EFFECT OF SiO_2 NANOPARTICLES ADDED TO DIESEL FUEL ON THE PERFORMANCE AND POLLUTANT EMISSIONS OF A FOUR STROKE DIESEL ENGINE

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ABSTRACT

Experimental work has been conducted using silica oxide SiO_2 nanoparticle as an additive to diesel fuel in a compression ignition engine in order to reduce pollutants emissions and to improve engine performance. A 10 ppm and 20 ppm of SiO_2 nanoparticle is added to the diesel fuel. The results showed that the SiO_2 nanoparticle blended with diesel fuel improve engine performance such as brake thermal efficiency and brake specific fuel consumption, increase in exhaust gas temperature and reduces carbon monoxide, and unburned hydrocarbon emissions. Also the results showed that the blend of the SiO_2 nanoparticle to diesel fuel led to increase in the carbon dioxide in the exhaust gases. The tests are carried out at constant speed of 1500 rpm, under different engine load conditions.

تأثير أضافة دقائق ثاني اوكسيد السيلكا المتناهية الصغر على اداء وانبعاث الملوثات لمحرك الديزل رباعي الاشواط

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الخلاصه

اجريت الدراسه التجريبيه باضافه اوكسيد السليكا على شكل ماده نانويه الى وقود الديزل واستخدم في محركات الاشتعال بالانضغاط بهدف تقليل التلوث وتحسين الاداء. تم اضافه (10 ppm) و (20 ppm) من اوكسيد السليكا الى وقود الديزل. اظهرت النتائج ان اضافه اوكسيد السليكا على شكل ماده نانويه الى وقود الديزل يحسن اداء المحرك مثل الكفاءه الحراريه ومعدل استهلاك الوقود النوعي، وكذلك تزداد درجه حراره غازات العادم وتقل تراكيز اول اوكسيد الكاربون و الوقود غير المحترق. كذلك اظهرت النتائج ان اضافه اوكسيد السليكون يؤدي الى زياده تركيز ثنائي اوكسيد الكربون في غازات العادم. اجريت التجارب على محرك يعمل بسرعه ثابته (1500rpm)، وتحت تاثير احمال مختلفه.

NOMENCLATURE

bsfc brake specific fuel consumption
LCV lower calorific value
$\dot{m}$ mass flow rate
N engine speed
P_b brake power
T Torque

GREEK SYMBOLS

η efficiency

SUBSCRIPTS

f fuel
th thermal

INTRODUCTION

Nanoparticles are the particles between 1 and 100 nanometers in size. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. Particles are further classified according to its diameter. Ultrafine particles are the same as Nanoparticle and between 1 and 100 nanometers in size, fine particles are sized between 100 and 2,500 nanometers, and coarse particles cover a range between 2,500 and 10,000 nanometer Kunnassery, et al [2015]. Nanoparticle of SiO_2 has the features of small particle size, narrow particle size distribution, porous, large surface area, and owns a large number of hydroxyl groups and unsaturated residual bonds on its surface and shows high reflectivity to long wave, visible light and ultraviolet ray. Silica Nanoparticle has large specific surface area and size of 15 µm to 30 µm. The several advantages of the nanoparticles over the organic molecules due to the nanoparticle size which can enter the contact area as molecules Kevin Kunnassery, et al [2015].

Using Nanoparticle as additives to diesel fuel is a promising method for improving the efficiency and improving the exhaust emissions of a compression ignition engine.

P. Jayanthi, et al [2016], studied the effect of copper oxide as an additive to the linseed oil biodiesel fuel on the performance and emission characteristics of a diesel engine running at constant speed of 1500 rpm at different operating conditions. It was found that the maximum increase in brake thermal efficiency occur at 80 ppm CuO. Also it was found that the copper oxide reduces the unburned hydrocarbon, smoke, carbon monoxide, and nitrogen oxides ay full load. The effect of cerium Nanoparticle addition in diesel fuel on the performance and emission characteristics of a diesel engine were investigated by Nithin Samuel, et al [2015]. The specific fuel consumption was decreasing as the cerium oxide Nanoparticle added. The reason behind that is the improvement in combustion of fuel and therefore less amount of fuel is required for a particular power. Also the thermal efficiency of diesel fuel mixed with cerium oxide is improved due to the the improvement of combustion process. Nano additives Cerium (CeO_2) were doped to diesel-biodiesel in a single cylinder diesel engine to determine the engine performance and emission characteristics by K. Ramarao, et al [2015]. Cotton seed oil methyl ester, with CeO_2 nanoparticle additives blend in different proportions with the neat diesel fuel. The results shows that lower specific fuel consumption, and less emissions of carbon monoxide and unburned hydrocarbon but higher nitrogen oxide emissions compared to neat diesel.

Experimental studies were carried out on a single cylinder four-stroke water-cooled diesel engine fuelled with diesel blended TiO_2 nanoparticles as an additive by Prabhu L, et al [2015]. The test was at constant speed of 1500 rpm. The tests were conducted at variable load, no load, 25%, 50%, 75%, and full load. The results show that there are rises in thermal efficiency as the addition of titanium oxide nanoparticles in biodiesel which act as a catalyst causing well combustion of biodiesel. The addition of titanium oxide decreases the hydrocarbon emission when compared with neat diesel and biodiesel blend. There is an increase in NO emission due to higher peak temperature obtained for nanoparticle addition. Also the addition of TiO_2 nanoparticle in diesel-biodiesel blends reduces the smoke further.

S. Karthikeyan, et al [2014] studied the exhaust emissions characteristics and performance of a four stroke, single cylinder, diesel engine. The tests were carries at constant speed of 1500 rpm under full load. The engine was fueled with various blends 80% diesel +20% canola oil methyl ester, 80% diesel +20% canola oil methyl ester + 50ppm zinc oxide and 80% diesel +20% canola oil methyl ester + 100 ppm zinc oxide. The properties such as pour point, cloud point, flash point, kinematic viscosity, cetane number, sulphated ash and calorific value of above blends were determined and compared with American biodiesel standards (ASTM D7467). It was found that the zinc oxide nanoparticles which accelerates early ignition of combustion shortens ignition delay and enhances NOx emissions. Experimental study on emission and performance of ICE fuelled by polanga oil diesel fuel blend were studied by M. Santhanamuthu, et al, [2014]. Iron oxide nanoparticles were added to polanga oil-diesel fuel blend as additive to improve engine performance. The tests were carried out for 10%, 20% and 30% (by weight) polanga oil with neat diesel. Iron oxide nanoparticle were doped in three different concentrations; 100, 200 and 300 ppm. It was found that at 25% polanga oil blend with diesel and concentration of 150 ppm iron oxide nanoparticles, the performance of the engine to be comparable to that run on neat diesel. Experimental study on the physicochemical properties and the performance of biodiesel of the addition of cerium oxide nanoparticle were investigated by Sajith, et al, [2010]. The physicochemical properties of the base fuel and modified fuel formed by dispersing the catalyst nanoparticle by ultrasonic agitation were measured using ASTM standard test methods. The effect of the additives nanoparticles on the engine performance, emissions and fuel properties, were investigated, and the levels of the additives were optimized. Comparisons of the performance of the fuel with and without additives were presented. The flash point and the viscosity of the biodiesel increased with the addition of the cerium oxide nanoparticles. The emission of the hydrocarbon and NOx were reduced as the addition of cerium oxide nanoparticles.

EXPERIMENTAL SETUP AND PROCEDURE

The engine used in the present work is single cylinder four stroke water cooled diesel engine (KIRLOSKAR AV1) as shown in Figure(1). The specification of the engine used are 80 mm bore, 110 mm length, 661.5 cc displacement, compression ratio of 16.5: 1 and produces 5 brake horse power. The load is applied using the electrical dynamometer and the readings are measured using the data acquisition system. The exhaust gas analyzer is used to measure the concentrations of carbon dioxide, carbon monoxide, nitrogen oxides, oxygen and unburned hydrocarbon gases formed during combustion as shown in Figure(2).

PREPARATION FUEL MIXTURE

There are two important issues needed to alleviate through this blending procedure to ensure that the nano particles well dispersed in the diesel and to ensure that the clinker phenomenon does not occur where in the nano particles stick together to form circular clusters due to the high temperature inside the engine cylinder and clog the nozzle. This was achieved in the present work by using ultrasonic device to mix the nano particle with the diesel fuel.Silica oxide nano particles are chosen to investigate its effect on diesel engine emission. In order blend nano particle with diesel fuel ultrasonic device is used as shown in Figure(3). Various steps used in the preparation of nanoparticle blend are described below:

- Ultra-sonication is used to mix the silica oxide SiO_2 nanoparticle (10 PPM) in the fuel 1 kg for 30 minutes.
- Ultra-sonication is used to mix the silica oxide SiO_2 nanoparticle (20 PPM) in the fuel 1 kg for 30 minutes.

MECHANICAL CHARACTERISTICS DETERMINATION

As the thermal equilibrium of the engine reached, the required data are recorded, also the emission parameters (CO, CO2 and HC) are recorded too, then performance of the engine are determined as the following.

The break power developed is determined from the relation:

$$P_b = \frac{2\pi NT}{60} \quad (1)$$

The thermal efficiency can be determined from the following relationship.

$$\eta_{th} = \frac{P_b}{\dot{m}_f \ (L.C.V)_f} \quad (2)$$

Break specific fuel consumption determined from the following formula:

$$bsfc = \frac{\dot{m}_f}{p_b} * 3600 \quad (3)$$

RESULTS AND DISCUSSIONS

Figure(4) shows the relation between brake power and the brake thermal efficiency at 1500 rpm engine speed for pure diesel fuel, 10 ppm SiO_2 nanoparticle added, and 20 ppm SiO_2 nanoparticle added to diesel fuel. It is clearly shown that the increase in brake power (load) led to increase in the brake thermal efficiency. It is also noted that the addition of SiO_2 nanoparticles improve the brake thermal efficiency as it work as catalyst which gives better combustion process.

Figure(5) shows the decrease in brake specific fuel consumption as the increase in the brake power. It's also shows a small improvement in brake specific fuel consumption as using SiO_2 nanoparticle is added to diesel fuel compared to pure diesel fuel, which is due to promoting the combustion process as the SiO_2 nanoparticles work as catalyst.

Figure(6) represents the relation between the exhaust gas temperatures with the brake power, for pure diesel fuel, 10 ppm SiO_2 nanoparticles, and 20 ppm SiO_2 nanoparticles added to diesel fuel. The results show that the exhaust gas temperature increase with the increase in the brake power, also it shows that the addition of SiO_2 nanoparticles increases the exhaust gas temperature due to the improving of the combustion process as the SiO_2 nanoparticles is a good catalyst.

Figure(7) shows the relation between the carbon dioxide emissions and the brake power; it is clearly shown that the carbon dioxide increases with the increase in brake power, especially at high rated load. A small increase in the carbon dioxide emission when using diesel enriched SiO_2 nanoparticles that's due to the improving in the combustion process as the SiO_2 nanoparticles is an catalysts.

Figure(8) and Figure(9) show the relation between the brake power and carbon monoxide emissions and the brake power and unburned hydrocarbon respectively. The results show that at high load (brake power) there are high concentration of carbon monoxide emissions and unburned hydrocarbon for all fuel used that's because of the increasing in richness at high loads. The addition of the SiO_2 nanoparticles to the diesel fuel reduce the concentrations of the carbon monoxide and unburned hydrocarbon emission as the SiO_2 nanoparticles work as catalysts and enhanced combustion process.

CONCLUSIONS

Based on the results presented and discussed in the previous paragraphs the following conclusions can be drawn:

1. The SiO_2 nanoparticles added to Diesel fuel acts as a burning promoter hence improve the engine performance as it increase the brake thermal efficiency and decrease brake specific fuel consumption.
2. The concentration of the carbon dioxide increase with the use of SiO_2 nanoparticles as the combustion process improved.
3. The concentrations of carbon monoxide and unburned hydrocarbon emissions reduced with the addition of SiO_2 nanoparticles to the diesel fuel.
4. The SiO_2 nanoparticles are good oxidizer catalysts and can improve the combustion process of the diesel engine.

Figure 1: KIRLOSKAR AV1 Diesel engine

Figure 2: Infrared Gas Analyzer

Figure 3 Ultrasonic device

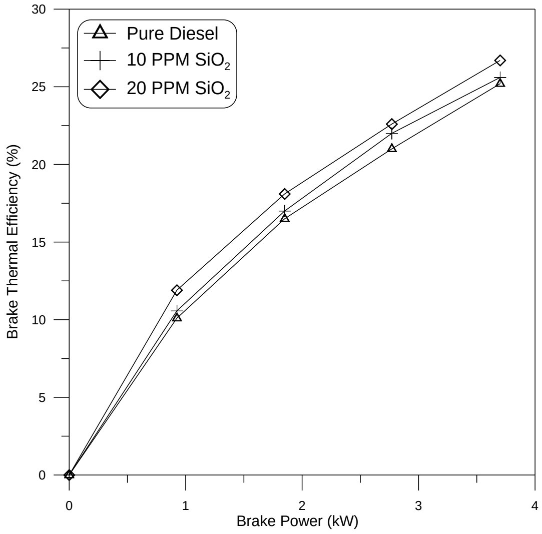

Fig.(4) Effect of brake power on brake thermal efficiency

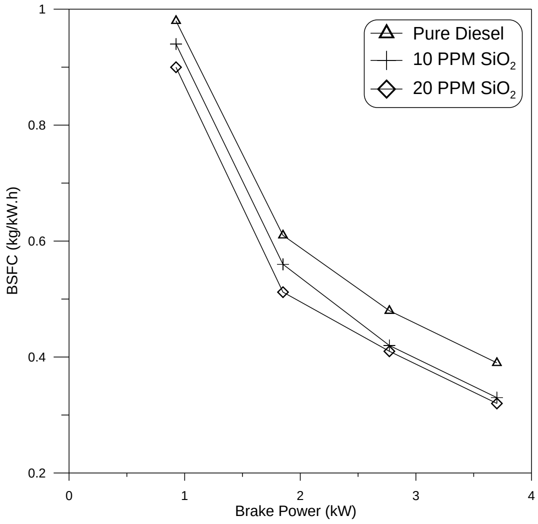

Fig.(5) Effect of brake power on brake specific fuel consumption

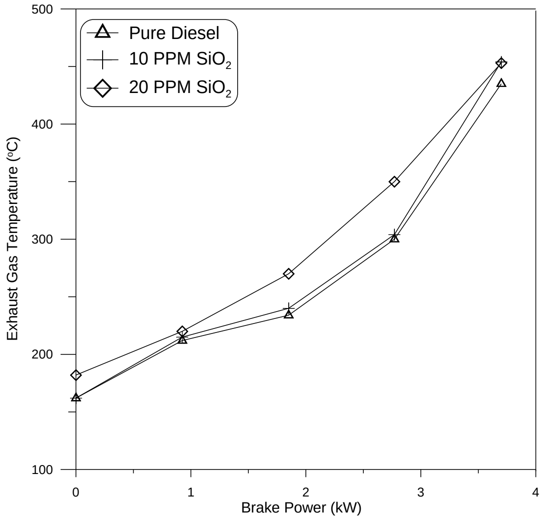

Fig. (6) Effect of brake power on exhaust gas temperature

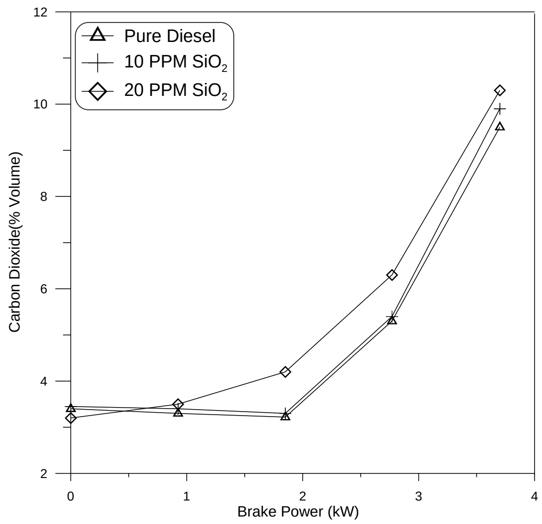

Fig.(7) Effect of brake power on carbon dioxide emissions

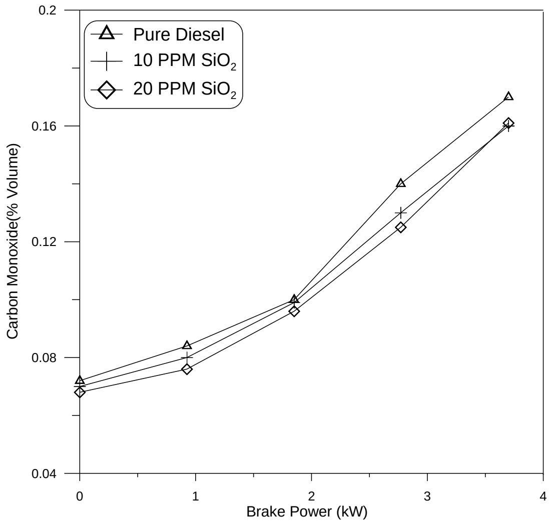

Fig.(8) Effect of brake power on carbon monoxide emissions

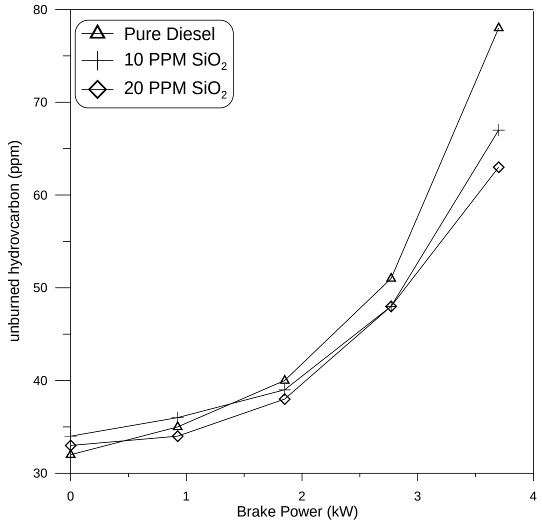

Fig.(9) Effect of brake power on unburned hydrocarbon emissions

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