Impact of Nano additives on optimized Mahua Bio-diesel Performance

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Abstract. In both industrial and transportation sectors, petroleum consumption has been increasing tremendously. It is known that increase in demand of fossil fuels leads to exhaust of petroleum products in future. Biofuel is a fuel made by chemically reacting alcohol with vegetable oils, fats, or greases, such as recycled restaurant greases. The metal-based additives are used in order to improve the quality of fuel by reducing the unburn hydrocarbons in IC engines, to minimize the exhaust gas harmful emissions. In the present experimental work, an attempt is made at investigating the effect of Aluminum oxide and copper oxide nanoparticles addition in Mahua biodiesel in a single cylinder water cooled direct injection four stroke diesel engine. Initially experiments are conducted to optimize the blend of transeterified Mahua oil with diesel fuel with respect to Combustion, performance and emission parameters. The nano fluids have been prepared from 50 ppm concentrations of Aluminum oxide and copper oxide separately, through an ultra-sonication process. For optimized biodiesel of Mahua oil, the effect of nano additives on Combustion characteristics viz cylinder pressure, Heat release rate, performance parameters such as BTE, BSFC and emission parameters HC, CO, CO_2, NOx emissions were evaluated and compared. In CI engines, with biodiesel usage reduces the emission particulates to the significant extent. Due to the presence of oxygen content in bio diesel, which causes increase in NOx formation. In this work there is significant reduction in emission oxides of nitrogen is noticed with nano additives due to control of in-cylinder temperature.
Key words: Combustion, Nano fluids, Heat release rate, Cylinder pressure, Emissions

1 Introduction

Biofuels production as an alternative and renewable energy source to replace the Petroleum based fuel supplies. Biodiesel fuels are suitable with the current fuel system and can be used without modification in diesel engines. This is the world's fastest rising alternative fuel for transportation. Because of good combustion properties, vegetable oils are considered one of the effective replacement fuels for internal combustion engines. It is the world's fastest-growing alternative fuel for transport. Because of the desirable combustion properties for many applications non edible oils are treated as one of the most effective natural fuels. The main cause of encouraging the internal combustion engine to look for alternative fuels is concerned about the problems associated with gasoline engine pollution.

In this scenario, bio-diesel is seen as the best alternative fuel for various sectors such as transport, agriculture, manufacturing, etc. Its production also creates jobs for rural people by planting plants which produce vegetable oil [1]. Biodiesel has desirable combustion properties and non-toxic biodegradability as it derived from local and renewable resources. It has been stated that the availability of 26 species of fatty acid methyl esters makes appropriate use as substitute fuel [2]. One of the motives for consuming Mahua oil as biodiesel is diminished emission trends because of its favourable combustion behaviour in comparison with diesel. Approximately a one-third yield of Mahua oil is found with its seeds by weight and is comestible and mostly in soap and production of glycerine. The heating value in comparison with diesel is 88.26% on weight basis and 96.3% on volume-basis [3]. The readiness of oxygen in the biodiesel enhances the heat in the combustion chamber at the end of the compression phase, leads to reduction of the emission particulates except oxides of Nitrogen emissions [4]. Mahua biodiesel preparation and its characteristics were considered to achieve lesser output of power and emissions on diesel engines [5]. It is reported that with biodiesel HC emissions are reduced by 16.2%, CO emissions are reduced by 11.4%, carbon dioxide emissions are reduced by 5.3% because of the presence of oxygen content. An enhancement of 8.4 percent in Nitrogen oxide emissions with optimal blend of Mahua methyl ester compared to diesel at peak load. Biodiesel exhibits higher cylinder temperatures as it contains higher oxygen content, leads to intensification of oxides of nitrogen emissions [6].
Modern nanotechnology offers great opportunities to process and manufacture materials with an average

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crystalline size of less than 50 nm and to apply the same to increase the thermal conductivity of fluids through dispersion [7, 8]. Using biodiesel nano additives, the obtained results conveyed enhanced fuel characteristics in improving the efficiency of combustion apart from reduction in harmful emissions. For Mahua biodiesel with nano additive is very much suitable as a substitute fuel for diesel engine to improve performance and emissions [9,10]. Biodiesel with oxygenated and metal oxide the addition shows less emission particulates at rated loads than fractional loads, resulting in lower BSFC, NOx, HC, CO_2 emissions [11,12]. The peak pressure of combustion and rate of heat release are improved with the addition of aluminum nano additive for Mahua methyl ester blend fuelled by the direct injection with approach of common rail type in diesel engine, leads to reduction in delay in ignition [13]. The BTE is enhanced by approximately 3% with nano additive of ZnO when compared to diesel, further diminishing in NOx emissions has been noticed [14]. By influencing 25 ppm Titanium nano additives, it is noticed that there is improvement in-cylinder pressure and heat release rate with reduced emissions, further 25 ppm Zirconium nano additives, reduced cylinder pressure and increased HC emissions and reduced CO, smoke emissions have been noticed [15]. This study is focused to present the impact of nano additives on characteristics of diesel Engine which is operated by using optimised Mahua biodiesel

2 MATERIALS & PROCEDURE FOR THE EXPERIMENTATION

2.1 Preparation of Mahua Biodiesel

As Mahua oil has high viscosity which leads to combustion problems such as handling of fuel, weak atomization, pressure of injection etc., the only solution to overcome these limitations is Transesterification of the oil. In the present work, to reduce the viscosity Transesterification is execute with alkali catalyst to have quicker reaction process. In this process, 500 ml of Mahua oil and methanol of 200ml are assorted including 5grams NaOH, which is placed for 2 hrs at approximately to 640°C in ultrasonicator to have stirring arrangement along with heating. Then it is retained in the condition for 8 to 10 hrs to separate glycerol from biodiesel. Further, any content of moisture in bio-diesel was sweep away for two times with distilled water and heated above 100° C to eliminate the acids. The aesthetic appearance of transeterified Mahua oil is shown in Fig1. In this investigation, for characteristic parameters of the diesel Engine evaluation the optimised blend i.e, 20% blend of Mahua biodiesel is chosen.

Fig. 1. Before and after transesterification process of Mahua oïl

2.1.1 Nano additives

Nano powders each of 50 ppm of alumina (Al2O3) and copper oxide (CuO) are supplemented distinctly to the optimal blend of Mahua Biodiesel. It was blended well after adding nanofluid, then it was poured into an apparatus where to be agitated with ultra-sonication shaker for about 45 minutes to render even absorption of biodiesel with nano powder addition. The properties of four different cases of fuel involved in the present study are given in Table 1.

Table 1. Properties of four fuel cases of the study

Characteristic Property	Diesel Fuel	Biodiesel (BD)	BDA1	BDA2
Heating value in MJ/kg	42.9	37.8	41.69	43.12
Density in gm/cc	0.841	0.844	0.827	0.842
Viscosity in cSt	3.59	5.89	3.37	4.3
cetane number	47	62	49	49.5
Flash point in ^{0}C	64	158	71	60
Fire point in ^{0}C	78	162	78	66

2.2 Experimentation Procedure

The Experimentation is proceeded on 4 stroke single cylinder diesel engine with water cooling and ratings are stipulated in Table 2. An AvL Combustion analyzer and AvL exhaust Gas analysers were used for evaluation of the main characteristics of combustion and Emission particulates. A Line diagram with all accessories of the test engine is shown with Fig 2. Initially, without imparting any load the test engine was run for certain duration to achieve stable condition.

Table 2. Design parameters of the test engine

Rated Power	5 HP /3.7 kW
Length of the Stroke	11 centimeters
Bore diameter	8 centimeters
Rated speed	1500 revolution per minute
Compression ratio	16.5:1
Number of cylinders	1
Swept volume	550 cubic centimeters
Fuel injection timing	21^0 Before TDC

Using the current dynamometer as loading device, combustion and emission parameters were reported for various fractional loads in stages. Experiments were performed using Mahua Methyl Ester Biodiesel with 20 percent blend without and with of nano additives of 50 ppm Al2O3 and CuO separately at five different loads i.e., at evaluated brake powers of 0.61, 1.08, 1.83, 2.22 and 2.86 kW respectively, for efficiency, combustion and emission parameters assessment.

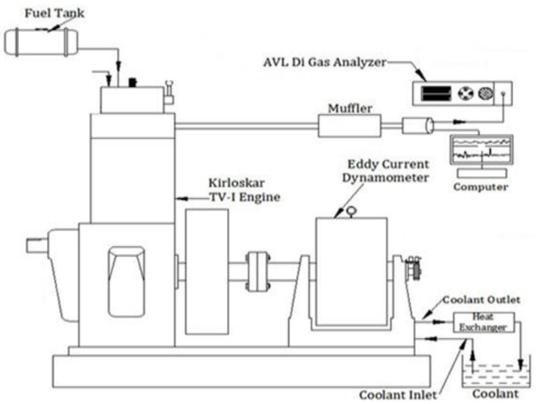

Fig 2. Experimental set up line diagram

3. Results and discussions

3.1 Cylinder Pressure

A distinction between pressure inside the cylinder and crank angle (CA) is presented in Fig 3. Using combustion analyzer for crank angle range of -180^0 CA before top dead centre (BTDC) to 180 degrees CA after top dead centre (ATDC), the cylinder pressure is noted for the purpose of analysis. For the optimal blend of biodiesel, the pressure at maximum load is perceived less compared to diesel. Biodiesel mixture displays a decrease of 4 percent. because of the lower heating value and rate of fire intensity. There is an improvement of about 5.7% in cylinder pressure with Al_2O_3 nano additive and 15.9% with CuO nano additive as compared with bio diesel blend. Unlike to biodiesel, where peak pressure is noticed at ATDC, with nano additives it occurs at TDC. This contributed to improve the performance characteristics due to boosted temperature inside the cylinder.

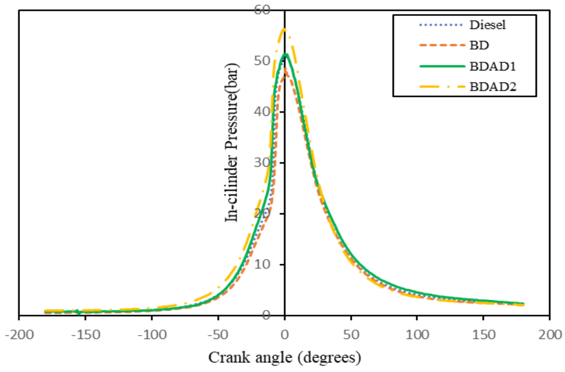

Fig 3. Variation of In-Cylinder pressure *vs* CA

3.2 Rate of Heat Release

The rate of heat release (HRR) was evaluated from 30° CA BTDC to 90° ATDC and Fig 4 shows the trends of all four cases of the fuel. In comparison with diesel, the rate of heat release is fewer with biodiesel i.e. 3.07% reduction is noticed. The HRR peak value of 106.6 kJ / m3-deg for biodiesel which is observed at 10° CA BTDC, whereas for diesel the value is 110 kJ /m^3-deg at 11^0 CA BTDC. A betterment on HRR for biodiesel with each nano additive compared to diesel, owing to the effective firing of the fuel mixture with superior quality. An increase around 15.4%, 20.6 % are observed for Al_2O_3 and CuO additives respectively at 11° CA BTDC due to the improvements in combustion with a limited quenching and a reasonable delay in ignition may be attributed to the improvement.

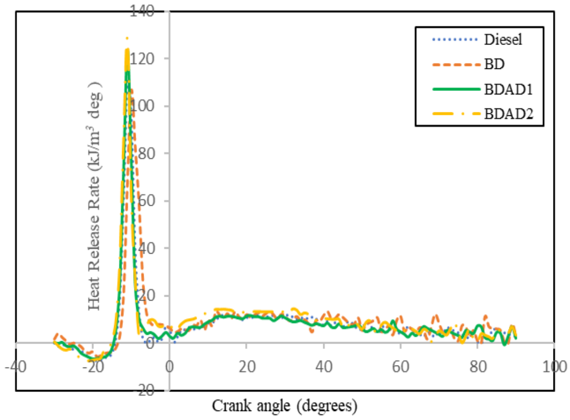

Fig 4. Variation of HRR *vs* CA

3.3 Brake Thermal Efficiency

Demonstrations of BTE variability for specific applied loads for different cases of fuels are presented in Fig 5. At part loads, the Mahua methyl ester-based bio diesel's thermal efficiency relative to brake power was inferior to that of diesel.

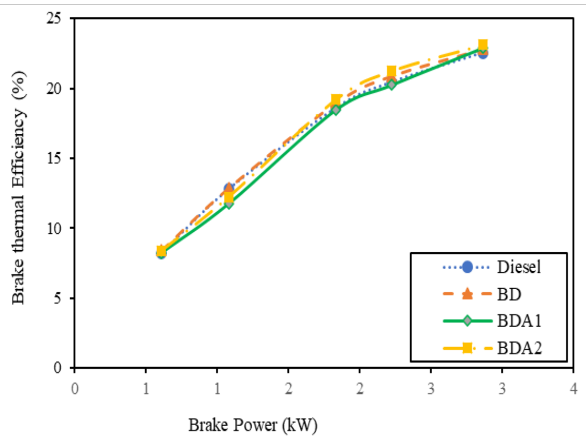

Fig 5. Variation of BTE *vs* BP

This is because of low explosiveness, viscosity and higher density of Mahua biodiesel leads to poor formation of mixture at low loads than tidy diesel. At full load with mahua biodiesel, it was detected that at 20% Mahua methyl ester blend; there is a small upgrading of 1% in BTE. It was also noted that there is a gain of 0.5% and 1.4% BTE with Al_2O_3 and CuO nano particle additives respectively. The origin may be because of increased volume-surface ratio of nano fuels which enable more fuel injected to react with water.

3.4 Specific fuel consumption (BSFC)

The BSFC variance with brake energy is shown at various loads for all fuel cases in Fig 6. It is noted that for all conditions, the reduction in BSFC is found from part loads to full load. The specific fuel consumption is 0.406 kg / kW-hr for standard engine with diesel operation at rated load. Whereas, with Mahua biodiesel it is increased by 2.5% because of increased viscosity and poor biodiesel mixture formation. It is observed that the maximum load with BDA1 and BDA2 is reduced by 1.6 percent and 4 percent compared to BD in BSFC. The reason may be due to the increased oxidation potential at higher loads with nano additives than with part loads.

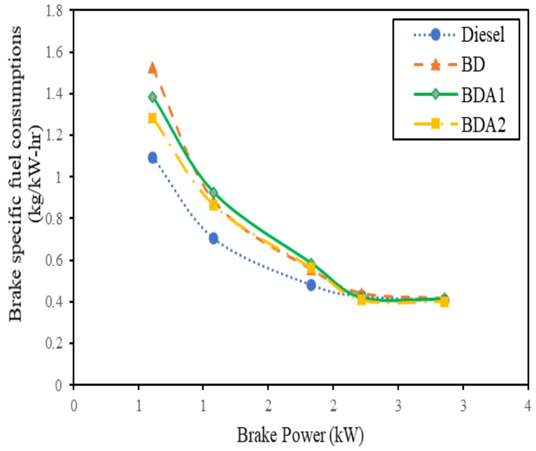

Fig 6. Variation of BSFC *vs* BP

3.5 Emission particulates of Hydrocarbon

The Fig 7, demonstrates the dissimilarities of hydrocarbon emissions for diesel and biodiesel and with additives cases. An increased trend is detected with increase of load. At the rated load, 16.2 % reduction is noticed with Mahua biodiesel. The use of oxygen in biodiesel contributes to effective burning of the fuel and thus to reduce the hydrocarbons emission particulates. It was also found that, relative to Al2O3 and CuO additives, there is a reduction of 5.5% and 7.9% in emissions. This is attributed, because of energy release by nano additives during expansion stroke in addition to the liquid fuel.

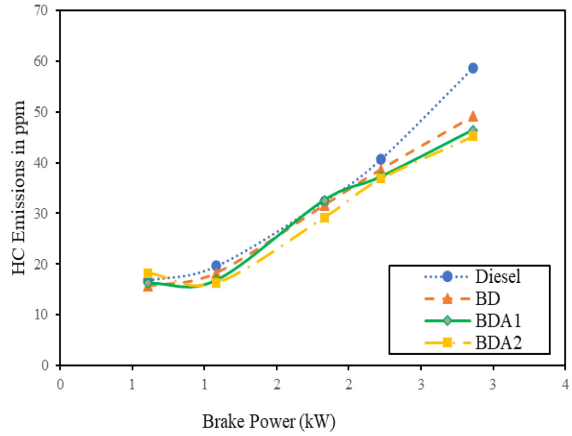

Fig 7. Variation of Hydro Carbon emissions *vs* BP

3.6 Emissions of Carbon monoxide

For all fuel cases of the study, with and without additives, the range of carbon monoxide emissions is depicted in Fig 8 at distinct loads and the trend observed is in growing with accumulation of loads. At rated load, the drop of CO particulates was noted as 11.4%, due to the accessibility of the oxygen in biodiesel to assist the burning of the fuel. With Al_2O_3 and CuO nano additives, there is a further reduction of 8.3% and 10.5% respectively at higher loads. This reason assigned may be improved atomization by micro-explosion events, thereby lowers the creation of emissions.

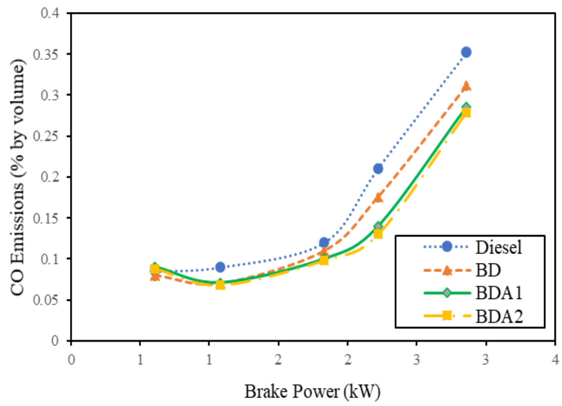

Fig 8. Variation of CO Emissions *vs* BP

3.7 Emissions of Carbon dioxide

For four different cases of study, Fig 9 shows dissimilarity of CO_2 particulates at five fractional loads. For Mahua methyl ester blend (BD) the emission was reduced by 5.2% as that of conventional fuel. The reason may assign as the availability of oxygen in Mahua biodiesel leads to effective firing resulting reduction in CO_2 emission. Apart, the emissions were reduced by 4.6% & 6.9% with addition of metal additives of Al_2O_3 and CuO respectively compared to MME biodiesel due to micro explosion, the adequate air/fuel mixing.

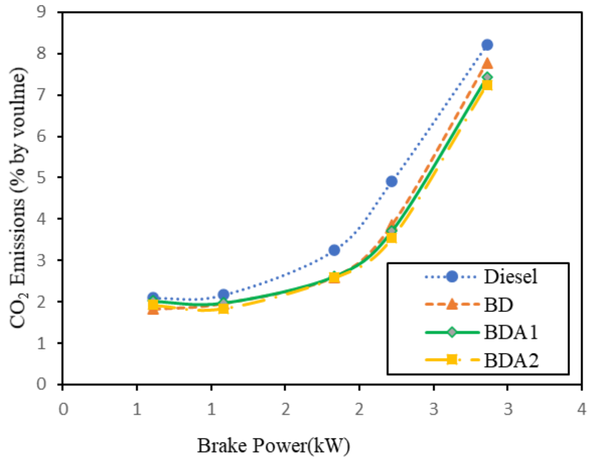

Fig 9. Variation of CO_2 emissions *vs* BP

3.8 Emissions of NO_x

The tendency of NOx particulates for all fuel cases of current study with Brake Power are shown in Fig 10. For increased loads for varying fuel types, the volume of NOx emissions will increase for all cases. For Mahua Biodiesel share, a growth of 8.4% was observed compared to diesel. Because of enhanced inside cylinder temperatures due to oxygen accessibility NOx particulates raised than diesel. Further with metal-based additives of Al_2O_3 and CuO, there is reduction of 4% & 1.4% in emissions is found compared to the results of without additives with Biodiesel. This because of Al_2O_3 additive acts as a heat descend results to diminish of combustion temperature.

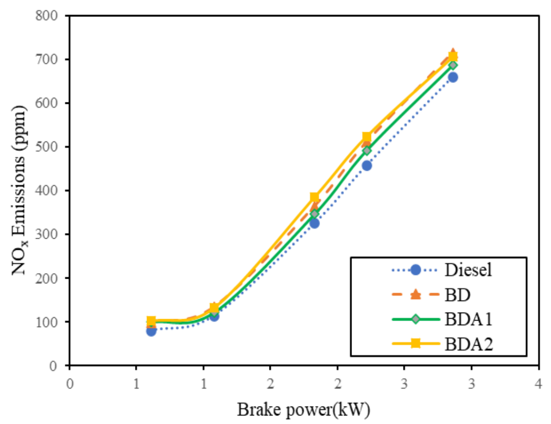

Fig 10. Variation of NO_x *vs* BP

4. Conclusions

This study accounts the part of nano additives in achievement of parameters of combustion, efficiency and emission by Mahua Biodiesel used on existing diesel engine. The key points are summarized below:

- The In-cylinder pressure and the HRR of Mahua biodiesel is less by 4% and 3.07% respectively compared to neat diesel operation due to low heating value of the biodiesel
- Further, there is an improvement of about 5.7% & 15.9% in cylinder pressure and 15.4 % and 20.6% in HRR with Alumina & CuO nano additives respectively with biodiesel is noted and this may be due to improvements in fuel combustion phenomena
- Performance parameters, BTE improved nominally due to reduced heat loss and BSFC was increased by 2.5 % due less volatility and viscosity of Mahua biodiesel
- It was also observed that for BTE, there is a small enhancement of 0.5% & 1.4% and a drop of 1.6% and 4% in BSFC with Oxides of Al_2O_3 CuO nano additives because of the larger area-to-volume ratio of nanoparticles results quick desertion and increased atomization
- HC emissions were reduced by 16.2%, CO emissions by 11.4%, CO_2 emissions by 5.2 % with Mahua biodiesel over diesel case. An 8.4% increase in NOx emissions with mahua fuel over diesel at rated load. Biodiesel exhibited higher cylinder temperatures due to the oxygen presence, which in turn enhanced the NO_x particulates
- with nano additives the mahua biodiesel receives additional oxygen which further improves the characteristics of combustion and particulates of emission
- However, it was noticed that a decrease of 4% & 1.4% with metal based nano additives of Al2O3 and CuO in case of NO_x particulates.

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