Experimental Investigation on Performance and Emissions of a Single Cylinder Four Stroke Diesel Engine By Adding Nanoparticles in Lubricating Oil

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Abstract- *The study of friction power in diesel engine is important as it significantly affect its performance. The present paper focuses on experimental investigation of performance of engine by adding nanoparticles in lubricating oil in lubrication system. The performance parameters to be studied includes influence on friction powe, brake thermal efficiency, specific fuel consumption, and exhaust gas temperature (EGT). Also its effect on emission of hydrocarbon (HC), carbon dioxide (CO2), carbon monoxide (CO) and nitrogen oxides (NOX) of the engine are studied. Test is carried out using two different nanoparticles (TiO2 and CuO) in different concentrations by weight in lubricating oil and at different loading conditions i.e. from idle to full load conditions at constant engine speed of 1500 rpm and emissions is measured by AVL 5 gas analyser. It is observed that addition of nanoparticles in lubricating oil reduces the friction power and improves the brake thermal efficiency. Also it reduces the brake specific fuel consumption but exhaust gas temperature has not much effect. Also it is observed that nano-oil has adverse effect on emission of HC, CO, CO2 and NOX. For all the nano-oil at different concentrations the emission of engine increased.*

Keywords- friction power, brake thermal efficiency emission, HC, NOX, CO2.

I. INTRODUCTION

A remarkable part of entire power loss in an internal combustion engine is due to the undesirable friction between rubbing surfaces of mechanical components. The development of low friction engines is necessary for the limitations in fossil fuels and tightening emission regulations. Since there are many sliding and rolling parts operating under various conditions in an engine, different lubrication regimes may be expected including hydrodynamic, elastohydrodynamic and boundary lubrication; even metal to metal contact is possible. A substantial part of the friction losses, however, can be considered as those of hydro dynamically lubricated contacts under normal running conditions. It is evident here that the friction losses increase with engine speed, and generally decrease with increasing oil temperature.

Lubricating oil play a critical role in reducing the frictional losses. Using high viscosity oil in engines will reduce the components wear and friction but may increase fuel consumption, otherwise the thin lubricant film will decrease fuel consumption but there is a danger of higher component wear rate. Engineers and scholars are working constantly to develop and test new lubricants to meet these challenges. Nanofluids are an innovative new class of fluids which can be engineered by suspended nanosized particles (1–100 nm) in conventional base fluids. A large number of papers have reported that surface modified nanoparticles stably dispersed in lubricants are effective in enhancing load-carrying capacity, antiwear, and friction reduction properties.

According to theories in the literature, colloidal effect, rolling effect, protective film, and the third body maybe the main mechanisms of friction-reduction and antiwear of nanoparticles in lubricant. So in the present dissertation work the two nanoparticles i.e. CuO and TiO2 are used as lubricating oil additives and its effect on the performance and emission characteristics of engine were studied. For experimentation single cylinder diesel engine with compression ratio 18 was utilized.

II. SETUP DESCRIPTION

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current dynamometer for loading. The schematic diagram of experimental setup is shown in Fig.1. By changing the clearance volume, the compression ratio can be changed. Setup is provided with necessary instruments for airflow, fuel flow, temperatures and load measurement. The set up has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements. Rotameters are provided for cooling water and calorimeter water flow measurement .For exhaust gas analysis AVL 5 Gas Analyser was used.

Table 1. Engine Specifications

Sr. No.	Description	Parts With Specification
1	Variable Compression Ratio Engine	Model: VCR, Single Cylinder Diesel, 4 Stroke, Water- Cooled Stroke 110 mm, Bore 80 mm, Manual crank start
2.	Power	2.237–3.728 kW
3	Speed	1450–1550 rpm
4	Maximum Load	10 kg
5	Injection pressure	200 bar
6	Compression ratio range	6:1–20:1
7	Lubrication oil	SAE 20W40
8	Dynamometer	Eddy Current Dynamometer
9	Exhaust gas Analyser	AVL 5 Gas Analyser

III. TEST CONDITIONS

VCR engine is allowed to run with diesel for 15 min to precondition the experimental setup. The cooling water is allowed to flow at constant rate of 80 ml/s through both cooling jacket and calorimeter. The compression ratio is set to 17 by changing the clearance volume of the VCR engine. An eddy current dynamometer with a load cell is used to load the engine.

Nano-oil was prepared by carrying ultrasonication followed by magnetic stirring. Ultrasonication was done for 6 hours followed by 2 hours of magnetic stirring. Three different concentrations of each nanoparticles in lubricating oil was prepared as 0.1, 0.2 and 0.3% by weight. For all the nano-oil in lubricating system, test setup is run from 0 to 100% load conditions.

In each test, the speed of the engine, manometer readings, exhaust gas emissions such as carbon monoxide, hydrocarbon, oxides of nitrogen, and carbon dioxide are recorded. Also the data of the measurements of mass of fuel consumption, brake power, indicated power, brake thermal efficiency and specific fuel consumption are recorded. Friction power was measured by Willans line method. Similarly, for each operating condition the performance and exhaust emission levels are measured.

IV. UNCERTAINTY ANALYSIS

Uncertainty in measurement of emission characteristics of exhaust gases with AVL 5 gas analyser (Model: AVL DITEST 1000) is discussed below.

1. The accuracy in CO emission measurement is ±0.02% vol.
2. The accuracy in measurement of CO2 emission is ±0.3 % vol.
3. Similarly the accuracy in HC and NOX emission measurement is ±4 ppm vol. and ±5ppm vol. respectively.

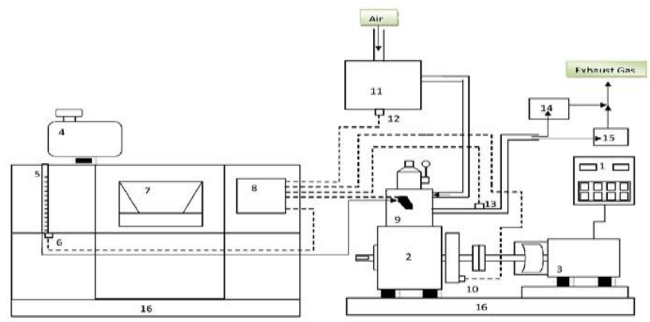

Fig.1. Schematic Diagram of Experimental Setup

1 Load Cell	9 Pressure Transducer
2 Engine	10 Speed Sensor
3 Eddy Current Dynamometer	11 Air Box
4 Fuel Tank	12 Air Sensor
5 Burette	13 Temperature Indicator
6 Fuel Sensor	14 Exhaust Gas Analyser
7 Computer	15 Smoke Meter
8 DAS	16 Bed

V. RESULTS AND DISCUSSION

The effect nanoparticles addition in lubricating oil on the performance and exhaust emission of an engine are shown from Figs. 2 to 9.

5.1 Variation of Frictional Power

The graphs below show the effect of nano-oil on frictional power of engine at compression ratio 18. From the graphs it is observed that highest reduction of 30.80% in frictional power was attained with 0.3% TiO2 nano-oil at CR18. In case of CuO nano-oil maximum friction power reduction was observed to be 21.80% with 0.1%CuO nano-oil. Also the engine had lower frictional power with all the nano-oils as compared with base oil in lubrication system.

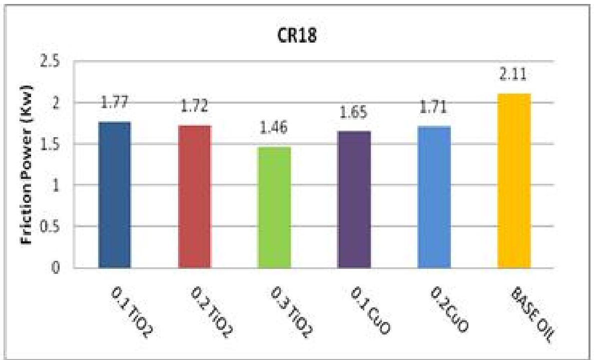

Fig.2 Variation of Friction Power with Nano-oil at CR18

5.2 Variation of Brake Thermal Efficiency

Brake thermal efficiency is defined as brake power of a heat engine as a function of thermal input from the fuel. It is used to evaluate how well an engine converts the heat from the fuel to mechanical energy.

Brake thermal efficiency increases with increase in load. Therefore efficiency of the engine is higher at the 10 Kg i.e. at full load.

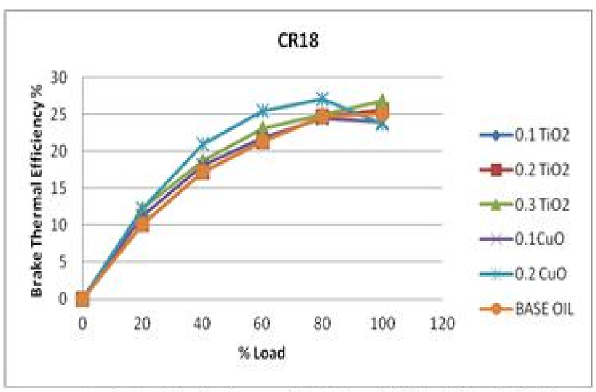

Fig.3. Variation of BTE with load at CR18

From the graphs it was observed that maximum of 7% increment in thermal efficiency with 0.3% TiO2 nano-oil at CR18.The reason behind this is the maximum reduction in frictional power occurred at the same condition. The CuO nano-oil has very good positive effect on BTE upto the 80% load but at 100% load it reduces abruptly.

5.3 Variation of Specific Fuel Consumption

Specific fuel consumption is the amount of fuel consumed by the engine to produce unit power per hour. From the Fig.4 it has been observed that at higher loads the BSFC decreases due to the increase in combustion temperature. Which in turns increases the conversion of heat energy to mechanical work and thereby the BSFC decreased.

It is evident from the fig.3 the 0.2%CuO nano-oil has lower SFC up to 80% loading but at 100% load its fuel consumption suddenly increases. But the 0.3TiO2 has minimum SFC rate because of the lower friction and high efficiency of engine operating with this lubricating oil. Also the SFC rate is lower for all the nano-oil as compared with base oil at all operating conditions.

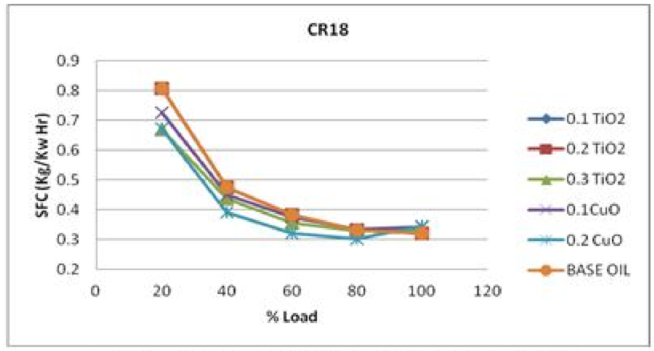

Fig.4 Variation of BSFC with Load at CR18

5.4 Variation of Exhaust Gas Temperature

Exhaust gas temperature is also an important parameter as it provides some qualitative information about the combustion process .Exhaust gas temperature is an indicator of the heat release rate of the fuels tested during combustion and its effective utilization to produce power. It depends on the combustion characteristics of the fuel and also on the heat loss to exhaust. Figure 4 shows the variation of exhaust gas temperature (EGT) with load for different nano-oil in lubracting system of diesel engine. It can be clearly seen from the figure that exhaust gas temperature increases with the increase in load. This is due to the fact that temperature after combustion becomes more as more fuel is required to be burnt at higher load condition.

From the fig.5 it was observed that exhaust gas temperature has very less effect of lubricating oil change. The curves of temperature have the same trends at all the loads and with all concentrations of nano-oil.

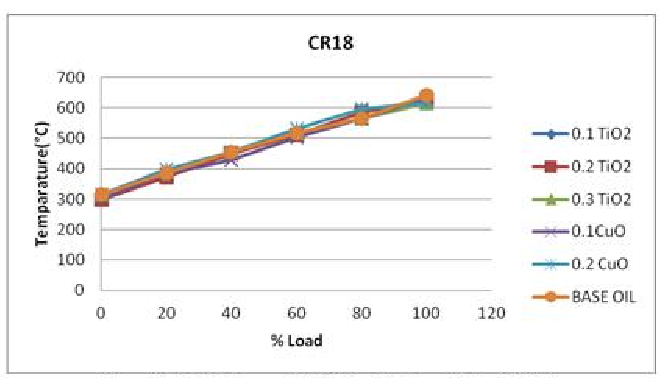

Fig. 5 Variation of EGT with Load at CR18

5.5 Variation of Unburned Hydrocarbon

Unburned hydrocarbons are emitted from CI engine due to low combustion temperature and presence of lean or rich mixture. Fuel exhaust hydrocarbons are composed of original fuel molecules and partially oxidized hydrocarbons. The Fig.6. shows that CI engine emits higher HC with increase in load. At higher loads CI engine requires rich mixture, due to poor atomization and local rich mixture formation incomplete combustion takes place. So as load increases the HC emission goes on increasing. The trend of increase in HC emission is remains same for all the concentration of nanoparticles in lubricating oil.

But from the graph it is clear that HC emission is higher for all the concentration of nano-oil than that of base oil. Highest rise in HC emission was found with 0.2% TiO2 and it was 100% more than that with base oil.

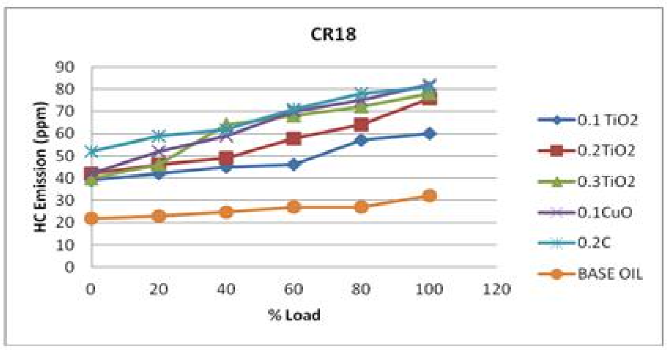

Fig.6 Variation of HC Emission with Load at CR18

5.6 Variation of Oxides of Nitrogen

Oxides of nitrogen are produced by oxidization inside the cylinder at a temperature of 2200 K. Nitrogen requires very high energy to break its triple bond. When the high combustion temperature favours oxidization NOX is produced.The emission of NOX increases with increases in the engine load due to the more amount of fuel injected at higher load which causes the higher cylinder pressure and increase in combustion cylinder temperature.

From the Fig.7 it is observed that NOX emission was increased with all the concentration of nano-oil except 0.1% CuO nano-oil. At the same time highest NOX emission was observed with 0.2% CuO nano-oil.

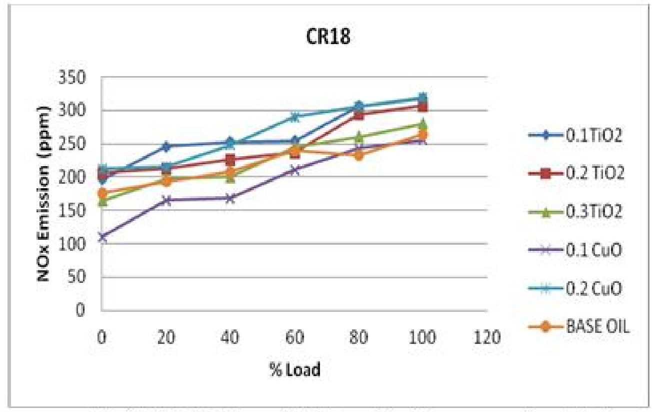

Fig.7 Variation of NOx with Copmpression Ratio.

5.7 Variation of Carbon Dioxide

Carbon Dioxide is produced when complete combustion of fuel is taking place. So higher the percentage of CO2 in the exhaust gas, better is the combustion of fuel.

From the graph it is observed that with all the concentration of nano-oil CO2 emission increases. The highest emission is observed with 0.2% CuO nano-oil. Also, the emission of CO2 increases with increases in load. This is due to the fact that due to the fact that at higher loads the combustion temperature increases which helps in complete combustion of the fuel.

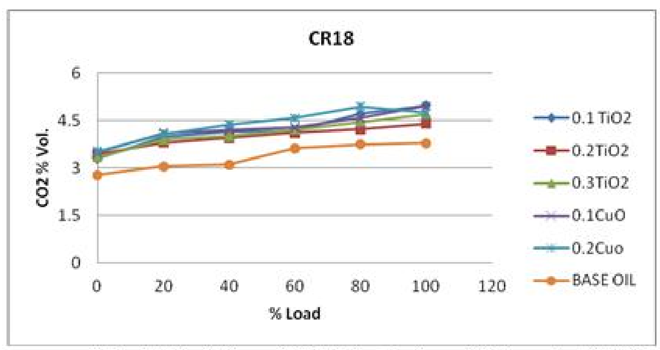

Fig.8 Variation of CO2 Emission with Load at CR18

5.8 Variation of Carbon Monoxide

The presence of CO in the exhaust of an engine is a representation of chemical energy of the fuel that is not fully utilised.

From Fig.9 it is found that CO emission increases with increase in load for all concentration of nano-oil. Here also highest CO emission was observed with 0.2% CuO nano-oil..With increase in load the CO emission increases because to meet maximum load, rich mixture is supplied to CI engine but same amount of oxygen is supplied for combustion of rich mixture resulting in higher CO emission.

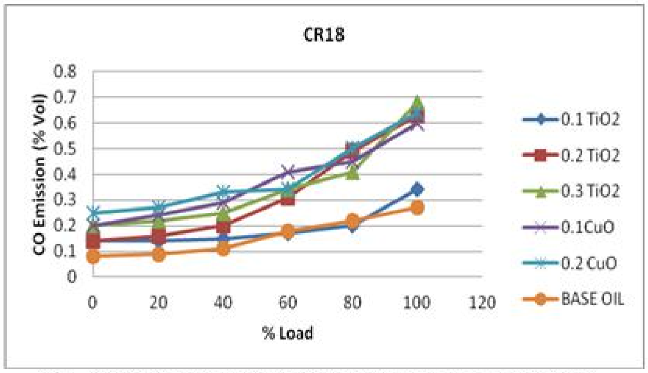

Fig. 9 Variation of CO Emission with Load at CR18

VI. CONCLUSIONS

Following are the conclusions made from the experimental results:

1. Addition of nano-particles in lubricating oil has both good and bad effect on the performance parameters of engine. But the addition of nanoparticles in oil causes increase in emissions of engine.
2. Addition of nanoparticles in lubricating oil reduces the friction power of engine. Maximum 30.86% reduction in friction power is occurred with 0.3% TiO_2 nano-oil at CR18.
3. In case of brake thermal efficiency the maximum rise of 7% is occurred with 0.3% TiO_2 at CR18. This is because there is maximum friction reduction occurred as discussed earlier.
4. Because of friction power reduction and maximum efficiency the brake specific fuel consumption is minimum at CR18 and with 0.3% TiO_2.
5. There is not much change in exhaust gas temperature is observed for all the concentration of nano-oil.
6. The effect of nano-oil on emission characteristics is very adverse. All the HC, CO, CO_2 and NO_X emissions are increased with all concentrations of the nano-oil as compared with that with the base oil.
7. Highest rise in emission is observed with 0.2% CuO nano-oil.
8. So from the above discussions, it is clear that TiO_2 nanoparticles in lubricating oil has greater reduction in friction power as compared with CuO at all the CR. But both they have adverse effect on emission characteristics.

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