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INVESTIGATION OF EFFECTS OF ADDITION OF ZINC OXIDE NANO PARTICLES TO DIESEL ETHANOL BLENDS ON DI DIESEL ENGINE PERFORMANCE, COMBUSTION AND EMISSION CHARACTERISTICS

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ABSTRACT

World at present is in a crisis of faster depletion of fossil fuel. Ethanol is a renewable fuel. The objective of this paper is to analyze the effects of addition of zinc oxide nano particles with ethanol-diesel blends in a diesel engine performance, combustion and emission characteristics of blends B1 (with 100 ppm ZnO nano particles in 20% ethanol and 80% diesel), B2 (with 200 ppm ZnO nano particles in 20% ethanol and 80% diesel), B3 (with 300 ppm ZnO nano particles in 20% ethanol and 80% diesel), B4 (with 400 ppm ZnO nano particles in 20% ethanol and 80% diesel) and B5 (with 500 ppm ZnO nano particles in 20% ethanol and 80% diesel) were analyzed and compared with that of E20 (20% ethanol and 80% diesel). There was an increase of heat release in all the blends in comparison with that of E20. There was an increase of peak pressure for the blends in comparison with that of E20. Brake Thermal Efficiency (BTE) of the blends was higher than that of E20. CO and HC emissions were also comparatively lower than E20. There was a slight increase of NOx emission for the blends at full load in comparison with that of E20. At lower loads there was an increase of smoke emissions for the blends and at higher loads on par with that of E20.

Key words: ZnO, Ethanol, Performance, Combustion, Emission, Diesel engine, ppm.

INTRODUCTION

Diesel engines are required for meeting the demand of the transportation, prime mover for power source for industry, agriculture etc., Even though diesel engines are producing very less emissions compared to that of spark ignition engines the growing global population of diesel engines will lead to major risk for environment and health hazards[1].

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Also the petroleum reserves for fossil fuels depleting in the near future. This paved a way to look for alternative fuel to reduce the consumption of fossil fuels or to replace the usage of fossil fuels. Alcohols and biodiesels used as alternative fuel in diesel engines are attractive[2]. Emissions from the alcohol fuels are comparatively lower than that of diesel in diesel engines. Among alcohols, ethanol is a renewable fuel and can be produced from biomass[3]. Many researchers tried for ethanol blended with diesel in diesel engines. Ethanol can be blended up to 15% with diesel without additive or emulsifier. Using ethanol in diesel engine has some limitations such as low cetane number, viscosity and high latent heat vaporization. In order to overcome the limitations alcohol fumigation, dual injection, alcohol-diesel blend and alcohol fuel emulsion can be employed. It was reported that the use of alcohol-diesel fuel blends in diesel engines extend ignition delay period of the combustion process[4,5]. This period depends on the kind of alcohol blended and becomes longer as the content of the alcohol in the blends is increased.

However, the use of alcohol as blend with diesel provides significant improvement in exhaust emissions. Ajav et al.[6] tested different proportions of ethanol-diesel fuel blends in a constant speed diesel engine. They observed that 9% increase was occurred in the brake specific fuel consumption (BSFC) with the blends up to 20% as compared to diesel fuel while the emissions of CO and NOx were lower with the use of blends[6]. Abu-Qquadis et al.[5] experimentally compared the effects of ethanol fumigation and blends with the diesel fuel on the performance and emissions of a diesel engine. They found that the fumigation and blends cause comparable results in terms of engine performance and emissions. On the other hand, there was an increase in the brake thermal efficiency (BTE), CO, and HC emissions, but decrease in soot concentration with use of ethanol blends. He et al.[3] tested ethanol-diesel blends with a solvent additive, which was used for avoiding phase separation and enhancing cetane number of the blends, thus improving ignition characteristics. They determined that there were reduction in smoke, NOx and CO_2 emissions with the increase of ethanol content in the blend for most of the engine operating conditions[3].

However, CO, acetaldehyde and unburned ethanol emissions showed increasing trends. Alcohols have different physical and chemical properties compared to conventional petroleum fuels. Therefore, some modifications in the engine and fuel system may be necessary in order to use alcohols in CI engines[7]. However, it was reported that the use of blends up to 20% does not require any important modification[8,9]. The objective of present study is analyzing the effects of addition of zinc oxide nano particles in E20 (20% ethanol and 80% diesel) in 100 ppm, 200 ppm, 300 ppm 400 ppm and 500 ppm (provide space) on the performance, combustion and emission characteristics of diesel engine.

EXPERIMENTAL

Material and methods

Preparation of blends

Initially 80% volume of diesel is taken in a beaker and 20% volume of ethanol is filled in the burette for blending. Ethanol used in this experiment is anhydrous (99.7% free from water). Ethanol is added and stirred well till a clear blend is achieved without phase separation. Prepared E20 blend [80% diesel and 20% ethanol] is kept undisturbed in a closed container for 2 hrs and observed for occurrence of phase separation between diesel and ethanol. Zinc oxide nano particles of size ranging from 40 nm to 100 nm is measured in 100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm were added to the diesel ethanol blend. Blending zinc oxide nano particle to diesel ethanol blend is challenging as it is not easily soluble. Ultrasonic stirring is done for making the zinc oxide nano particle to blend with E-20. Stirring and testing for settling of ZnO were done for several times periodically to ensure that all the nano particles are properly blended with E-20. The blend is kept undisturbed for observation to ensure that there is no settlement of undissolved ZnO, which may clog the fuel injection pump, so this observation is important step. Prepared blends of E-20-ZnO-100 ppm (B1), E-20-ZnO-200 ppm (B2), E-20-ZnO-300 ppm (B3), E-20-ZnO-400 ppm (B4) and E-20-ZnO-500 ppm (B5) are taken for testing the performance, combustion and emission characteristics of diesel engine.

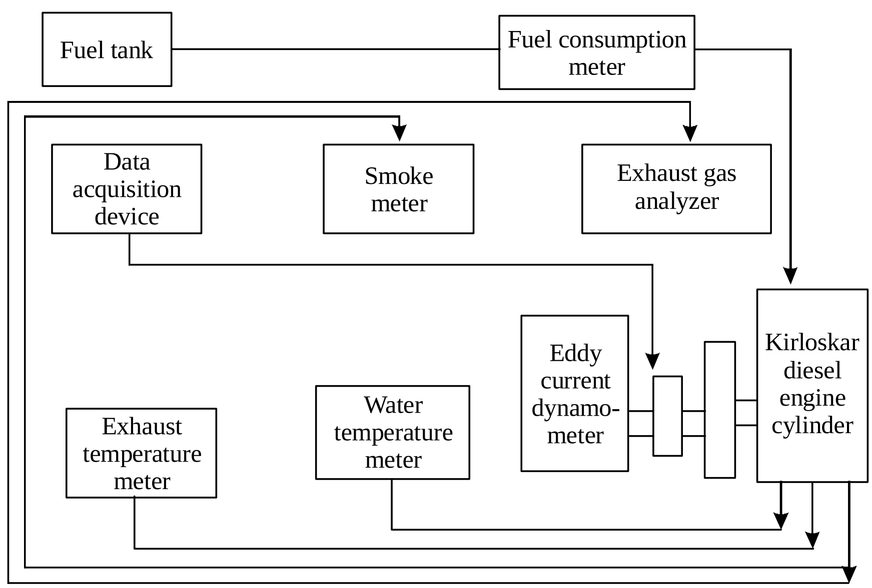

Fig. 1: Experimental test set up

A Kirloskar engine of 4.4 kW @ 1500 rpm water cooled engine coupled to an eddy current dynamometer is used for testing the E-20 and blends**.** The injection system consists of a pump line nozzle fuel injection system and~~,~~ no modification was made to the injection system during the test.

Figure 1 presenting the layout of the test set up instruments and equipments connected with the engine. The data acquisition device duly connected to capture the pressure variation and heat release rate in the engine. Avl Di gas make exhaust gas analyzer is used for capturing the emission parameters. Each test is conducted three times and the average of three readings is taken for analysis. For emissions five readings are taken and the average of five readings is taken for analysis. The performance and operating parameters such as the engine speed, exhaust temperature, inlet temperature, airflow, torque output fuel consumption and cylinder pressure were measured.

RESULTS AND DISCUSSION

Performance parameters

Brake Thermal Efficiency (BTE)

Brake thermal efficiencies of the blends are presented in Fig. 2. It is observed that the BTE of the blends are all higher than that of E20. The increase~~s~~ in the BTE is proportional to the increase of ZnO nano particles in the blend. This is due to the higher heat release of the blend containing ZnO. Higher heat release is the result catalytic action of zinc oxide nano particles in the blend.

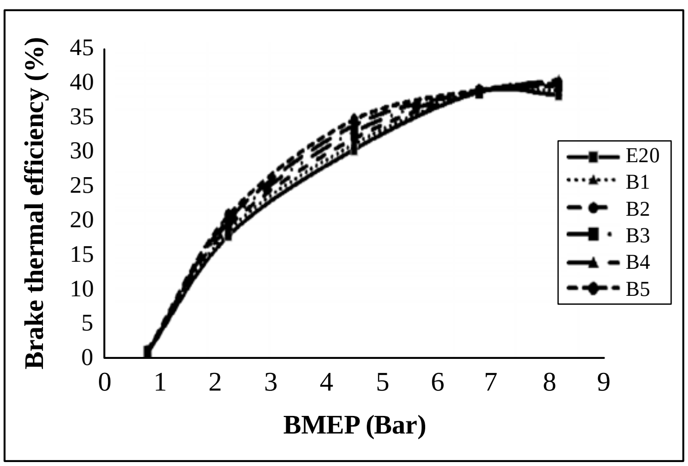

Fig. 2: Brake thermal efficiency (increase of BTE)

Brake specific fuel consumption

BSFCs of the blends are presented in Fig. 3. It is observed that there is a decrease of fuel consumption for all the blends in comparison with that of E20. The reduction of BSFCs are from 6.8% to 31.5%. This is due to the higher temperature of the combustion chamber at higher loads. This higher temperature gives opportunity for the oxygen to react with fuel and thereby reducing the fuel consumption**.**

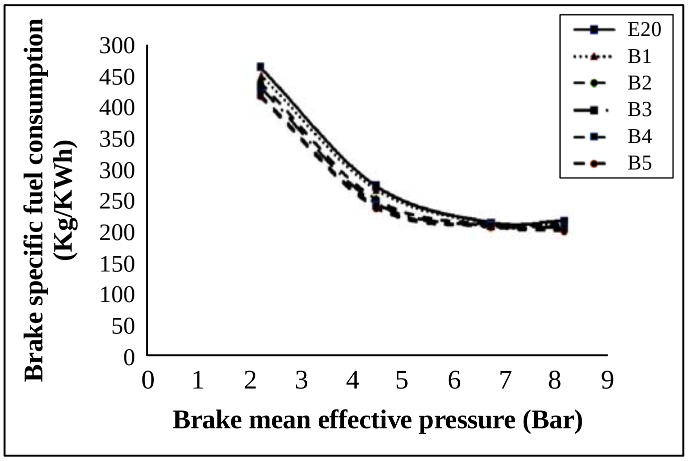

Fig. 3: Brake specific fuel consumption (decrease of BSFC)

Combustion parameters

Pressure crank angle diagram

Pressure crank angle diagram of the blends at full load is presented in Fig. 4. The maximum pressures for the blends are little lesser than that of E20.

The angles at which the maximum pressure occurs for the blends are at 8 deg and 9 deg after top dead centre.

Heat Release Rate (HRR)

Heat release rate for the blends is presented in Fig. 5. It is observed that there is an increase of heat release rate with the increase of ZnO nano particles in the blend. The increases of are up to 50% for the blend containing 500 ppm ZnO. The occurrence of maximum HRR for the blends is at -1 deg. for blends B1, B2, B3 and B5 before Top Dead Centre (TDC); for B3 alone at TDC. This higher heat release rate is the reason for the increase of BTE for the blends.

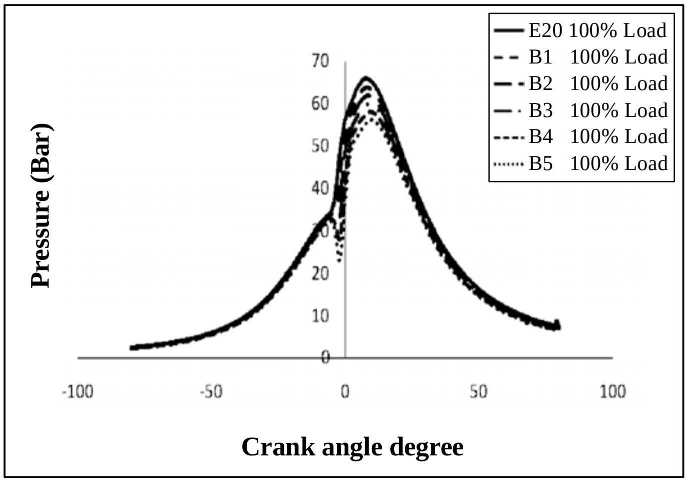

Fig. 4: Pressure crank diagram

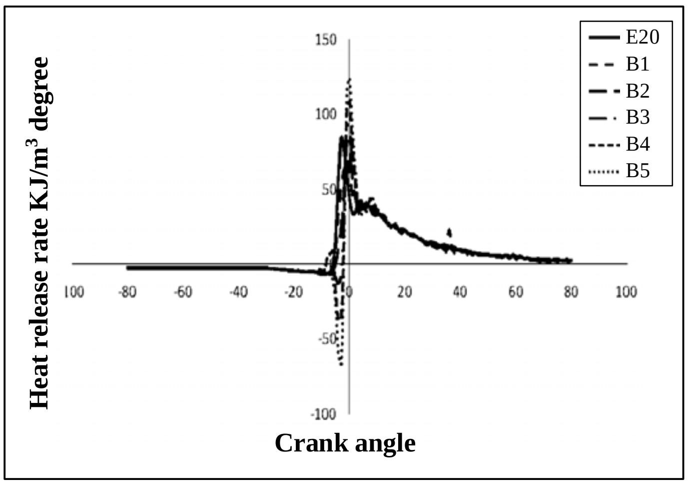

Fig. 5: Heat Release Rate (increase of HRR)

Emission parameters

Carbon monoxide emissions (CO)

Emissions of CO for the blends are presented in Fig. 6. From the graph, it is seen that the CO emissions for all the blends are less in comparison with that of E20. The decreases are up to 50% at higher loads and no change in no load condition. This is due to higher temperature in the combustion chamber giving opportunity for better combustion for the blends containing ZnO nano particles.

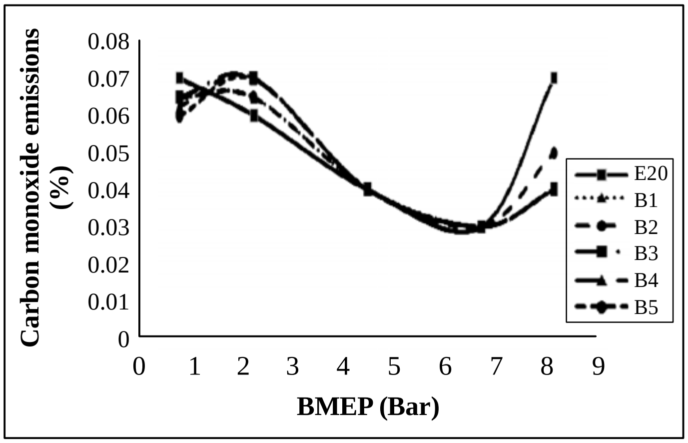

Fig. 6: CO emissions

Nitrogen oxides emission (NOx)

NOx emissions for the blends are presented in Fig. 7. From the graph, it is observed that NOx emissions for all blends are low in comparison with that of E20 at various loads. This is due to the more affinity of the oxygen to react with fuel at higher temperature than that with nitrogen in air. The reduction of NOx emissions are up to 29.48% from 15.80% at higher load.

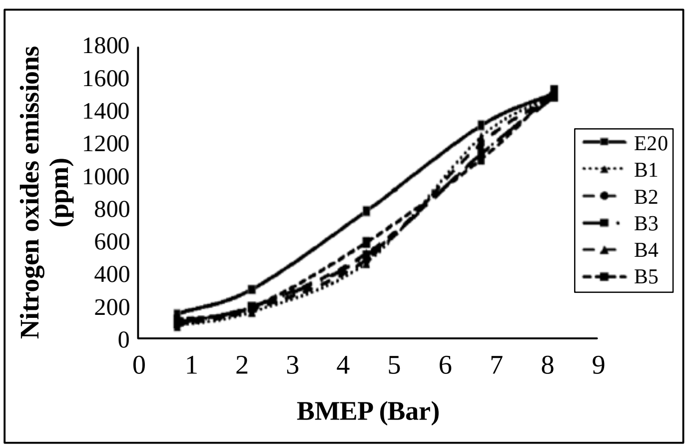

Fig. 7: NOx emissions (Decrease of NOx)

Smoke emissions

Emissions of smoke for the blends are presented in Fig. 8. From the results, it is observed that the smoke emissions for the blends are low in comparison with that of E20. The reductions of smoke emissions for the blends are from 89.13% at low loads up to 47.34% at higher loads.

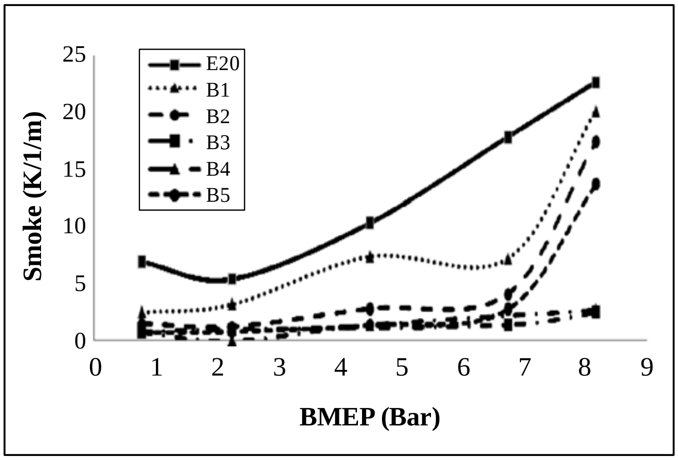

Fig. 8: Smoke emissions (decrease of smoke)

CONCLUSION

The performance, combustion and emission characteristics of the blends B1, B2, B3, B4 and B5 has been conducted, analysis has been made in comparison with that of E20. The following conclusions has been arrived:

- BTE of all the blends are higher in comparison with E20, there is an increase of BTE up to 29.4% at no load and 7.4% at full load for blend B5.
- BSFCs for all the blends are lower than E20. Reduction of BSFC is up to 16.5% for B5 at no load and up to 6.8% at full load.
- The heat release rate for all the blends are higher than E20. The highest heat release rate is 37.241% at full load for blend B5.
- The CO emissions for all the blends are lower than E20 in all the loads. NOx emissions for all the blends are lower than E20 in all the loads. Smoke emissions for all blends are lower than E20 and the maximum reduction is up to 89.13% at no load for B5.HC emissions for the blends are slightly higher than E20.

- From this, it can be concluded that there are advantages to blend zinc oxide nano particles in E20, which is comparatively clean fuel than that of diesel and gives a direction to reduce the dependency of full diesel operation preserving some portion of fossil fuel. Future work can be done for various nano particles and higher ppm of ZnO nano particles without affecting the environment.

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