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INVESTIGATION ON EMISSION PATTERN OF BIODIESEL AND NANO-PARTICLES

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Abstract

This work investigates the detailed study on emission characteristics of Compression Ignition Engine (single cylinder, four-stroke Direct Injection) fuelled with diesel, Mustard oil biodiesel (MOBD) and Aluminum oxide nanoparticle (Al_2O_3). Adding a nanoparticle with biodiesel (MOBD $Al_2O_3$100) revealed a decrease in HC and CO emission by 2.2 and 4.3% respectively when compared with neat MOBD at all loads conditions. Smoke and NO_x emissions were decreased by 3.4 and 4.8 respectively due to rapid evaporation of air-fuel mixtures resulting shorten ignition delay period.

Keywords: Al_2O_3; Diesel engine, Mustard biodiesel.

1. Introduction

Diesel engines are widely employed in transport, industrial and power generation sectors due to its lower fuel consumption and its sturdiness (Arul Gnana Dhas et al., 2018; Balan et al., 2018). Demerits of the diesel engine are creating harmful to the ecological environment by emitting harmful pollutants like Nitrogen oxides (Joy et al., 2017), unburned hydrocarbon(Joy et al., 2019), Carbon monoxide(Kishore Pandian et al., 2017) and smoke(Mahalingam et al., 2018). Many numbers of research articles have reported, increase in NO_x emission has shown by using biodiesel blends with diesel(Yuvarajan et al., 2016a, 2016b, 2016c, Devarajan, 2018; Venkata Ramanan and Yuvarajan, 2016). In order to reduce NO_x emission number of attempts has been executed by various researchers like homogeneous mixture preparation through port fuel injection and after treatment method(Velliyan et al., 2018a, 2018b, 2019; Yuvarajan et al., 2018; Sudalaimuthu et al., 2018; Siva et al., 2018). But without altering the engine design and by modification of fuel has proved a reduction of NO_x emission by introducing nanoparticle as an additive (Devarajan et al., 2018b, 2018a). The nanoparticle has high surface area contact between air-fuel mixture, which boost the heat transfer and resulting in the reduced ignition delay and high latent heat of evaporation (Vinoth Kanna et al., 2018a, 2018b; Devaraj et al., 2018).

Addition of Magnesium (Al-Mg) and cobalt oxide (Co_3O_4) nanoparticle with jatropha biodiesel reported reduced exhaust emission and increased performance parameters. (Mahalingam et al., 2018; Devarajan et al., 2016a; Senthilkumar et al., 2018; Devarajan and Munuswamy, 2016). Yuvarajan et al 2018a revealed adding silver oxide nana particles additive to the Neem oil biodiesel results in enhanced engine performance and reduction in emission, owing to quick evaporation of air-fuel mixtures results pathway to reduced delay period. According to Appavu et al 2017, cerium oxide nanoparticles addition to diesel, biodiesel and ethanol blends shows reduced heat release rate and a marginal decrease in ignition delay. Ganesan et al 2018a, b, reported the influence of emission characteristics of adding aluminium oxide nanoparticles with jojoba methyl ester. Pandian et al 2017, showed nanoparticle with biodiesel help in increased engine performance and reduced emission due to the high surface contact area between air-fuel mixtures (Prabhu and Venkata Ramanan, 2018a, 2018b). From the various research findings it is noted, adding of nanoparticles to methyl ester helps to speed up the combustion. The novelty of the experimental work is to reduce NO_x and smoke emission by using Al_2O_3 as a nanoparticle, added with Mustard oil biodiesel (MOBD) in different proportions.

2. Materials and methods

2.1. Fuel preparations

Mustard oil biodiesel (MOBD) is derived by transesterification process. Table 1 shows the fatty acid methyl ester of biodiesel. Aluminum Oxide nanoparticles blended with diesel, mustard methyl ester with the help of the ultrasonic device. Adding of 0.025g of the nanoparticle to diesel, methyl ester of 1litre is referred to be 25ppm(0.025 g/l). Then the added mixture is shaken well and introduced into ultrasonic vibrator at a frequency of 20KHz for 30 min to get uniform dispersion (Mahalingam et al., 2018). Similar way 100ppm and 200ppm blends were achieved (Devarajan et al., 2018f). Table 2 shows the properties of test fuels.

Table 1. A fatty acid composition of biodiesel

Fatty acids	Biodiesel
Myristic C14:0	0.00
Palmitic C16:0	24.20
Stearic C18:0	25.80
Oleic C18:1	37.20
Linoleic C18:2	12.80

Table 2. Properties of Tested fuels

PROPERTIES	MOBD	Diesel	METHOD
Density @ 15°C (gm/cc)	0.844	0.8200	ASTM D4052
Kinematic Viscosity	4.28	2.4	ASTM D445
Calorific Value (kJ/kg)	37510	42957	ASTM D240
Cetane Index (CI)	51	47	ASTM D976
Flash point (°C)	141	48	ASTM D620

2.2 Experimental Setup:

Current work is conducted in Four-stroke, single cylinder, compression ignition engine. AVLDI gas444, AVL 437 was employed to measure CO, HC and NO_x and smoke opacity respectively. ASTM testing procedure was employed to get fuel properties. The experiment was carried out by starting the engine initially with diesel fuel to maintain a steady state (warm-up condition), followed by diesel, MOBD, MOBD$Al_2O_3$100, MOBDAl2O3200. Constant speed is followed throughout the experiment. Engine specification is given in table 3. The Range and accuracy details of exhaust gas analyzer are tabulated at table 4

Table 3. Specification of Experimental Setup

Make, Model	Simpson –S217
Stroke	4
Cylinder	Two
Rated Power	4.5 kW
Rated speed	1800 rpm
Bore diameter (D)	91.44 mm
Stroke (L)	127 mm
Compression ratio	18.5:1
Injection Timing	23° BTDC
Injection pressure	200 bar

Table 4. Range and accuracy details of exhaust gas analyzer.

Pollutant	**Range**	**Accuracy**
CO	0-15.0 vol. %	0.01 vol. %
HC	0-30000 ppm vol.	±1 ppm vol.
NOx	0-5000 ppm vol.	±1 ppm vol.
Smoke meter	0-100%	± 1%

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3. Results and discussion

3.1 NOx Emission:

Exhaust emission in the compression ignition engine depends on the fuel distribution and the time of mixing (Pandian et al., 2018; Radhakrishnan, 2017). Since the fuel is injected just before the combustion process, the fuel distribution is non-uniform and follows heterogeneous mixture. This results in a rapid increase of burned gas temperature inside the cylinder creating the NO_x emission (Vinoth Kanna, 2018). Figure 1 illustrates the variation in NO_X emissions for MOBD and MOBD$Al_2O_3$100 and MOBD$Al_2O_3$200. Due to higher oxygen content in MOBD, resting higher temperature at the time of combustion causing increased NO_x emission compared to diesel (Devarajan and Ramanan, 2016a; Devarajan and Madhavan, 2017). A blending of nanoparticles to biodiesel(MOBD$Al_2O_3$100, MOBD$Al_2O_3$200) shows decreased NO_x emission compared to MBD at all loads. Addition of Al_2O_3gives shorten ignition delay and promotes the effective catalytic reaction between the air-fuel mixtures resulting in lower NO_x emission (Siva Subramanian et al., 2018b).

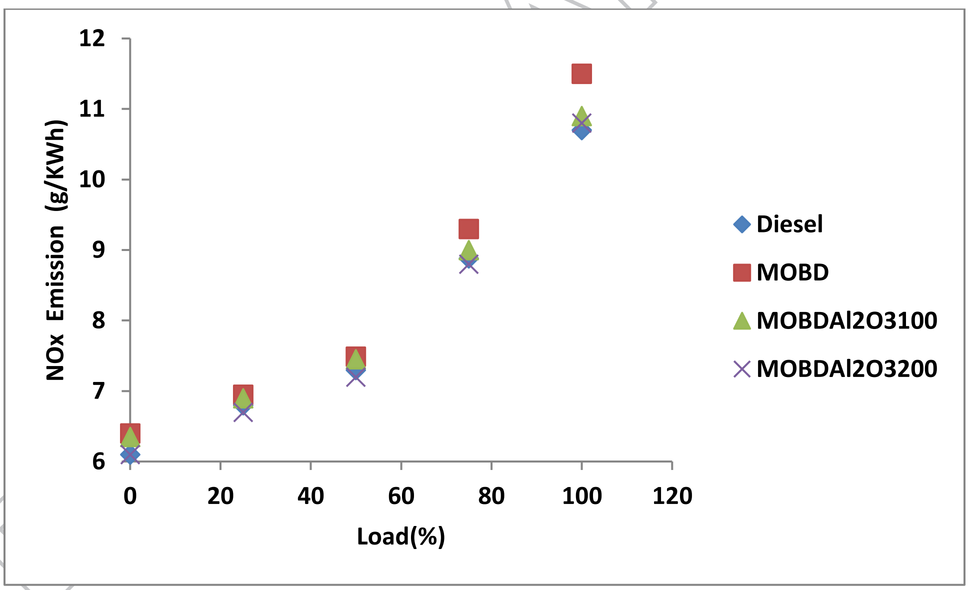

Figure 1. Change in NO_X emissions

3.2 CO Emission:

At rich air-fuel mixtures, carbon monoxide emission is formed owing to insufficient oxygen. Carbon-mon-oxide emission may occur at poor mixing, inadequate oxygen to burn air-fuel mixtures and incomplete combustion (Devarajan et al., 2017a; 2017b, 2018d). Figure 2 illustrates the variation in

CO emissions for MOBD and MOBDAl$_2$O$_3$100 and MOBDAl$_2$O$_3$200. MBD shows less CO emission compared to diesel, due to its oxygen content present in it. MOBDAl$_2$O$_3$100, MOBDAl2O3200 shows less CO emission than MOBD at all loads. The presences of Nano addition to biodiesel act as a catalytic activity for improved combustion resulting in less CO emission (Rathinam et al., 2018; Siva Subramanian et al., 2018; Arul Gnana Dhas et al., 2018).

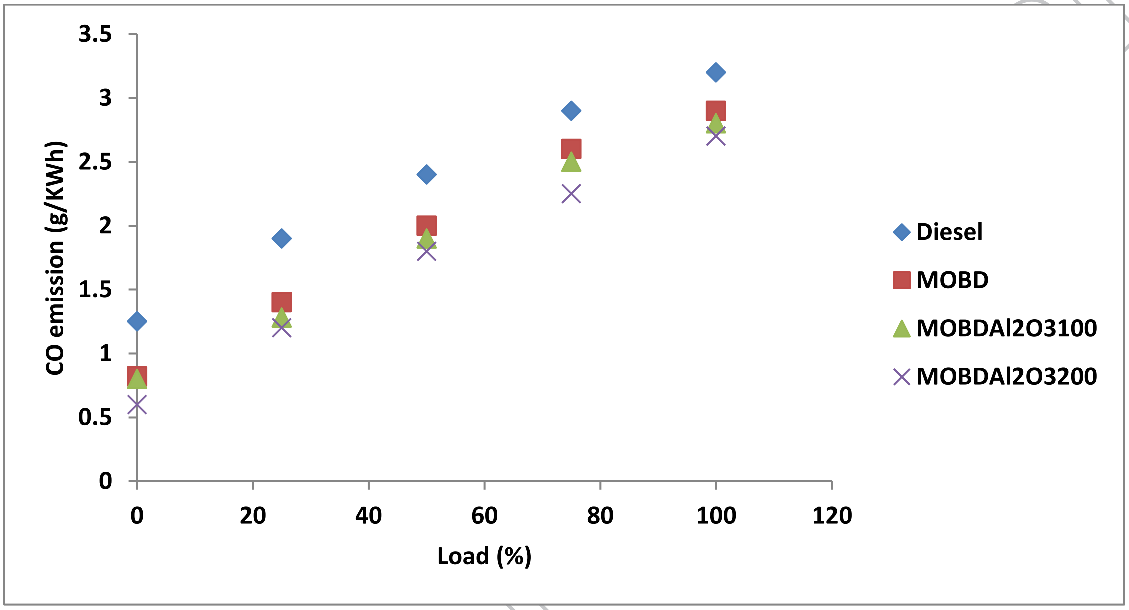

Figure 2. Change in CO emissions

3.3 HC Emission:

When compression and combustion process occurs in an engine, there is a rapid increase in pressure force, which tends the gas(air-fuel) mixtures in the cylinder into crevice volume (Devarajan et al., 2016). These gases do not participate in primary combustion. During the expansion and exhaust process, this gases leave the crevices and resulting in the unburned Hydrocarbon. Due to poor atomization of fuel droplets may cause lower cylinder wall temperature leads to incomplete combustion causing unburned hydrocarbon. Figure 3 illustrates the variation in HC emissions for MOBD and MOBDAl$_2$O$_3$100 and MOBDAl$_2$O$_3$200. MOBD shows less HC emission compared to diesel, owing to its surplus oxygen content helps to achieve better combustion. MOBDAl$_2$O$_3$100, MOBDAl$_2$O$_3$200 resulting less HC emission than MBD, owing to its larger surface area creates chemical reactivity between the air-fuel mixtures (Rathinam et al., 2018; Ravikumar and Saravanan, 2016).

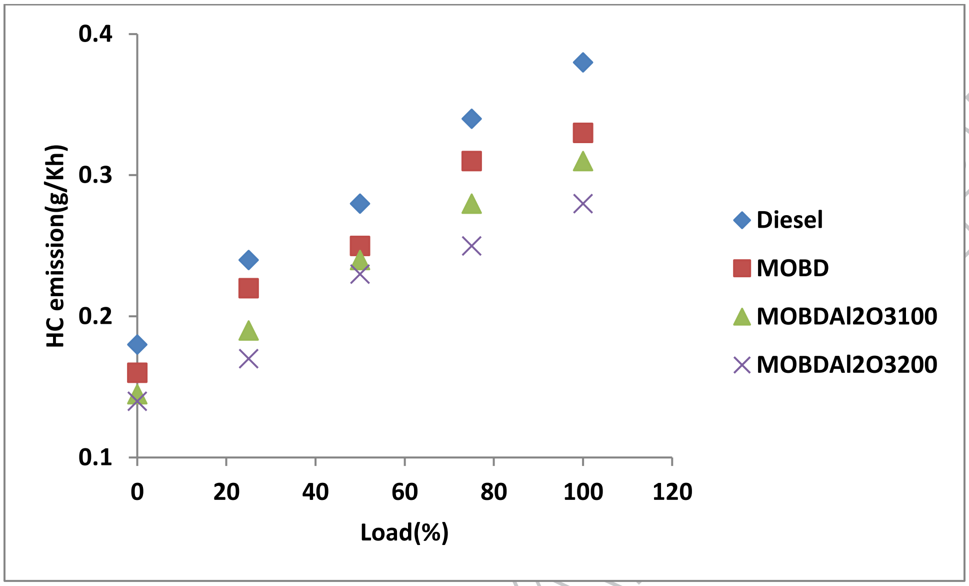

Figure 3. Change in HC emissions

3.4 Smoke:

Figure 4 illustrates the variation in CO emissions for MOBD and $MOBDAl_2O_3100$ and $MOBDAl_2O_3200$. Due to fuel pyrolysis, at rich fuel mixture tends to high-temperature zones owing to the formation of smoke emission (Yuvarajan and Ramanan, 2016b, 2017). $MOBDAl_2O_3100$, $MOBDAl_2O_3200$ shows reduced smoke emission compared to MOBD and Diesel. Nanoparticles present in the fuel blend promotes the turbulence, where the air-fuel mixture gets improved mixing for combustion and resulting reduced smoke emission at all loads (Pandian et al., 2018).

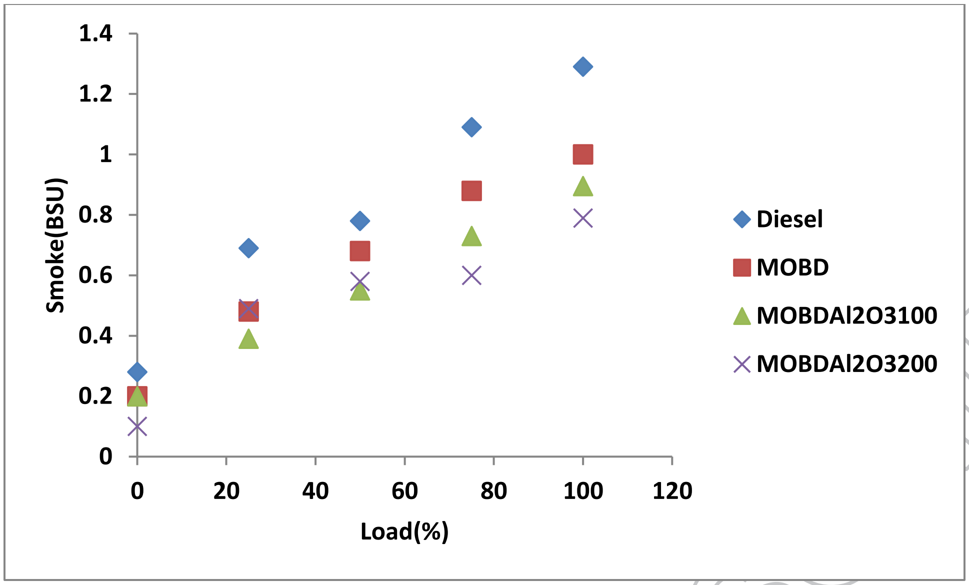

Figure 4. Change in smoke emissions

4. Conclusion:

Current work is conducted in four stroke, single cylinder, compression ignition engine fuelled with diesel, MOBD, MOBDAl2O3100 and MOBD$Al_2O_3$200. The outcome of Al_2O_3 nanoparticle, with base fuels (diesel+MOBD) emission characteristics, were investigated. The footprint of the petroleum diesel and non-petroleum fuels was compared in this work as follows.

- Presence of Nanoparticles in biodiesel (MOBD$Al_2O_3$100 and MOBD$Al_2O_3$100) shows reduced CO, HC and smoke emission at all loads compared to diesel.
- NOx emission resulted high for MOBD, MOBD$Al_2O_3$100 and MOBD$Al_2O_3$200 compared to diesel.
- Influence of Al_2O_3in MOBD shows the decrease in CO, HC and smoke emission at all working conditions due to the catalytic effect and more surface area contact between air-fuel mixtures

- Influence of $MOBDAl_2O_3100$ and $MOBDAl_2O_3100$ shows a reduction in NO_X while comparing with MOBD due to shortening ignition delay and heat absorption of water molecules present in Nanofluids.
- No provisions were provided to remove the nanoparticle after the combustion from the exhaust system. However, the removal of nanoparticle in tailpipe after combustion is in the future scope of research.

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