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AN EXPERIMENTAL INVESTIGATES TO STUDY THE EFFECT OF ZINC OXIDE NANOPARTICLES FUEL ADDITIVES ON THE PERFORMANCE AND EMISSIONS CHARACTERISTICS OF DIESEL ENGINE

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ABSTRACT
This study investigates the effect of Zinc Oxide (ZnO) nanoparticles fuel additives on the performance and emission characteristics of diesel engine. Diesel fuel was mixed with the ZnO nanoparticles in the mass fractions of 50 and 100 ppm by using ultrasonicator. Direct injection (DI), water cooled four cylinders, in-line, natural aspirated Fiat diesel engine was used and run at a constant speed (1500 rpm) and constant fuel injection pressure (400 bar) with varying the operation load. The obtained results were compared with those obtained when the engine run at the same conditions but with diesel fuel. Measurements indicated that there is improvement in the thermal efficiency and the brake specific fuel consumption with increasing the dosing level of ZnO nanoparticle in the blended fuel. The emission results at all loads showed that NO_x and smoke generated by ZnO blended fuels were less than those generated by diesel fuel. Diesel fuel produced CO and HC more than ZnO blended fuels at high load and less at low load.

KEY WORDS: Combustion, Diesel Engine, Nanoparticles Fuel Additives, Gases Emissions

INTRODUCTION :-

The growing interest in diesel engines in the last years, is the result of high efficiency which making it more economical than gasoline engines, which made diesel engines more frequently used than others [Labecki, 2012]. Although the diesel engine is one of the more sources of regulated emissions such as nitrogen oxides, particulate matter and unregulated emissions such as hydrocarbons and sulphur oxides [Sajeevan, 2013] . The researchers used several means to improve engine performance and reduce emissions. One of the most important of these modifications is a metal-based additives [Bagri, 2013]. Metal based elements, such as manganese, iron, copper, barium, calcium and platinum etc., which are used as a combustion catalyst for hydrocarbon fuels. Nano materials are more effective than bulk materials because of its higher surface area. Nano material chosen depends upon the size and catalytic effect on the combustion of hydrocarbons [Raja, 2015] . Metal oxides such as cerium oxide, copper oxide, iron oxide and cobalt oxide are used as fuel additives by a number of researchers [Mohan, 2015], they observed a considerable improvement in the thermal efficiency and both regulated and unregulated emissions. Zinc oxide is one of the most important of metal oxides additives, where Zinc oxide nanoparticle is acting as an antioxidant, possibility to prepare structures, low price and corrosion inhibitors of anti-wear property [Karthikeyan, 2014].

Karthikeyan et al. [Karthikeyan, 2014], were evaluated the performance and emission characteristics of Promolin Stearin wax oil biodiesel blended with diesel(D) and 50PPM and 100PPM concentration of Zinc Oxide(ZnO). The zinc oxide additive blends have been improved the calorific value but did not had any clear influence on the other properties. The Brake Specific Fuel Consumption BSFC was decreased and Brake thermal efficiency BTE has been increased with the increase in the dosing level of ZnO in the fuel. The CO and HC had clear reduced with the increase of the nanoparticle as compared to B20. The NO_x emissions of all blended fuels did not have any considerable effect . [Elangom 2014], had studied the effect of Zinc Oxide nanoparticle fuel additives on the performance and emission characteristics of Grape Seed Oil Methyl Ester blended with diesel (D) and 50PPM and 100PPM concentration of Zinc Oxide (ZnO). They have been notes that there was an increase in NO_x and CO_2 emissions for ZnO nanoparticle blends, where CO, HC and smoke emissions are lower for ZnO nanoparticle blended fuels . In the research of [Prathima, 2014], the nano size zinc oxide nanoparticle was less than 100nm with 50PPM and 100PPM concentration was mixed in diesel (D) and canola oil methyl ester biodiesel (B) and fueled with various blends. Their results have been showed that slight improvement in calorific value and kinematic viscosity. The BSFC was decreased with increase in the dosing level of ZnO to the fuel. The BTE of additive fuel was improved at higher load. It was notes that minimum CO and HC recorded with the ZnO blend fuel compared to B20 while the maximum NO_X emission was recorded with the use of ZnO blended fuel .

The works of [Selvaganapthy,2013] identified the reduce of ignition delay with Zinc Oxide nanoparticle addition to diesel fuel, while peak pressure and heat release rate increased due the presence of particles. They found that the brake thermal efficiency increased with increased in NO_x emissions . The main focus of this work was to investigate the effects of Zinc Oxide (ZnO) nanoparticles fuel additives on the performance and emission characteristics of diesel engine. Diesel fuel was mixed with the ZnO nanoparticles in the mass fractions of 50 and 100 ppm by using ultrasonicator. The engine was run at a constant speed (1500 rpm) and constant fuel injection pressure (400 bar) with varying the operation load (0.6, 1.2, 2.4, 3, 3.5) bar (brake mean effective pressure (bmep)).

EXPERIMENTAL SETUP :

Experimental apparatus of engine under study is direct injection (DI), water cooled four cylinders, in-line, natural aspirated Fiat diesel engine. A photograph of the engine is shown in Fig.1, whose major specifications are shown in Table 1. The engine was coupled to a hydraulic dynamometer through which load was applied by increasing the torque. The Multigas model 4880 emissions analyzer was used to measure the concentration of nitrogen oxide (NO_x), unburned total hydrocarbon HC, CO2 and CO. The analyzer detects the CO, CO_2, HC, NO_x, and O_2 content. The gases are picked up from the engine exhaust pipe by means of a probe. A ray of infrared light (which is generated by the transmitter) is send through optical filters on to the measured elements. The engine exhaust smoke emissions were measured using the AVL – 415 smoke meter.

RESULTS AND DISCUSSIONS :

Performance Characteristics

The Brake Specific Fuel Consumption (BSFC) at different loads (brake mean effective pressure (bmep)) are shown in fig.2. In general, there is a decrease of the BSFC with an increase in engine load , the increase in BSFC at low load is a result of the incomplete combustion of fuel. It can be seen that the BSFC values for DZnO50 and DZnO100 blends less than that of diesel fuel, and the BSFC decrease with increasing in ZnO dosing level. This effect may be due to the reduction in the ignition delay with increasing of nanoparticles level by virtue of enhanced surface area to volume ratio which leads to more complete combustion, in addition to the effect of calorific value increase with increasing of nanoparticles level.
Fig.3 shows that the thermal efficiency of the engine was increased with the addition of nanoparticles , this may be probably attributed to the improvement of combustion which leads to decrease the BSFC and increase the efficiency .

Emission Characteristics

Fig.4 shows the variation of NO_x emissions with operation loads for diesel,DZnO50 and DZnO100. The NO_x concentration values increase with increase of engine load for all types of fuels. The reactions forming NO_x are highly temperature dependent, so the NO_x emissions have a close relation with the engine load. Also, NO_x emissions decrease with ZnO level increase at all operation loads. As mentioned in performance results, the ignition delay reduced with using ZnO blended fuels compared to diesel fuel, The shorter ignition delay of ZnO blends leads to reduce the premixed burn fraction (PMBF) of combustion and this will reduce the combustion temperature which leads to decrease the NO_x emissions. Premixed combustion, during which in-cylinder pressure and temperature are very high, plays an important role in NO formation. Techniques to control NO_x formation are mainly linked to a reduction in combustion temperature during this phase of combustion.
Fig.5 shows that the smoke emission of ZnO blends fuels was lower than of Diesel fuel, the difference is particularly obvious at high engine load, but there is a little difference at low engine load. The reduction of smoke number with ZnO blends fuels can be attributed to the

increase of oxygen content in the fuel. The oxygen in the fuel can assist in reducing smoke formation during the stage of diffusion combustion. The improvement is more obvious at high engine loads when a larger percentage of fuel is burned in the diffusion phase and also because the nanoparticles act as catalysts for the oxidation reaction.

The characteristics of CO emission are shown in Fig.6. The difference between the CO emissions at high and low loads is quite clear. The CO emissions decrease generally with the increase of engine load, due to the increase of combustion temperature.CO emissions are primarily controlled by the local fuel-air equivalence ratio. In general, low local cylinder temperatures and lean fuel-air mixture regions at low engine loads may cause the combustion reactions to be unstable, so that CO can't continuously react into CO_2. The carbon monoxide concentration appears to freeze, leading to CO emission. The addition of ZnO decrease the CO emissions especially at high load , DZnO100 shows the lower CO values .The molecular oxygen in nanoparticles blends fuels improves the combustion for local rich mixtures leads to less fuel-rich zone formation; consequently, the CO emission decreases, in addition to being a catalyst . **The** characteristics of unburned hydrocarbons HC emissions are shown in Fig.6. Both CO and HC emissions are the products of incomplete combustion and they tend to decrease with load increase. The total hydrocarbon emissions are generally formed as a result of flame quenching. The formation of higher CO and HC emissions are strongly related to the viscosity of fuel. Higher viscosity also leads to longer spray penetration. As a result, wetting of the cylinder walls eventually leads to the formation of higher CO and HC emissions by incomplete combustion. The lower emissions of CO and HC for ZnO blends fuels could be possibly attributed to the enriched combustion characteristics of nanoparticles leading to high catalytic activity because of their higher surface to volume ratio and improving fuel air mixing which leads to improve combustion .

CONCLUSIONS :

The reduction in the ignition delay with increasing of nanoparticles level by virtue of enhanced surface area to volume ratio which leads to more complete combustion, in addition to the effect of calorific value increase with increasing of nanoparticles level leads to increase the thermal efficiency and decrease BSFC with increasing the dosing level of ZnO nanoparticle in the blended fuel.

This reduce in the ignition delay with using Zno blended fuels compared to diesel fuel leads to reduce the premixed burn fraction of combustion and this will reduce the NO_x emissions due to decreasing the combustion temperature. It is also found that the smoke emissions decrease with ZnO proportion increase, due to the increase of oxygen content in the fuel and also because the nanoparticles act as catalysts for the oxidation reaction.

CO and HC are lower for ZnO nanoparticles blended fuels, due to high catalytic activity because of their higher surface to volume ratio and improving fuel air mixing which leads to improve combustion.

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Table 1, tested engine specifications

Engine type	4cyl., 4-stroke
Engine model	TD 313 Diesel engine reg
Combustion type	DI, water cooled, natural aspirated
Displacement	3.666 L
Valve per cylinder	Two
Bore	100 mm
Stroke	110 mm
Compression ratio	17
Fuel injection pump	Unit pump 26 mm diameter plunger
Fuel injection nozzle	Nozzle hole dia. (0.48mm) , Spray angle= 160^o, Nozzle opening pressure=40Mpa

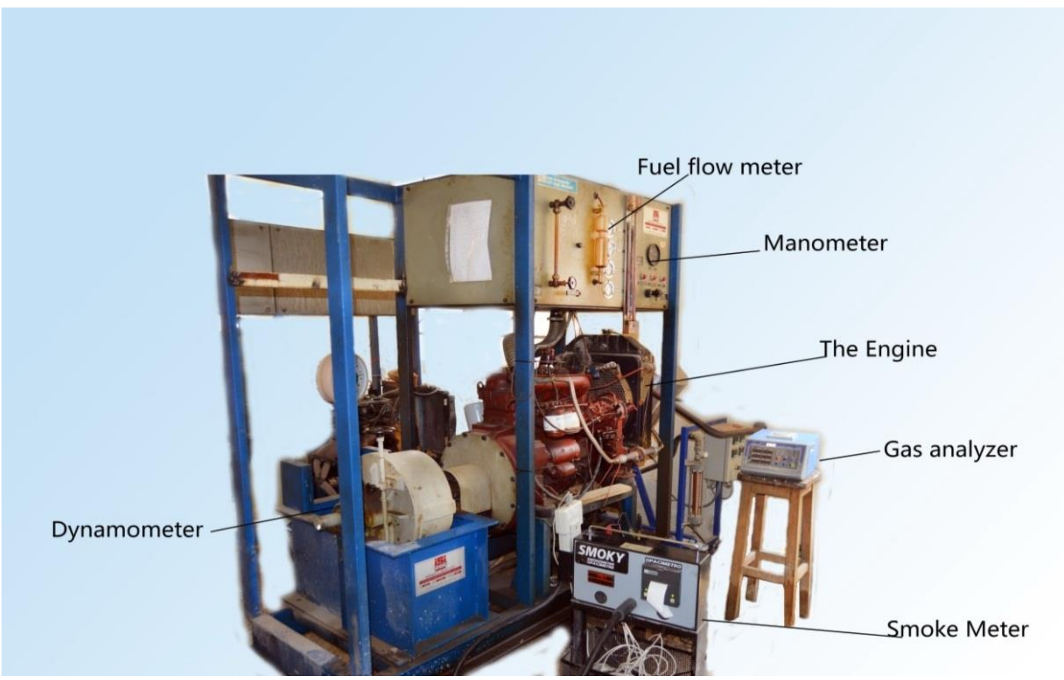

Fig. 1 photograph of the engine

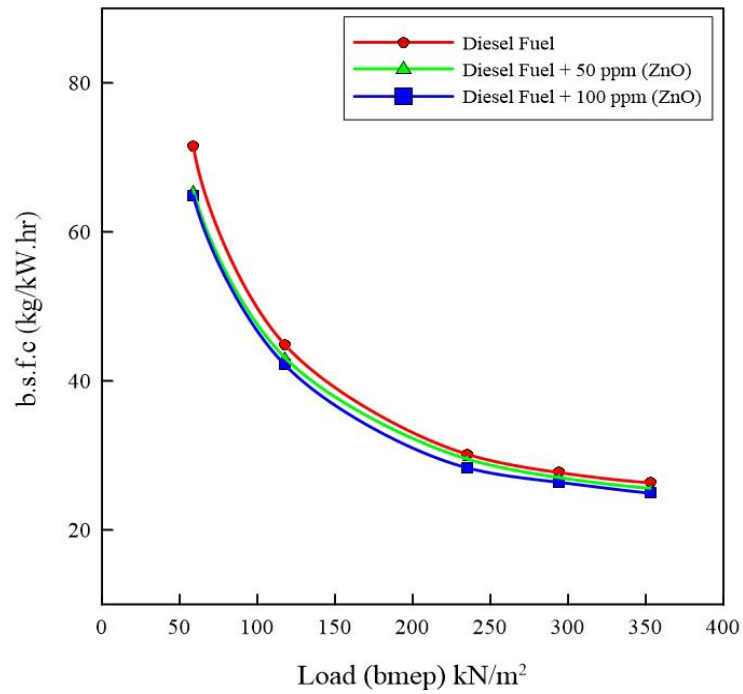

Fig. 2 the brake specific fuel consumption (bsfc) at different loads for three types of fuels.

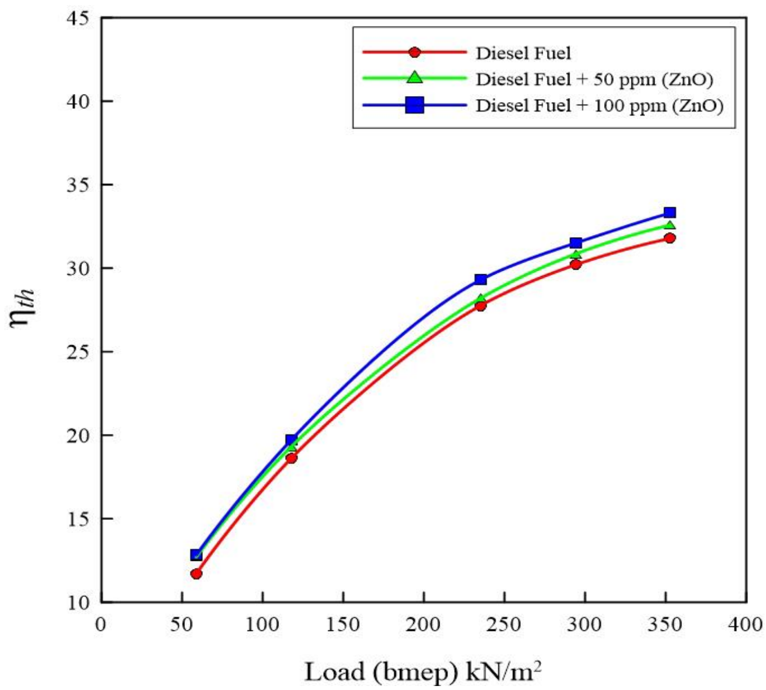

Fig. (3) the brake thermal efficiency at different loads for three types of fuels.

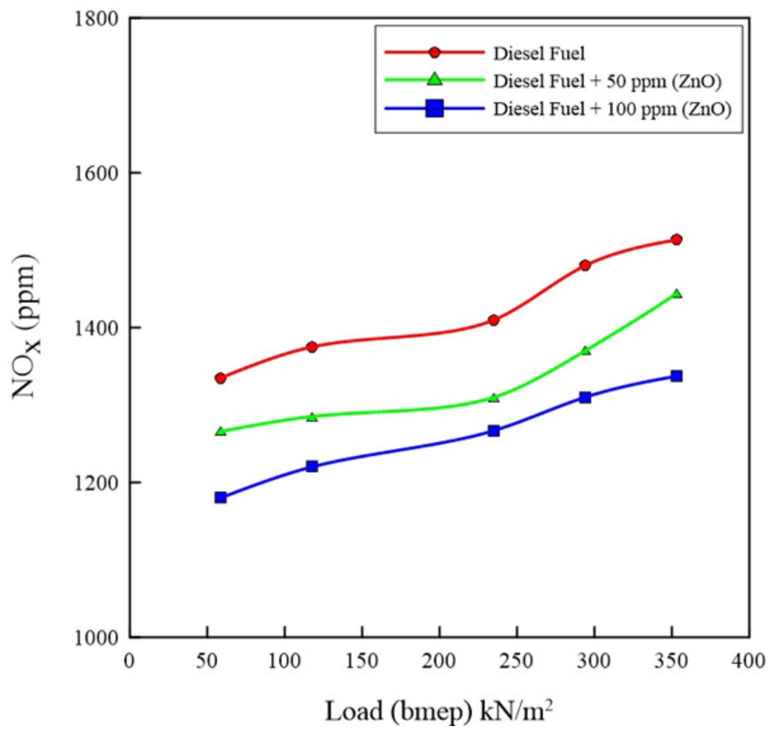

Fig. (4) nitrogen oxide NOx emissions for the three types of fuels at different loads.

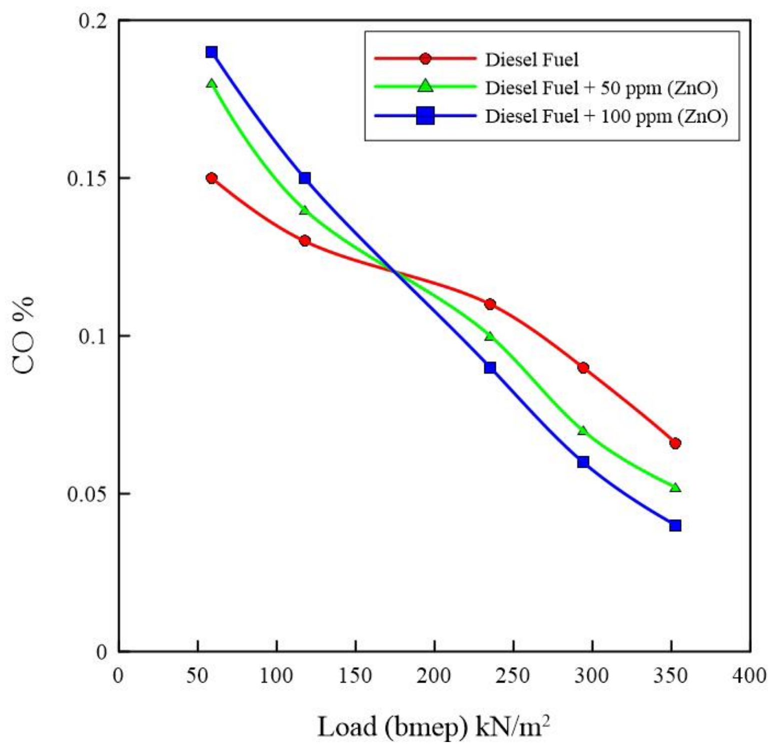

Fig. 5 the carbon monoxide emissions for the three types of fuels at different loads.

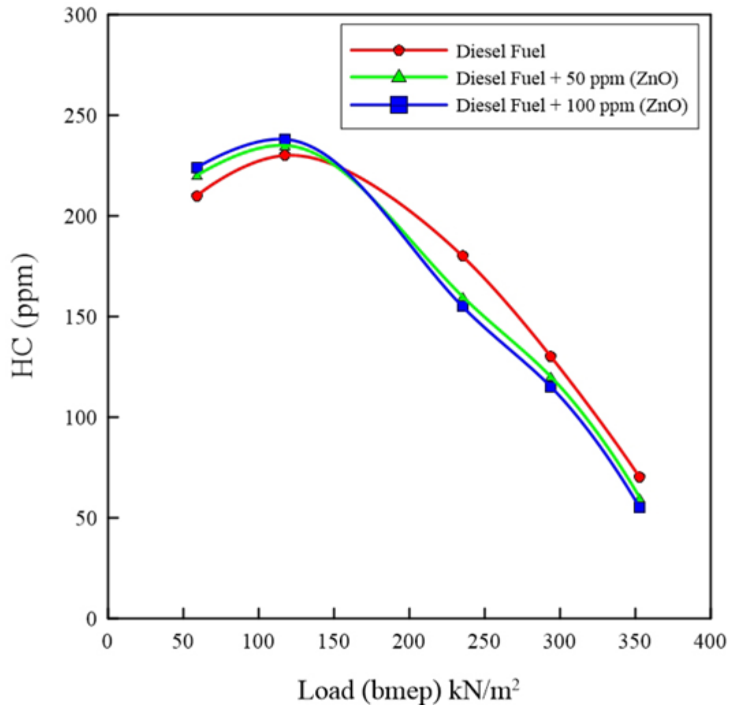

Fig. 6 the unburned hydrocarbon emissions for the three types of fuels at different loads.

REFERENCE :

Bagri S.and Choube A.”Influence of Additives on the Performance and Emission Characteristics of CI Engine - A Review”. International Journal of Emerging Trends in Engineering and Development. Issue 3, Vol.4 . 2013.

Elango A., Karthikeyan S., Prathima A, ”An environmental effect of GSO methyl ester with ZnO additive fuelled marine engine”, Indian Journal of Geo-Marine Sciences. Vol.43(4),pp 564-570. 2014.

Karthikeyan S. , Elango A., Prathima A, “Performance and Emission Study on Zinc Oxide Particles Addition with Promolion Stearin Wax Biodiesel of Engine”, Journal of Science and Industrial Research, Vol. 73, 2014.

Labecki L. , Ganippa L.C.”Effects of injection parameters and EGR on combustion and emission characteristics of rapeseed oil and its blends in diesel engines”. Fuel 98 (2012) 15–28 (40).

Mohan N., Sharma M., Singh R. C. and Pandey R. K.”Performance Study of Diesel Engine Using Nanofuel”. International Conference of Advance Research and Innovation (ICARI-2015).

Prathima A, Karthikeyan S. , Elango A.,“Diesel engine performance and emission analysis using oil methyl ester with the nano sized zinc oxide particles”, Journal of Science and Industrial Research, Vol. 21, 2014.

Raja V .A., Kumar S A, Sakthinathan G. “A Review Of Nano Additive In Diesel”, Journal of Chemical and Pharmaceutical Sciences. Issue 7: 2015.

Sajeevan A. C. and Sajith V.”Diesel Engine Emission Reduction Using Catalytic Nanoparticles: An Experimental Investigation”. Journal of Engineering. Vol.2013- 589382.

Selvaganapthy A., Sundar A., Kumaragurubaran B. and Gopal P.,”An Experimental Investigation to Study the Effects of Various Nano Particles with Diesel on Di Diesel Engine”. ARPN Journal of Science and Technology. VOL. 3, NO. 1, January 2013.