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Role of nanoadditive blended biodiesel emulsion fuel on the performance and emission characteristics of diesel engine

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ABSTRACT

An investigational research is carried out to found the performance and emission characteristics of a direct injection (DI) diesel engine with aluminium oxide nanoparticle additives in water and biodiesel blend. Palm methyl ester was produced by transesterification and blended with water. Aluminium oxide nanoparticles of 50 and 100 ppm in proportion are subjected to high-speed mechanical agitation followed by ultrasonication. The experimentations were conducted on a single cylinder DI diesel engine at a constant speed of 1500 rpm using different aluminium-oxide (AL_2O_3)-blended with emulsified biodiesel (PBD5%W+100ppm, PBD10%W+50ppm, PBD15%W+100ppm, PBD20%W+50ppm) and the outcomes were compared with those of neat diesel and Palm biodiesel. The experimental results indicated that brake thermal efficiency of PBD20%W+50 ppm and PBD+15%W+100ppm aluminium oxide was increased by 3-4% with 1.72% betterment in specific fuel consumption. Emissions of nitrogen oxide and hydrocarbon were reasonably lower than diesel fuel.

Keywords: Bio diesel; emulsification; surfactants; diesel engine; emissions.

INTRODUCTION

Faster depletion of fossil fuels and strict emission regulations drive the researchers to search for alternative fuels for diesel engines. Efforts have been made to use straight vegetable oils as fuel in diesel engines. But higher viscosity of vegetable oil restricts its direct use in diesel engines. So the vegetable oils are converted in to biodiesel using transesterification process. Biodiesel is a renewable energy, which is considered the most viable alternative for replacement of mineral diesel fuel in compression ignition engines [1, 2]. It is a biodegradable fuel comprised of fatty acid methyl ester and synthesized from the transesterification of vegetable oil or animal fats [3]. The world currently mandates biodiesel usage based mostly on blending with diesel fuel. These blends are designated according to the biodiesel blending volumetric percentage, where B100 represents 100% biodiesel, B20 indicates 20% biodiesel and B30 indicates 30% biodiesel, depending on the volumetric percentage [4]. Palm oil is derived from a plant that is perennial and grows in tropical regions, especially humid lowlands. In general, palm oil has the highest oil yield compared to other common biodiesel feed stock; as a comparison, production is about thirteen times higher than that of soybean [5]. It very well may be finished up from the examination that the fuel properties of palm biodiesel have affected the majority of the ignition parameters, psychochemical properties and higher oxygen content [6,7]. The reduction in emissions accomplished by appropriately planned diesel-water emulsification is universal regardless of engine. The essential advantage of water-diesel emulsions in diesel engines is a prominent decrease in NO_x emissions [8], Nano-added substance mix reduced peak pressure heat release rate and ignition delay as compared to neat diesel, it was likewise revealed that there was lessening in NO_x and smoke emissions with emulsified fuel [9]. The adding of water as emulsion improved combustion efficiency. It was found that brake power, engine power and also the engine torque were enhanced with the emulsified powers for both diesel and benzene till expansion of 25% water. Adding water to diesel-benzene could reduce bad emissions of the vehicles [10, 11].

The emulsion technique had higher capability of synchronous lessening of NO_x and smoke outflow at all loads than water injection method. In any case, CO and HC levels were higher with emulsion than water infusion [12]. Discharges of NO_x and PM diminished up to 30% and 60%, individually though hydrocarbons and carbon monoxide increased with increasing s water content in the emulsion. The combustion efficiency was enhanced when water was emulsified with diesel up to 15 % [13]. The combustion began before for biodiesel and its blends compared to diesel [14]. The peak cylinder pressure of biodiesel and its blends was found to be higher than that of diesel fuel at lower loads and almost identical at higher engine loads. The peak pressure rise rate and peak heat release rate for biodiesel were higher than those for diesel fuel at lower engine loads, but were lower at higher engine loads [15]. The vegetable oil ordinarily contains free fatty acids, water, high viscosity and poor volatility, some techniques to overcome these troubles are Preheating, Blending, Micro emulsion, Pyrolysis (Thermal breaking), transesterification. The area describes the execution parameter BTE and BSFC of biodiesel gotten from a few vegetable oils. Additionally, discharge parameters like carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NO_x), and smoke thickness of different biodiesel mixes have been watched [16]. The functional groups in the emulsifiers, bio-oils, and diesel are dissected by a Fourier transform infrared spectroscopy (FTIR) to recognize the qualities of emulsions. Where three commercial Emulsifiers (i.e., Span 80, Tween 80, and Atlox 4914) and the bio-oils created from the quick pyrolysis of wood squanders were utilized. The outcomes propose that Atlox 4914 gives the best execution compared with Span 80 and Tween 80. The relationship of ideal HLB and HHV gives the best outcome [17]. The emulsification innovation has been considered to lessen the NOx emanation level of fuel. The surfactants (span80 and tween80) add for an appropriate blending of w/o and o/w/o emulsions. The impacts of the emulsification factors, for example, hydrophilic-lipophilic adjust (HLB), and water content on the fuel properties and emulsion qualities of W/O and O/W/O emulsions were examined. The trial comes about demonstrate that the surfactant blend with HLB = 13 delivered the most astounding emulsification dependability while HLB = 6 created the least emulsification stability [18]. The presence of oxygen in the soybean biodiesel, and the better blending abilities of the nanoparticles, diminish the CO and unburned HC considerably, however there is a little increment in NOx at full load condition [19]. The distinctive qualities of the molecule agglomerates are responsible for the different micro explosion behaviour that was observed

[20]. Significant decrease was also observed in level of pollutants in emissions using nanoparticles. Characterization of AlO(OH) nanoparticles utilising XRD and TEM was analyzed [21]. This study aims to characterize the emulsified biodiesel fuel properties for its application in diesel engine and to conduct the experimental investigation without modifying the engine settings such as injection timing, injection pressure, and compression ratio. Moreover, experiments with biodiesel, diesel, Biodiesel with water emulsion by adding aluminium oxide nano particles are conducted.

MATERIALS AND METHODS

Preparation of Biodiesel

The raw Palm oil was extracted from the seeds of Palm fruit. The Figure 1 shows the (a). Palm fruit and Palm oil (b). The raw oil was procured from the local market and the biodiesel was prepared by transesterification process as shown in Figure 2.

(a) (b)

Figure 1. Palm fruit (a) and Palm oil (b).

Methodology

Biodiesel is prepared from palm oil using transesterification process. The steps that are carried out while preparing biodiesel using palm oil by transesterification process are as follows: First 1 litre of palm oil is poured in a pan and then heated up to a temperature of 60°C. A beaker is filled with 200ml of methanol and then about 3.5 g of Sodium Hydroxide is added as a catalyst. The beaker is closed and then stirred for about half an hour and Sodium Methoxide is formed as a result. The heated oil is poured into a separate container and then the Sodium Methoxide solution is mixed along with the heated oil. The mixture is allowed to settle for about 12 hours and then the biodiesel is formed along with glycerine, deposited at the bottom. Finally, the biodiesel is separated from the container by using the separating funnel and then it is added in the definite proportions along with the water to be used for the experimental verifications by adding aluminium oxide.

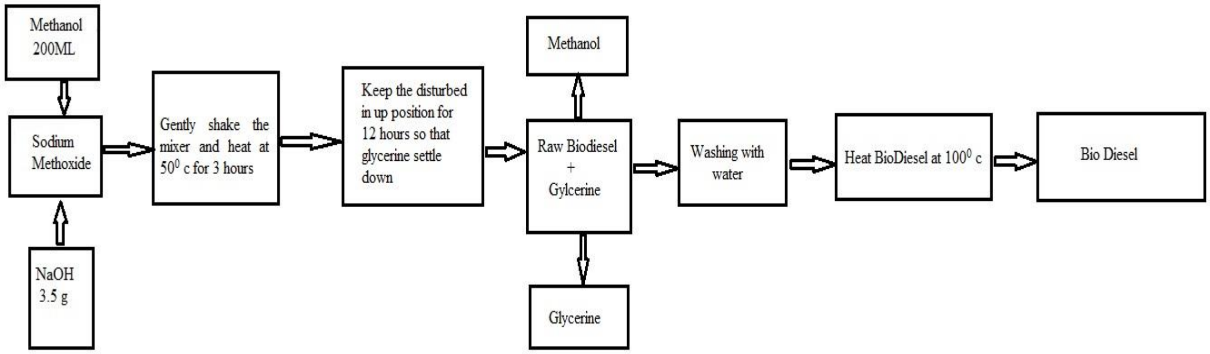


Figure 2. Transesterification process

Preparation of Nano Particle Blended Emulsified Palm Blends

The biodiesel emulsion fuel is prepared by emulsification technique comprising of palm biodiesel, (5%,10%,15%,20%) of water, and 2% of surfactants (Span80 and Tween80) with the aid of a mechanical agitator as shown in Figure 3. The prepared biodiesel emulsion fuel is mixed with the alumina nanoparticles in the mass fractions of 50 ppm and 100 ppm with the aid of ultrasonicator set at a frequency of 20 kHz for 2 hr. The resulting fuel samples are termed as PBDS 5W100A, PBDS10W50A, PBDS15W100A, PBDS20W50A. The fuel samples are characterized and their properties are tabulated in Table 1.

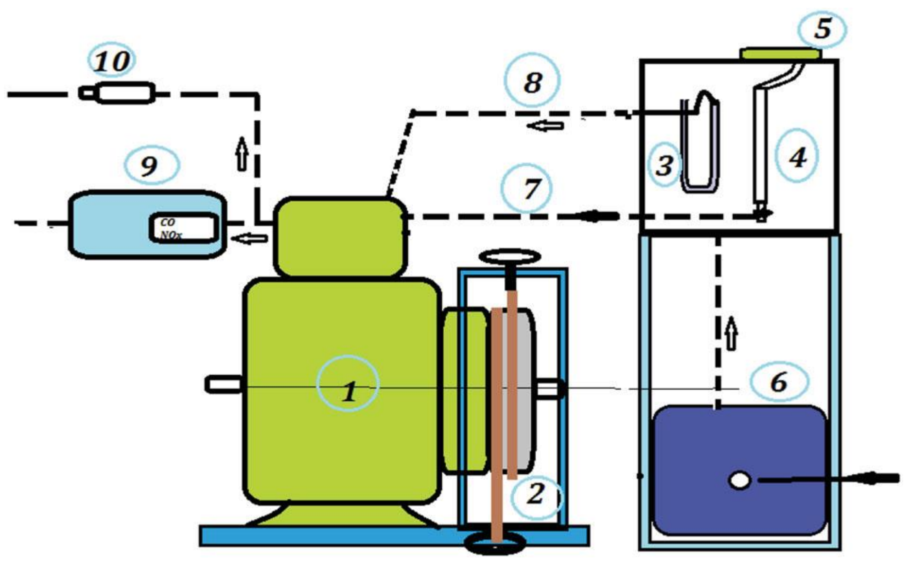
Figure 3. Emulsified biodiesel with different nano particles concentration

Table 1. Properties of tested fuel samples

Fuel	Flash Point (^{0}C)	Fire Point (^{0}C)	Viscosity (Centistokes)	Calorific value(kJ/kg)
Diesel	52	57	5.32	43000
Bio diesel	170	175	7.57	39900
Emulsion1 (5%w+100ppm)	168	172	7.23	39000
Emulsion 2 (10%w+50ppm)	170	174	7.9	37800
Emulsion 3 (15%w+100ppm)	172	176	8.3	37500
Emulsion 4 (20%w+50ppm)	179	183	8.5	36700

Experimental Setup and Procedure

In the investigational preparation, a single-cylinder, four-stroke, constant speed, water-cooled, high-speed diesel engine with a rope brake dynamometer is used as shown in Figure 4. The specifications of the engine are given in Table 2. To measure the air consumption, an air box with small orifice is provided at the air inlet. A 5 Gas analyzer and smoke meter with smoke gun are used to analyse the exhaust gas and smoke, respectively.



1. Engine
2. Mechanical loading
3. Manometer
4. Fuel level indicator
5. Fuel tank
6. Air box
7. Fuel in
8. Inlet air through air box
9. Five gas analyzer
10. Smoke gun

Figure 4: Schematic diagram of Experimental setup

Table 2. Engine specifications.

Description	Specification
Bore	80mm
Stroke	110mm
RPM	1500
BHP	5HP SINGLECYLINDER)
Compression Ratio	16.5:1
Method of loading	Manual
Injection pressure (bar)	200
Make	Kirloskar AV-1

RESULTS AND DISCUSSION

The experimental analysis on the performance and emission characteristics of a diesel engine with alumina-nano-added blends of emulsified Palm bio diesel is illustrated in this section.

Performance and Characteristics

The variation of BTE with respect to engine loads, for different emulsified bio diesel with nano additives blends of PME (PBD5%W+100ppm, PBD10%W+50ppm, PBD15%W+100ppm, PBD20%W+50ppm) is shown in Figure 5. The BTE was increased with the addition of Nano in all tested emulsified biodiesel blends compared to neat diesel. Because of the effect of micro-explosion of the water droplets contained in the emulsion fuel, which helps to break the larger size droplets oil into smaller one, accelerating fuel evaporation and mixing with air, thereby resulting in a faster combustion process and the higher BTE. The BTE is improved by 3 to 4 % with BD+20%W+50 ppm and BD+15%W+100 ppm of Al_2O_3 because improved combustion characteristics and uniform burning [19,20].

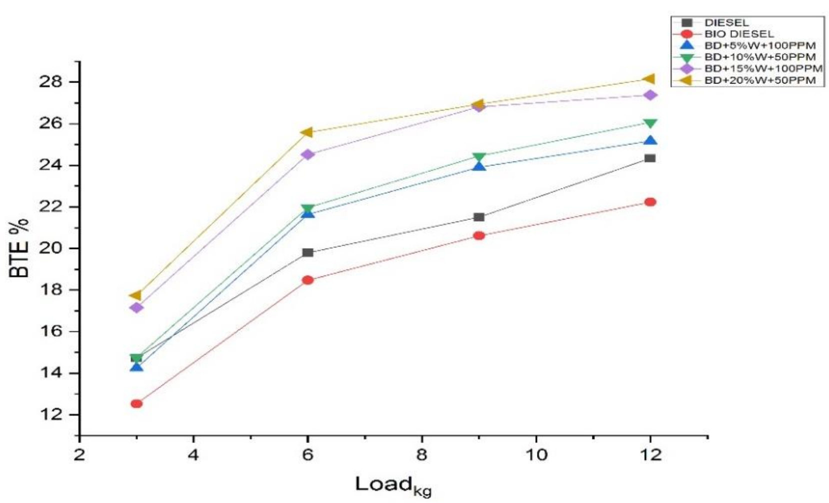


Figure 5. Load v/s BTE for Emulsified Bio diesel with nano additives

Figure 6 shows the variation of BSFC with respect to engine loads, for different emulsified bio diesel with nano additives blends of PME (PBD5%W+100ppm, PBD10%W+50ppm, PBD15%W+100ppm, PBD20%W+50ppm) is shown in Figure 6. The BSFC was decreased with the addition of Nano in all tested emulsified biodiesel blends because of improved surface to volume ratio by the catalytic effect during the combustion. The BSFC for PBD+15%W+100 ppm of aluminium oxide was lowest as 0.28 kg/kWh, which is 1% better than diesel. And also due to the presence of the alumina nano particle that increases the atomization rate and the large surface area, of the fuel leading to complete combustion [19,20].

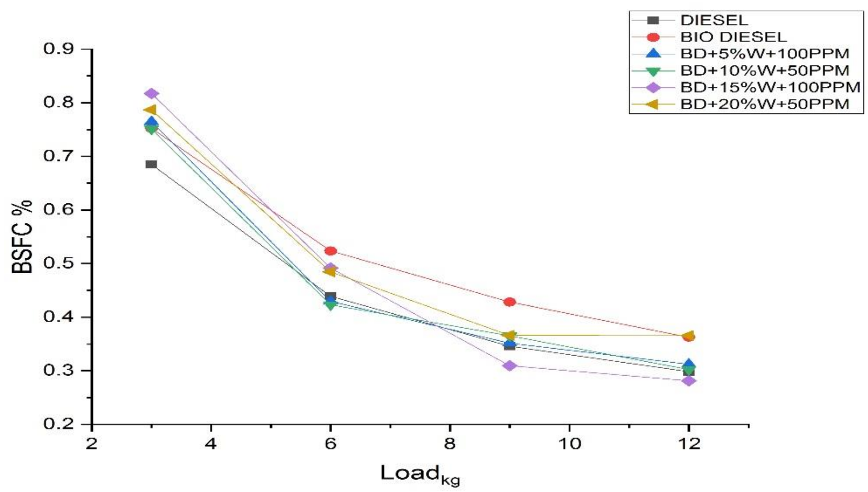


Figure 6. Load v/s SFC for emulsified bio diesel with Nano additives

Emission Characteristics

The disparity of NOx with respect to the load for the tested Al_2O_3 nano-added emulsified biodiesel blends is shown in Figure 7.

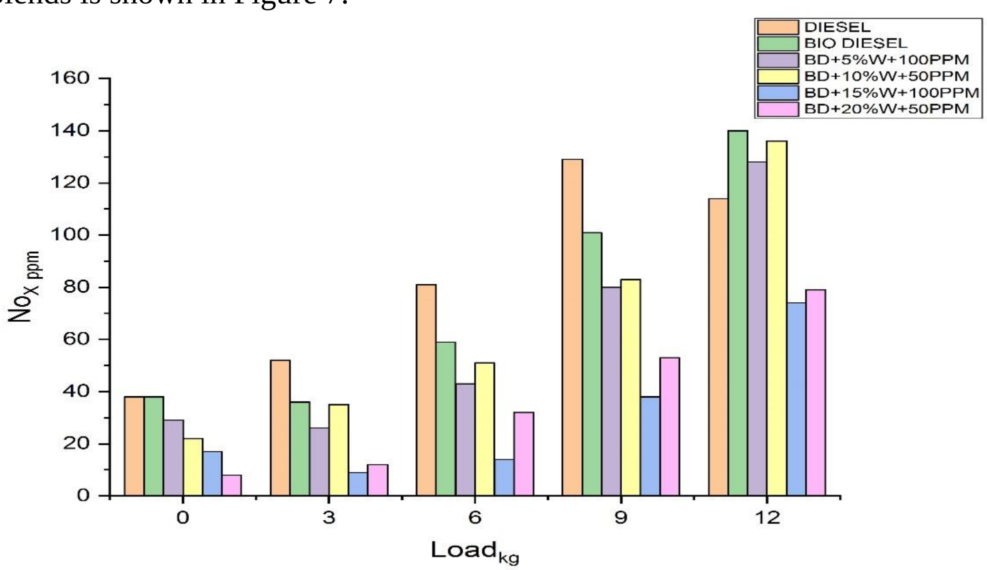


Figure 7. NO_X Vs Load for emulsified bio diesel addition of nano additives

Formation of NOx mainly depends on higher temperature presents in the exhaust gas. The variation of NOx emission with engine load for diesel, PBD and PBD emulsions with nano additives are shown in fig. NOx formation 114 ppm for full load condition while operating with diesel. PBD Produces 140 ppm of NOx emission at full load condition. The corresponding NOx emission values of (PBD5%W+100ppm, PBD10%W+50ppm, PBD15%W+100ppm, PBD20%W+50ppm) are 128ppm,136ppm,74ppm,79ppm. at full load operating condition. The reason behind reduced NOx emission, It is the presence of water which absorbs heat to evaporate there by bringing down the peak temperature of the flame with adding the nano powder NOx emissions are reduced with compare to diesel [20,21].

Figure 8 shows the variation of HC with engine load for diesel, PBD and PBD emulsions with nano additives are shown in Fig 8. Hydrocarbon emission of 7 ppm for 3kg load varies to 18ppm for full load condition of diesel. Incase of PBD varies from 4ppm at 3kg load to 17ppm for full load condition. The corresponding NOx emission values of (PBD5%W+100ppm, PBD10%W+50ppm, PBD15%W+100ppm, PBD20%W+50ppm) are 12ppm,13ppm,11ppm 13ppm.With adding the nano powder the HC emissions are decreased because of complete combustion of the fuel inside the cylinder [19].

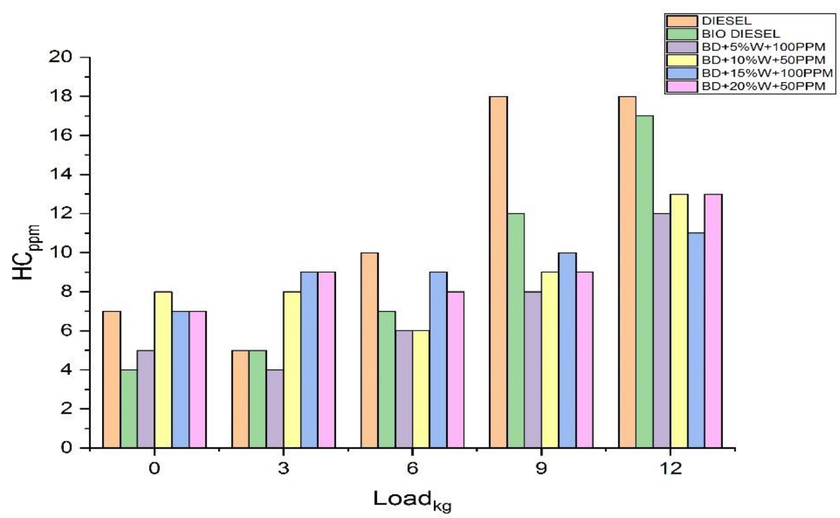


Figure 8. HC Vs Load for emulsified bio diesel addition of nano additives

Figure 9 shows the variation of CO_2 emission with engine load. The CO_2 emission increases with the engine load. At the partial loads almost all the nano-added tested fuels have given the same or lesser CO_2 emissions compared to pure diesel. With addition of nano particles CO_2 emission decreased compare to diesel. Because of complete combustion of the fuel inside the cylinder.

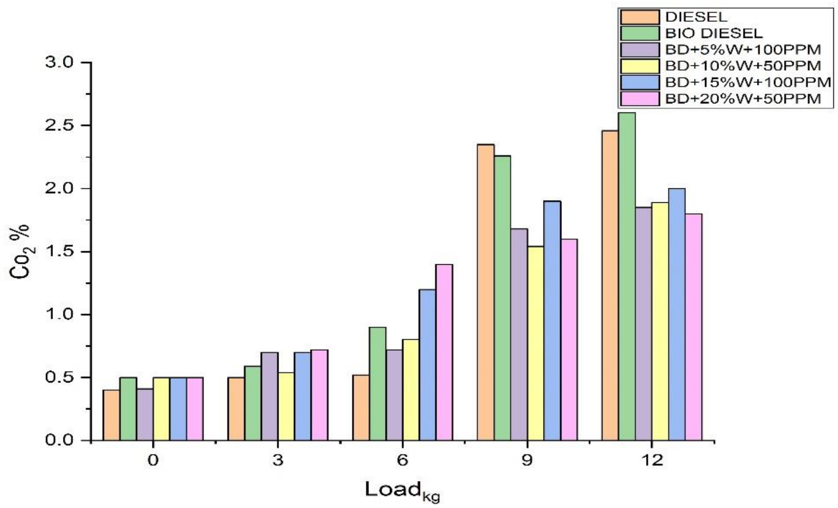


Figure 9. CO_2 Vs Load emulsified bio diesel addition of nano additives

Figure10 shows the variation of CO emission. The CO emission increases with the engine load. Carbon monoxide is emitted as a result of incomplete combustion of carbon and oxygen under high temperature inside the cylinder. At full load condition diesel having 0.038% CO and the bio diesel contains lower CO compare to diesel 0.027%. And (PBD5%W+100ppm, PBD10%W+50ppm,PBD15%W+100ppm,PBD20%W+50ppm)produces0.022%,0.021%,0. 04%,0.036%.With adding the nano powder the CO emissions are same as diesel and slightly decreased for PBD5%W+100PPM , PBD10%W+50PPM because of complete combustion of the fuel inside the cylinder.

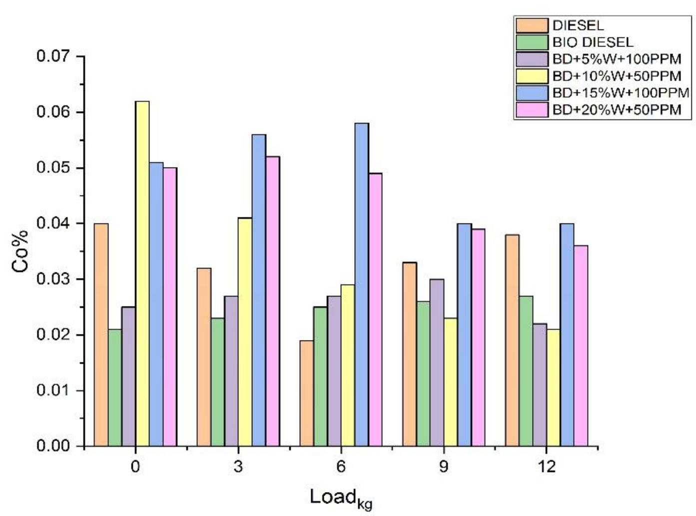


Figure 10**.** CO Vs Load emulsified bio diesel addition of nano additives

CONCLUSIONS

The performance and emission characteristics of a single cylinder diesel engine with various proportions of cerium oxide nano particles in different blends of biodiesel are investigated. The effects of cerium oxide nano particle additive in diesel biodiesel blends are analyzed. The following major conclusions are arrived from the analysis of experimental investigations: The BTE increases for PBD20%W+50 ppm and PBD+15%W+100ppm aluminium oxide by 3% to 4% when comparing with the diesel. The SFC reduces by 1.72% with addition of ppm ALUMINA to PBD+15%W+100ppm. The NOx emissions of PBD20%W+50 ppm fuel are lower by 35-40 ppm at maximum loads compared to diesel. The CO and HC emissions are same as diesel and slightly decreased for nano added emulsified biodiesel because of complete combustion of the fuel inside the cylinder.

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