoder is used to measure the position of crank angle, which is installed over the crankshaft with 2500 pulses/revolution.

The engine test is carried out at a constant speed of 1500 rpm and different loads are applied, which includes: 30, 50, 75 and 100%. The combustion of fuel is measured using a fuel mass flow meter and the measurement of air fuel ration is measured using a Lambda sensor. The measurements of emission from CO, HC, and CO_2 is done using gas analyzer with infrared measurement. An electrochemical method is used to measure the level of Oxygen and NOx emission.

2.3. Engine Performance and Combustion Characteristics

The main specification of the performance of the engine include: brake thermal efficiency (bte) and brake specific fuel consumption (bsfc). This is measured under different load capacity when different metal blends are added as additives.

2.4. Experimental Set-up

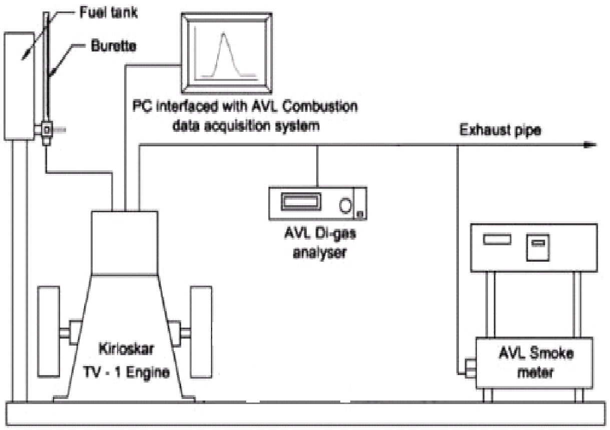

Figure 1. Experimental Setup

2.5. Method of Experiment

The experiment is carried out under two phases and the experimental set up at full load using DX60 is shown in Fig.1. Here, in the first phase, the test is carried out with diesel engine using neat diesel. In the second phase, 20ppm,40ppmand60ppmblends of CeO_3 nanoparticleis added asan additive in neat diesel fuel.The speed of the engine is maintained at 1500 rpm with no load capacity and feed control is adjusted to attain higher rated capacity with steady state condition. The measurements like speed of rpm, consumption of fuel, power output and exhaust gas temperature is measured in computer. In order to maintain the speed at permissible limit, the engine is been loaded gradually. The experimental data is noted three times and the mean of all values is noted.

3. EXPERIMENTAL INVESTIGATION

3.1. Engine Performance

The performance characteristics of engine with blended diesel with and without $CeO_2$is found using brake thermal efficiency and emission is found using CO, CO_2, FC and NOx. The performance is tested over unmodified diesel engine and the results obtained from DX20, DX40 and DX60 ppm is tested against neat diesel fuel, which is discussed herein:

3.2. Exhaust Gas Temperate (egt)

Fig.2 shows the cylinder pressure variation with crank angle using diesel as fuel, and DX40 and DX60 blends over varying loading capacity. From the results, it is found that the peak pressure of the cylinder is high for the diesel fuel. The other important phenomenon in testing the fuel is the ignition delay and the DX60 diesel blend has reduced ignition delay than the other mixtures of diesel. This is purely due to the easier evaporation of the blended mixture and has improved ignition rate with increased surface area/volume ratio.

3.3. Brake Thermal Efficiency (bte)

The thermal efficiency is defined as the heat equivalent of brake

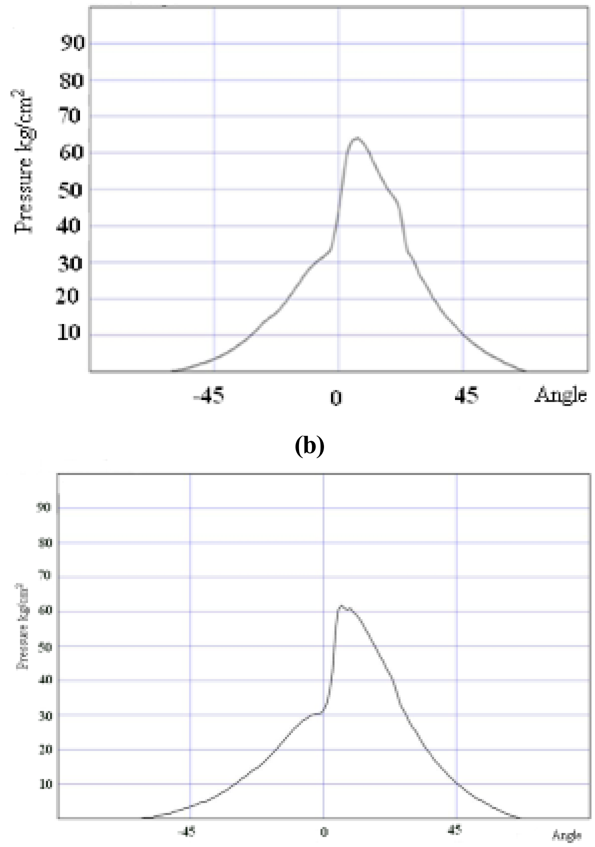

Figure 2. Pressure vs crank angle diagram (a) DX20 4kW load, (b) DX60 at 4 kW load

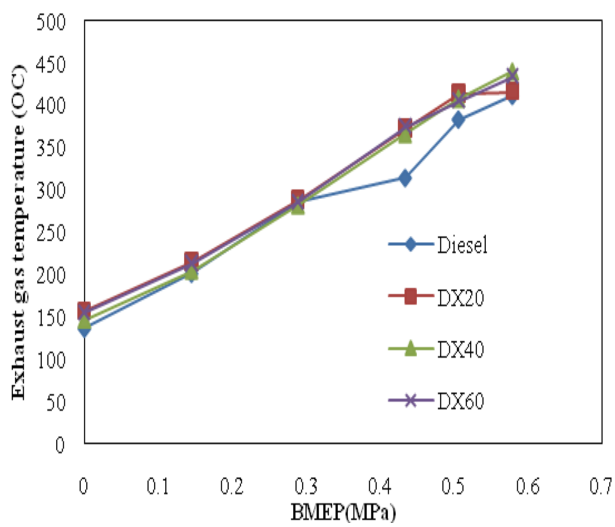

Figure 3. Variation of EGT with respect to engine loads

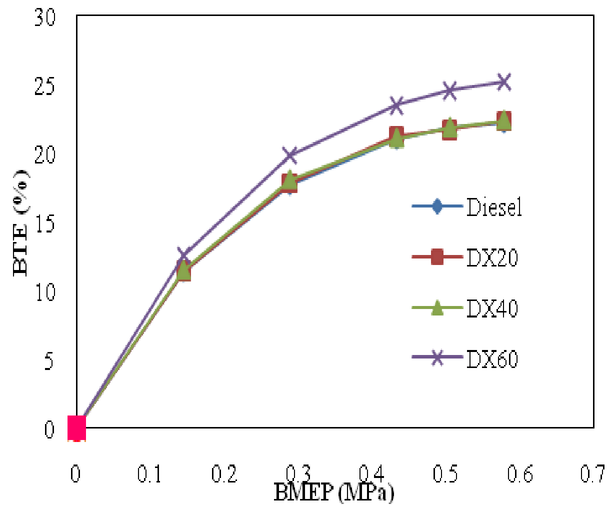

Figure 4. Variation of BTE with respect to engine loads

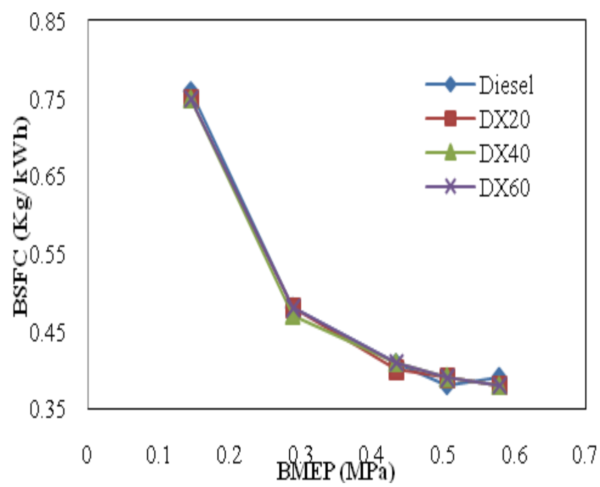

Figure 5. Variation of BSFC with respect to engine loads

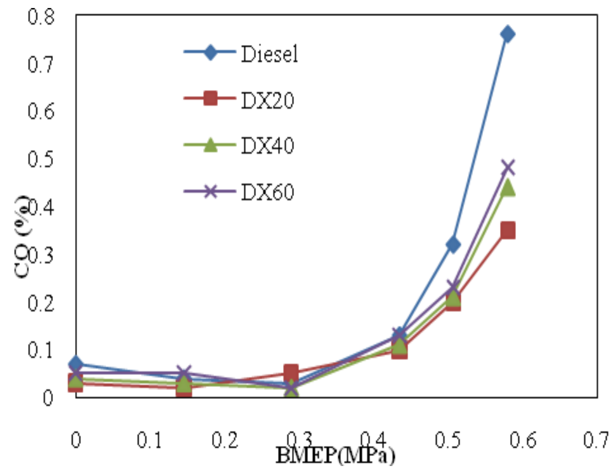

Figure 6. Variation of CO emission with respect to engine loads

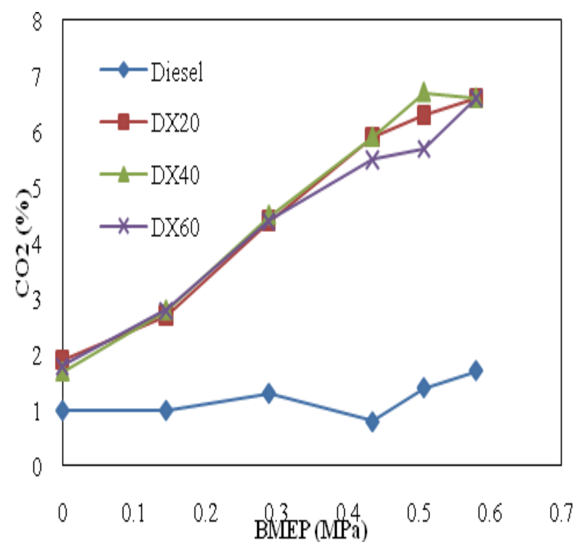

Figure 7. Variation of CO_2 emission with respect to engine loads

power to heat equivalent of the consumed fuel. The Fig.2 shows the results of bte values against the blended fuels. As presented, it is found that the combustion of DX60ppm blended CeO_2 fuel has higher bte than DX20 and DX40 ppm fuels, and with neat diesel fuel. Since the calorific value of the DX60ppm is high and this leads to increased bte. The presence of more nanoparticles with higher ppm density has improved the bte values in a diesel fuel and other fuels with DX20ppm and DX40ppm has deteriorated performance even if CeO_2 is added as an additive. This deteriorated performance of the less ppm fuels is mainly due to the unfavorable impacts of bte. In emulsified fuel blend with DX60ppm CeO_2 measured to be with higher bte than the neat fuel and less ppm nano particles. Specifically, the combustion of DX60ppm nano particle has increased the value of bte to 23, which is an approximate 13% increase than the neat diesel blend.

3.4. Brake specific fuel consumption (bsfc)

The bsfc is defined as the ratio of consumed diesel fuel to the generated engine power over a given time. The Fig.6 shows the results of bsfc at various load capacity. The increased bfsc value is due to the addition of CeO_2in the fuel which possess lower calorific value. However, the raw diesel with lesser rate CeO_2 deteriorates the calorific values. Further, the increasing ppm of CeO_2 in the diesel fuel has marginally improved the bsfc value.

3.5. Emission Characteristics

3.5.1.Corbon Monoxide (CO)

The Fig.7 shows the emission rate of CO from diesel blends at various loads. The results shows a marginal reduction of CO gas emission in nano particle blended diesel fuel than the neat diesel fuel. It shows a reduction of 37% at 60ppm with full load engine capacity. This is attributed to increased surface area/volume ratio.

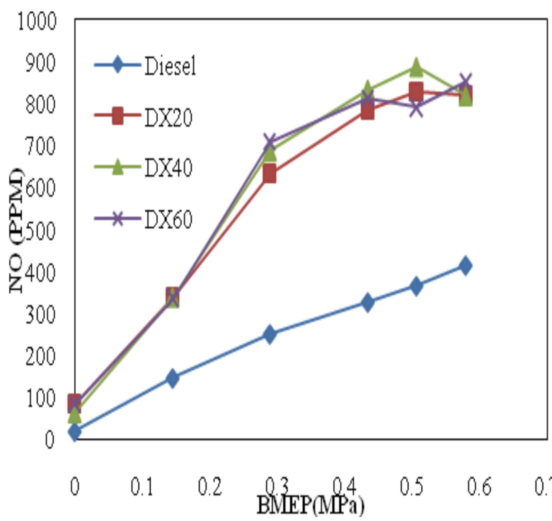

Figure 8. Variation of NO emission with respect to engine loads

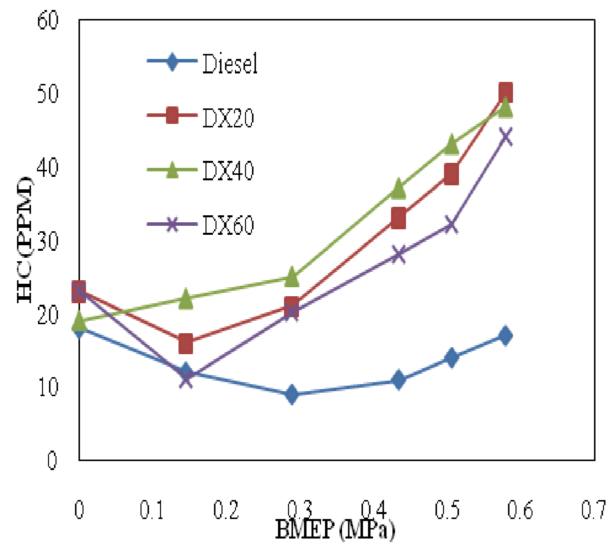

Figure 9. Variation of HC emission with respect to engine loads

Also, presence of nanoparticles increases the catalytic activity in diesel fuel and this has reduced the ignition delay. This effect results in increased ratio of fuel-air mixing inside the combustion chamber of the engine and that leads to complete combustion.

3.5.2. Carbon Dioxide (CO_2)

From the Fig.8, it is found that the emission of CO_2 is increasing when the engine runs on neat diesel fuel under all operating conditions. However, the rate of emission is reduced when the nano particles is added with the diesel fuel. The lower level of emission clarifies that the complete combustion of fuel occurred inside the engine and finally an average reduction of 25% of emission is seen in nanoparticle and diesel blend.

3.5.3. Nitrogen Oxide (NO)

Further, the NO emission level from the diesel is tested in the neat form and in the blended form. The high thermal stability forms Ce_2O_3fromoxidationofHC and soot is active after initial combustion cycle [20]. It is seen further that the emission of NO is expected and the influence of Ce_2O_3 is shown in Fig.9. It is also seen that the emission of NO substances has increased gradually with average increment of 51% when the dosing level of nanoparticles is of 60 ppm. The flame analysis revels that the presence of combustion temperature, oxygen content and reaction temperature leads to increase in NOx levels [21].

3.5.4. Hydrocarbons

The emission of HC with different loads is shown in Fig.10. The variation of HC emission with different dose level of Ce_20_3 in diesel is noted. Here, the emission of HC has increased around 40% upon the addition of additives and the nanoparticle acts as a oxidation catalyst and this lowers the combustion of carbon during the activation temperature and this possibly leads to emission of HC during combustion.

3.5.5. Smoke

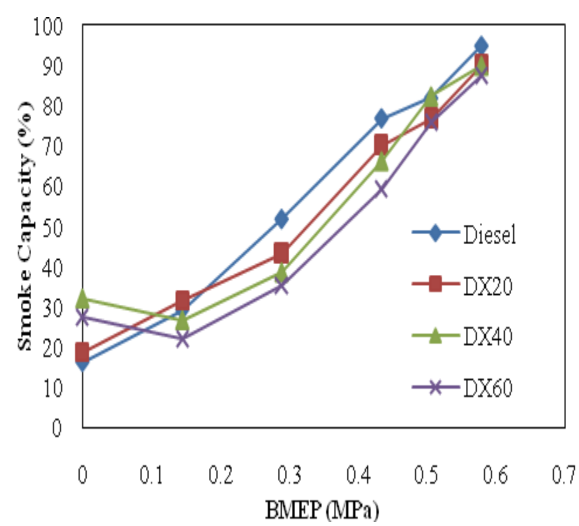

Figure 10. Variation of smoke opacity with respect to engine loads

The emission of smoke capacity is shown in Fig.11 and it is seen that there is significant reduction of emission of smoke in diesel nano particles blend than neat diesel. This reduced emission is due to the presence of ignition characteristics and the nanoparticles in the diesel fuel has led to shorter delay ignition with improved evaporation rate and ignition characteristics. It is seen further that the addition of nanoparticles at full load capacity leads to reduction of 8% smke with improved ignition rate, better combustion and improved air-fuel mixing ratio.

4. CONCLUSION

In this paper, the addition of nanoparticles with diesel emulsion has reduced the peak pressure, ignition delay and heat release rate than the conventional diesel emulsion fuel operation. From the results, it is inferred that the break thermal efficiency of the nanoparticle diesel emulsion has improved with cerium oxide. It is seen that the brake thermal efficiency with DX60 blends is increased to 13% with reduced fuel consumption, CO emission and smoke is reduced to 37& and 8%, respectively at full load capacity of the DX blend. It is also concluded that the brake thermal efficiency of DX20 and DX40 is marginally higher than DX60 and non-blended diesel fuel. It is concluded finally that the brake thermal efficiency is improved along with reduced emission rates for DX20 and DX40 than DX60 and non-blended diesel fuel. The emission of CO from the diesel engine is lesser in DX20 than the other fuels due to the inclusion of 60ppm CeO_2 additives. Such inclusion led to favouring conditions on emission through complete combustion of 60ppm additive. Further, the emission of HC particles from the 60ppm blend is found lesser than the other blends and diesel fuel and this achieves better combustion of 60 ppm fuel. Finally, the smoke capacity of 60ppm blend fuel has attain reduced rate than the other fuels.

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Table 1. Performance characteristics of variant Diesel Fuels with and without additives

	Load (kW)	EGT °C	SFC kg/kW hr	CO (%)	CO_2 (%)	HC ppm Vol	Nox ppm Vol	Smoke Capacity (%)	BTE (%)
Diesel Fuel	0	137	-	0.07	1	18	19	16.5	0
	1	202	0.76	0.04	1	12	146	29.5	11.41
	2	287	0.48	0.03	1.3	9	251	52	17.74
	3	315	0.41	0.13	0.8	11	327	77	21.08
	3.5	384	0.38	0.32	1.4	14	366	82	21.87
	4	412	0.39	0.76	1.7	17	415	95	22.27
Diesel Fuel with 20ppm additive of Nano cerium oxide (DX20)	0	158	-	0.03	1.9	23	84	18.8	0
	1	216	0.75	0.02	2.7	16	339	31.5	11.49
	2	289	0.48	0.05	4.4	21	633	43.3	17.88
	3	373	0.4	0.1	5.9	33	786	70.3	21.26
	3.5	414	0.39	0.2	6.3	39	828	76.8	21.78
	4	446	0.38	0.35	6.6	15	820	90.2	22.39
Diesel Fuel with 40ppm additive of Nano cerium oxide (DX40)	0	147	-	0.04	1.7	19	63	32.1	0
	1	205	0.75	0.03	2.8	22	339	26.7	11.51
	2	282	0.47	0.02	4.5	25	687	38.6	18.1
	3	366	0.41	0.11	5.9	37	834	66.2	21.12
	3.5	408	0.39	0.21	6.7	43	888	82.3	21.89
	4	440	0.38	0.44	6.6	16	819	89.9	22.41
Diesel Fuel with 60ppm additive of Nano cerium oxide (DX60)	0	155	-	0.05	1.8	23	86	27.4	0
	1	213	0.75	0.05	2.8	11	338	22.1	12.6
	2	286	0.48	0.02	4.4	20	710	35.3	19.87
	3	375	0.41	0.13	5.5	28	814	59.4	23.49
	3.5	406	0.39	0.23	5.7	32	792	76.1	24.56
	4	434	0.38	0.48	6.6	16	852	87.6	25.18

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