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Hydrogen behavior in dual fuel mode diesel engine with nano diesel

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ABSTRACT

Investigation focus the major problem of the compression ignition engine such as high smoke and oxides of nitrogen emission which cause health effect to human beings and alternate energy for an I.C engine. The simple and effective method for controlling the smoke and NOx emission in diesel engine could be achieved only by means of fuel reformulation. NOx emission was further improved by means of combusting of nanofluid emulsion as an injected fuel. In this present study experimental investigation was done in Kirloskar single cylinder, four stroke, constant speed, water cooled, and compression ignition engine coupled with the eddy current dynamometer. The experimental set up consists of AVL DI-gas analyser and AVL smoke meter was used for the measurement of HC, CO, CO2, NOx and smoke emissions. The emission characteristics showed better improvement for the reformulated fuel such as diesel emulsion and diesel nano emulsion. Smoke emission of the diesel emulsion was reduced from 46.2% to 44% and the oxides of nitrogen emission also reduced from 520 ppm to 320 ppm at peak power output compared to the diesel fuel. An oxide of nitrogen emission was further reduced to 250 ppm by addition of nano particle in the diesel emulsion. Combusting of reformulated Fuel in the diesel engine was a simple and effective method for improving the smoke and oxides of nitrogen emission, further improvement was achieved by addition of nano particle in the emulsified fuel.

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1. Introduction

Diesel engines are widely used as a prime mover in various application such as auto mobile, Agricultural, locomotive, Marine, Industries, earth moving and mining equipments for power generation due to their high efficiency and high torque [1–3]. Even though the diesel engines have high torque and high efficiency but the major problem was high smoke and oxide of nitrogen emissions [4–6]. Because of the more stringent government regulation on the exhaust emissions, this problem provide a strong enforcement for the researchers to use of alternative fuel in the diesel engine to reduce the environmental effects of the human[7]. It is commonly known that efficient combustion in diesel engine can be achieved only by means of fuel reformulation and the use of alternative fuels as a diesel engine fuel. Among the several alternative fuels, hydrogen is the only less polluting fuel with better combustive property [8–10]. Diesel fuel can be partially replaced by supplying hydrogen in the dual fuel technique which results in reduced smoke and increased NOx emission [11–15]. Then NOx emission is reduced by using water diesel emulsion as a pilot fuel [16]. In hydrogen diesel dual fuel operation, the combustion is inferior at part load condition which was improved by using Nano fluids as a pilot fuel [10].

Diesel engine will work smoothly in water-in-oil emulsion. In this type of emulsion water act as a dispersed medium and oil act as a continuous medium [17]. The surfactant's hydrophilic-lipophilic balance value has to be less than 7 for water-in-oil emulsion for better stability [18]. In case this type of fuel with the water content leads to reduce IC engine combustion chamber the peak cycle temperature [19]. Secondary atomization of this fuel is also an added advantage due micro explosion water inside the fuel.

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Oxides of nitrogen and smoke emissions are reduced by this emulsified fuel [20].

The emerging technology in research fields is Nano technology. Adaption of nanotechnology to the alternative fuels is a technique to improve the performance and emission in CI engine. The combustion and emission behaviour improve by the addition of small amount of nanoparticles along with the conventional fuel in the engine. Separation of hydrogen atom and formation of the covalent oxygen in the water molecule is due to the present of the Nanofluids [21]. Generation of hydrogen atom is enhanced by nanoparticles. Hydrogen atom dissociated rom the water participate in the combustion and improves the brake thermal efficiency. Due to high flame velocity and mass diffusivity the efficiency will get improved [22]. The combustion and emission characteristics get improved due to substantial properties of nanoparticles such as evaporation rate, mixing rate and surface to volume ratio is higher compared to micro sized particle [23–26]. Smoke and HC emission are reduced due to the presence of excess amount oxygen inside the combustion chamber [27].

Dual fuel engine is a modified diesel engine in which more than one fuel is supplied spontaneously to run the engine so it is called as dual fuel engine. Operating the engine in a dual fuel mode gives pathway to use different type of fuels in the diesel engine which reduce the usage of the conventional fossil fuel in greater extent. Simultaneous reduction of oxides of nitrogen and smoke emission were possible with dual fuel mode of operation. Highly volatile fuels with octane number was used as primary fuel. In general hydrogen, LPG, ethanol and methanol were used as primary fuel. Fuel which contains considerable amount of viscosity and high cetane number was used as pilot fuel. Diesel and vegetable oil are the most commonly used pilot fuel.

Hydrogen induction setup was used to induct the hydrogen as a primary fuel in the intake manifold for dual fuel technique with safety measures, because hydrogen is highly explosive gas among the other combustible fuel. Induction setup consists of Directional check valve, Flow control valve, Gas flow meter and Flame trap.

2. Properties of test fuel

The properties of various pilot fuels such as diesel, water-diesel emulsion, Nanofluids emulsion and primary fuel (hydrogen) was found from the literature is been furnished in the below Table 1.

3. Experimental setup

The schematic diagram of engine experimental set up is shown in the Fig. 1. Kirloskar AV1type single cylinder, four stroke, constant speed, water-cooled, direct injection compression ignition engine coupled with an eddy current dynamometer which was used for the experimental test investigation. A digital speed indicator was used to measure the speed of the engine. Burette and stop watch arrangement was used to measure the fuel consumption of the engine. AVL DI-gas Analyzer was used to measure the engine exhaust emission. Intensity of the smoke emission was measured by means of AVL smoke meter. Exhaust gas was trapped from exhaust line and feed in to AVL DI- gas and smoke meter separately by an exhaust probe.

4. Engine test procedure

Engine coolant oil level and coolant flow was ensured within the limit to avoid overheating. Engine was slowly cranked to ensure the flow of air to the intake manifold and fuel supply line from fuel tank to the fuel injector without any blockage. Fuel line was checked for air lock which causes problem while stating the engine. Initially base fuel diesel was tested for its performance and emission characteristics for variable brake load condition. For each brake load condition fuel consumption rate was measured by observing the level of the fuel in the burette which is mounted in the control panel by using stop watch for volume basis. In case of mass basis the fuel consumption rate is measured by observing the weighing machine mass value for a fixed range time. Engine exhaust emission such as CO, NOx, HC and smoke were also measured from the AVL Di gas analyser and AVL smoke meter which is connected from the engine exhaust probe. Followed by base fuel test, diesel-emulsion and diesel-Nanofluids fuel was tested by following the same procedure.

5. Result and discussion

5.1. Comparative study of performance and emission characteristics

5.1.1. Brake thermal efficiency

The variation of brake thermal efficiency of diesel, diesel emulsion and diesel Nano emulsion with brake power is shown in the Fig. 2. The thermal efficiency of the diesel emulsion is reduced from 28.42% to 26.71% compared to the diesel at high load condition. This is because of reduction in overall temperature of the combustion zone due to higher latent heat of vaporization of water present in the diesel emulsion. But the thermal efficiency was increased with diesel Nano emulsion compared to the diesel emulsion because of decomposition of water molecules into hydrogen and oxygen atom by means of catalytic reaction of the nanoparticles which result in burning of hydrogen in the combustion zone.

5.1.2. Specific fuel consumption

The variation of specific fuel consumption of diesel, diesel emulsion and diesel Nano emulsion with brake power is shown in the Fig. 3. The specific fuel consumption of the diesel emulsion is increased from 0.288 kg/kW-hr to 0.348 kg/Kw-hr compared to diesel fuel. This is because of reduction in overall calorific value of the diesel emulsion (38.8 MJ/kg) due to the presence of non-combustible water content in the diesel emulsion fuel. But the specific fuel consumption was reduced with the diesel Nano emulsion from 0.348 kg/kW-hr to 0.340 kg/kW-hr compared to the diesel emulsion at high load because of increased calorific value (39.8 MJ/kg) of the diesel Nano emulsion due to the presence of Nano particle.

Table 1
Properties of test fuel.

S. no	Properties	Diesel	Diesel emulsion	Nanofluids emulsion	Hydrogen
1	Kinematic Viscosityat 30 °C (CST)	4.1	4.9	4.98	–
2	Flash Point (°C)	55	62	65	–
3	Fire Point (°C)	61	–	–	–
4	Density at 30 °C (kg/m^3)	830	858	859	0.08
5	Calorific Value (kJ/kg)	44,000	38,800	39,800	120,000
6	Cetane Number	45–50	43	50	
7	Flame velocity (m/s)	0.3	–	–	3

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Fig. 1. Engine experimental setup.

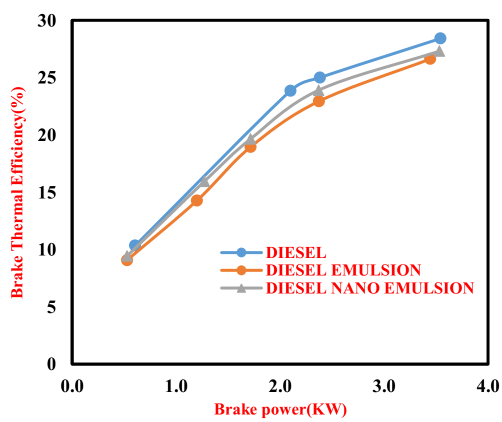

Fig. 2. Brake thermal efficiency Vs brake power.

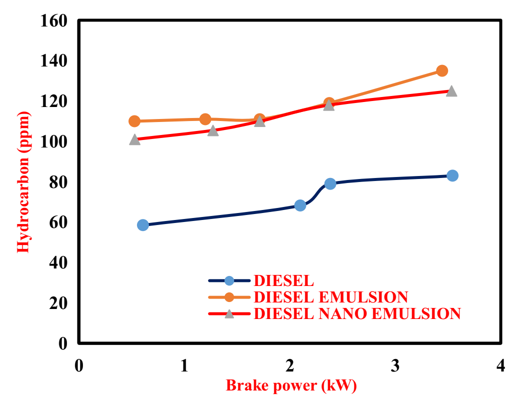

Fig. 4. Hydrocarbon emission Vs brake power.

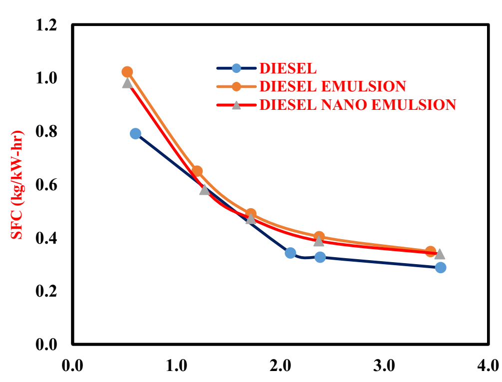

Fig. 3. SFC Vs brake power.

5.1.3. Hydrocarbon emission

The variation of Hydrocarbon emission of diesel, diesel emulsion and diesel Nano emulsion with brake power is shown in the Fig. 4. The hydrocarbon emission of diesel emulsion is increased from 83 ppm to 135 ppm compared to the diesel fuel because of reduced cylinder temperature due to high latent heat of vaporization of water present in the diesel emulsion. This will result in reduced evaporation and mixing rate of the fuel. Hydrocarbon emission was reduced for diesel Nano emulsion compared to the diesel emulsion because of high evaporation rate and mixing rate of fuel that result in improved combustion rate of the charge.

5.1.4. Carbon monoxide emission

The variation of carbon monoxide emission of diesel, diesel emulsion and diesel Nano emulsion with brake power is shown in the Fig. 5. Carbon monoxide emission of the diesel emulsion was increased from 0.09% to 0.12% compared to the diesel fuel. This is because of reduced oxidation rate due to higher latent heat of vaporization of water molecule in the fuel. The CO emission was reduced from 0.12% to 0.11% with diesel Nano emulsion because of higher evaporation rate fuel that results in conversion of carbon

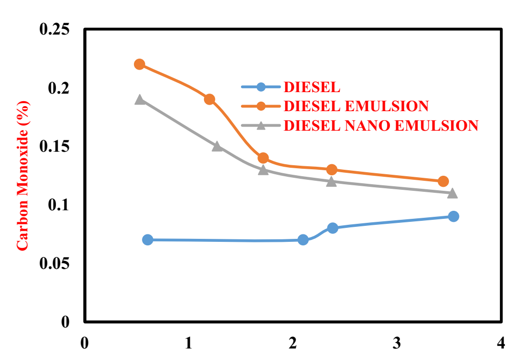

Fig. 5. Carbon monoxide emission Vs brake power.

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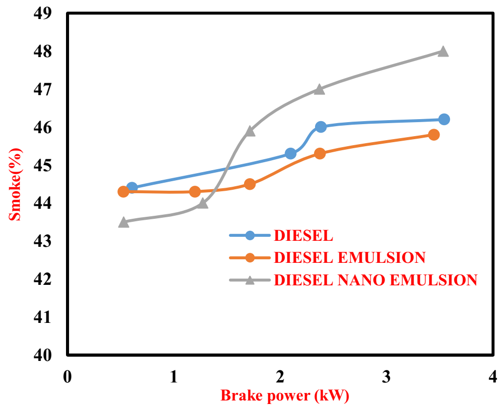

Fig. 6. Smoke emission Vs brake power.

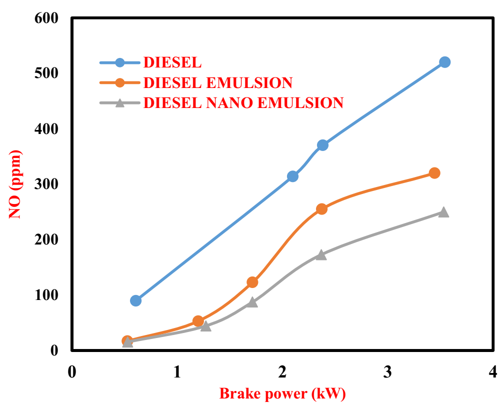

Fig. 7. NO emission Vs brake power.

monoxide into carbon dioxide. Carbon monoxide was converted to carbon dioxide by means of supplement of oxygen atom by decomposition of water molecule in to hydrogen and oxygen atom due to the catalytic reaction of Nano particle.

5.1.5. Smoke emission

The shows variation of smoke emission of diesel, diesel emulsion and diesel Nano emulsion with Brake power is shown in the Fig. 6. Smoke emission of the water diesel emulsion was reduced from 46.3% to 45.3% compared to the diesel fuel at high load condition. This is because of micro explosion which results in secondary atomization of the fuel by this evaporation rate and mixing rate is increased which result in improved combustion rate. But the Smoke emission was increased with the diesel Nano emulsion compared to the Diesel emulsion because of increase in viscosity of the Nanofluids emulsion which causes poor atomization of the injected fuel.

5.1.6. No emission

The variation of NO emission of diesel, diesel emulsion and diesel Nano emulsion with brake power is shown in the Fig. 7. NO emission of the diesel emission was reduced from 520 ppm to 320 ppm compared to the diesel fuel at Peak load. This is because of reduction of peak cycle temperature in the combustion zone due to high latent heat of vaporization of water content in the diesel emulsion. NO emission was further reduced up to 250 ppm for diesel Nano emulsion because of high thermal conductivity of Aluminium oxide Nano particle that causes further reduction in peak cycle temperature.

6. Conclusion

Water diesel emulsion and diesel Nano emulsion is prepared by reformulation of standard diesel and tested in a single cylinder constant speed water cooled direct injection diesel engine for investigation of performance and emission characteristics. Some of the important inference is furnished below after the investigation of the experimental results

- The reduction in percentage thermal efficiency of the diesel emulsion was 6.26% compared to the diesel at high load condition. But the brake thermal efficiency was increased with diesel Nano emulsion compared to the diesel emulsion.
- The specific fuel consumption of the diesel emulsion was increased from 0.288 kg/kW-hr to 0.348 kg/kW-hr compared to diesel fuel. But the specific fuel consumption was reduced with the diesel Nano emulsion from 0.348 kg/kW-hr to 0.34 kg/kW-hr compared to the diesel emulsion at high load.
- The increase hydrocarbon emission of diesel emulsion was 62.65% compared to the diesel fuel. But the hydrocarbon emission was reduced for diesel Nano emulsion compared to the diesel emulsion at all power output
- The increase in Carbon monoxide emission of the diesel emulsion was 33.3% compared to the diesel fuel. But the CO emission was reduced with diesel Nano emulsion because of higher evaporation rate Nano particle that results in conversion of carbon monoxide into carbon dioxide.
- Smoke emission of the water diesel emulsion was reduced by 6.99% compared to the diesel fuel at high load condition. But the smoke emission was increased with the diesel Nano emulsion compared to the diesel emulsion.
- The reduction in NO emission of the diesel emulsion was 38.46% compared to the diesel fuel at peak load. NO emission was further reduced up to 250 ppm for diesel Nano emulsion.

From the experimental results it was found that diesel-Nano emulsion shows better improvement in performance and emission characteristics except smoke emission compared to diesel emulsion.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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