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EXPERIMENTAL EXAMINATION AND ANALYSIS ON COMPRESSION IGNITION ENGINE USING SIMAROUBA BIODIESEL, HIPPE BIODIESEL AND AL_2O_3 NANO ADDITIVE BLENDED BIODIESEL

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ABSTRACT

In this research work, experiments have been conducted to determine performance characteristics, emissions and combustion physiognomies of a single cylinder, four stroke VCR diesel engine using pure diesel, simarouba oil methyl ester(SOME) biodiesel, Hippe oil methyl ester (HpOME) biodiesel, and aluminium oxide nanoparticles were added to HpOME-20 as an additive in mass fractions of 25 ppm, 50 ppm and 75 ppm with the help of a mechanical Homogenizer and ultrasonicator with cetyl trimethyl ammonium bromide (CTAB) as the cationic surfactant. It was observed from results that HpOME(B20) biodiesel at 3.5kw Brake power(BP) gives 4.7% more BTE, 3.33% reduction in BSFC, 0.437% increase in Volumetric efficiency, reduced hydro carbon (HC) emissions(7.69%), reduction in Carbon Monoxide (Co) with slightly increased in Nox emissions in comparison with SOME (B20) biodiesel. Further experiments were conducted using different aluminium oxide nanoparticles ANP-blended biodiesel fuel (HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20 + ANP75) and the results obtained were compared with those of pure diesel and Hippe oil methyl ester(HpOME20). The results shows a considerable augmentation in the brake

thermal efficiency and a minimal reduction in the detrimental pollutants viz., CO, HC and sNox) for the nanoparticles blended biodiesel.

KEYWORDS: Aluminium oxide nanoparticle(ANP), Hippe oil methyl ester (HpOME), Simurouba oil methyl ester (SOME), Transesterification, Combustion, Emission, Mechanical Homogenizer.

I. INTRODUCTION

Over hundred years ago Rudolf C C Diesel, the inventor of the compression ignition engines that still bear his name, demonstrated at a World Fair that agriculturally produced seed oil (peanut oil) may be used as fuel. The use of these agriculturally derivative oils as a fuel was phased out by petroleum-based diesel fuels that became more widely available because they are cheaper in price as a result of government subsidies in the 1920's. In the present situation with the diminution of the petroleum-based diesel, the demand for alternatives to petroleum-based fuels continues to increase. The increase in the consciousness of these alternative biofuels is not only because of the depletion of fossil fuels, but also because these bio-energy resources have lower emissions than conventional fuels and more over they are made from renewable resources. Biofuels refer to any kind of fuel generated which is made mostly from biomass or biological material collected from living or recently living resources. Transportation sectors have shown precise interest in biofuels because of the potential for rural development. In a country like India where it is observed that biodiesel can be a viable substitute automotive fuel. Biodiesel is a wildest growing alternative fuel and India has better resources for its production. Owed to the exhaustion of the fossil fuels day by day, there is a inevitability to find out an alternative steadfastness to fulfill the energy prerequisite of the world. Petroleum fuels play an vibrant role in the fields of transportation, industrial development and agriculture.[1,2] Fossil fuels are fast exhausting because of increased fuel consumption. Steady with the approximation of the International Energy Agency, by 2025 global energy consumption will intensify by about 42%.[3] Many investigations are going on to substitute the diesel fuel with an suitable alternative fuel such as biodiesel. Biodiesel is one of the unsurpassed accessible sources to accomplish the energy constraint of the world.[4] Nonedible sources viz., cotton seed oil, pongamia oil, Mahua oil, Jatropha oil, and Karanja oil have been investigated for biodiesel fuel production.[5] Currently, rigorous efforts have been made by many scientists and researchers to use numerous sources of energy as feed in prevailing diesel engines. The make use of straight vegetable oils (SVO) is insufficient due to some disapproving physical and chemical properties, predominantly their viscosity and density. Because of higher viscosity, SVO causes imperfect combustion, poor fuel atomization and carbon unseating on the valve and injector seats subsequent in stark engine problems. When diesel engines are fuelled with conventional vegetable oil as fuel, it leads to unfinished combustion. The probable methods to surpass the problem of higher viscosity have been blending of vegetable oil with diesel fuel in the appropriate magnitudes and proper transesterification of vegetable oils to yield biodiesel.[6–8] The process of transesterification has been accomplished worldwide as a efficacious means for biodiesel production and viscosity lessening of vegetable oils.[9] Transesterification is the procedure, by means of an alcohol (e.g. either ethanol or methanol) in the occurrence of catalyst to pause the triglyceride molecules of the raw vegetable oil directly into ethyl or methyl esters (fatty acid alkyl esters) of the vegetable oil with glycerol as a by-product.[10] Ethanol is one among the chemical product preferred for the process of transesterification when compared to methanol since it is derived from renewable sources (agricultural waste) and is evidently and biologically non-detrimental for the environment. Mechanism of transesterification process is shown in Fig. 2.

Generally, methyl esters of vegetable oil propose the lessening of destructive consume emissions from the diesel engine such as CO, HC and smoke but it escalated the NOx emissions.[11–17] The NOx production is the most precarious stricture that has a strong outcome on the environment through acid rain, human diseases, etc. Additionally, CO and NO are principal pollutants in the formation of atmospheric ozone, which is an important conservatory gas.[18,19] Many academicians and researchers have found that the B20 biodiesel blend gives greater and better thermal efficiency and emission parameters when compared to other biodiesel blends.[22] Among the dissimilar techniques reachable to reduce exhaust emissions from the diesel engine while employing biodiesel, the use of fuel-borne metal catalyst is currently focused because of the benefit of enrichment in fuel efficiency while reducing unsafe exhaust emissions and health intimidating chemicals.[23] Aluminium oxide nanoparticles at high temperatures dissociate into Al2O and oxygen:

$$Al_2O_3 \longrightarrow Al_2O + 2O$$

Al2O3 is rickety at high temperatures during the process of combustion in the combustion chamber, so it also crumbles as follows:

$$Al_2O \longrightarrow 2Al + 2O$$

Many researchers found that the combustion comportment of methyl esters with the accumulation of nanosize peppy materials as a colorant progresses the combustion and engine performance of diesel engines. In addition to the above, due to the trivial magnitude of nanoparticles, the constancy of fuel suspensions should be conspicuously improved [24–26]. In this examination, aluminium oxide nanoparticles have been added in various proportions (25, 50 and 75 ppm) to a biodiesel blend (HpOME20) which is found to be improved than SOME20 to examine the performance, emission and combustion of the single cylinder, four stroke VCR diesel engine without any variation.

II. BIODIESEL PRODUCTION

Simarouba oil and Hippe oil which is also referred to as Mahua oil is prevalently heated to a range of temperature of 100–120 ^{0} C to eliminate water contents existent in raw vegetable oil which is monitored by the process of filtration. The raw vegetable oil is processed by one base-catalysed transesterification process where it is amagamated with 200 ml of methanol and 7 g of potassium hydroxide (KOH) pellets per litre of vegetable oil and is placed on a hot plate magnetic with a prominent stirring arrangement for 1–1.5 h up to 60^{0}C and then it is allowed to settle down for about 6–8 h to obtain biodiesel and glycerol. The biodiesel obtained is further washed with distilled water two to three times for the exclusion of acids and heated above 100 ^{0}C to eliminate the moisture existent in the biodiesel.

A. Process of extracting Biodiesel

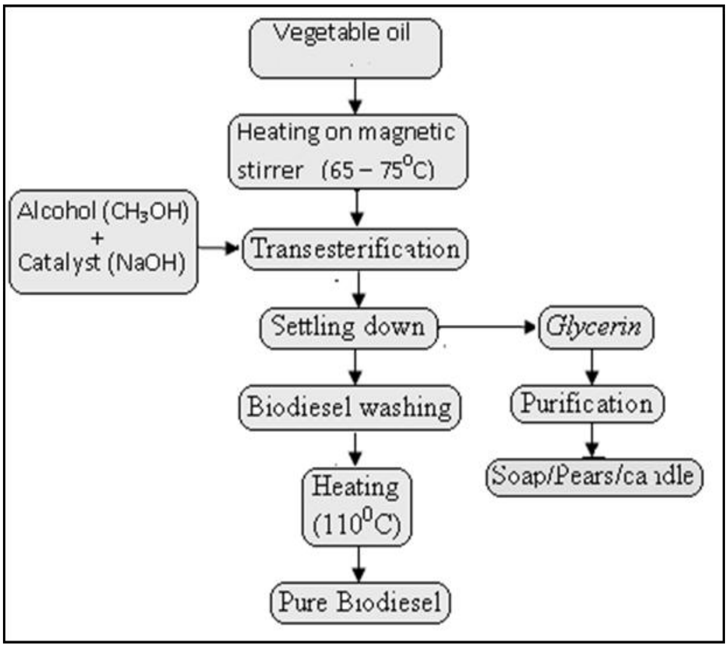

Fig. 1: Flow chart of Biodiesel production.

B. Transesterification Process

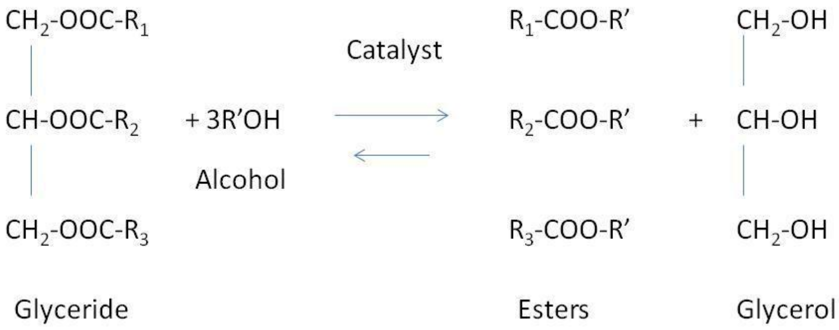

Fig. 2: Transesterification of triglycerides with alcohol in presence of catalyst, where R is the alkyl group.

III.BLEND PREPARATION

A. Biodiesel blends preparation.

The Simarouba oil methyl ester biodiesel obtained by transesterification is blended with neat diesel on volume basis as per the requirement to form blends like SOME10, also called as B10(10 % SOME + 90 % Diesel), B20(20% SOME +80 % Diesel), B30 and B40. Similarly blends of Hippe oil methyl ester biodiesel are prepared (HpOME10, HpOME20, HpOME30 and HpOME40).

B. Nanofluid preparation

The inimitable hybrid biodiesel-nanoparticle blends for the present study have been prepared by employing homogenizer and ultrasonicator. Aluminium oxide is selected as nanoparticle additives to HpOME20 because of their improved properties like higher thermal conductivity, mechanical and magnetic properties. The callous size of the nanoparticles varies from 32 nm to 48 nm. The nanoparticles have been verbosed in the solvent with the aid of a homogenizer. Nanoparticles typically have a high surface contact area and consequently amount of surface energy will be high. Nanoparticles clustered together to generate a micro molecule and twitch to sediment. To make nanoparticles be stable in a base fluid, it should need to accomplish surface modification. Cetyl trimethyl ammonium bromide (CTAB) is a cationic surfactant and it eventuates as an envelope on the surface of the nanoparticles and makes the surface as a negative charge. Henceforth the particle sedimentation has been monitored and controlled. In order to scatter the nanoparticle to the base, the method of magnetic stirrer has been adopted. A known amount of aluminium oxide nanoparticles (25, 50 and 75 ppm) and CTAB

(100 ml for 1Lt) has been weighed and poured in the ethanol solvent and magnetically stirred for 2 h. Then it creates an even nanofluid.

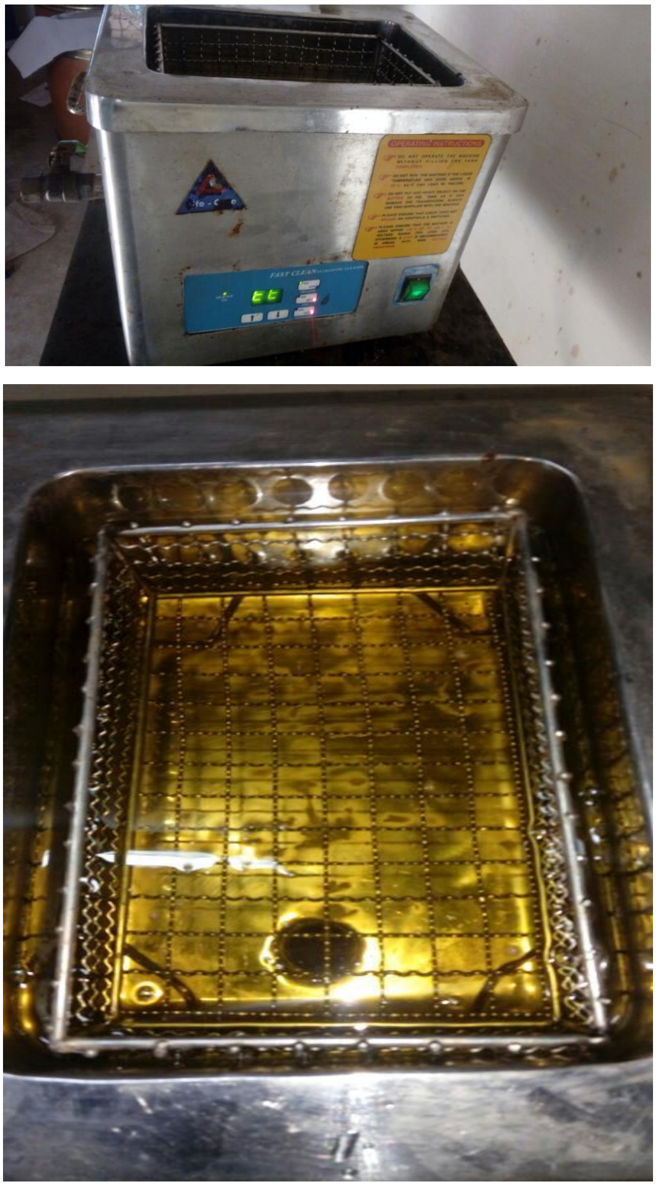

Fig. 3 (a) & (b) Ultrasonicator setup

C. Hippe oil methyl ester-nanofluid blend preparation

The aluminium oxide nanofluid was added to the Hippe oil methyl ester blend (HpOME20) in three different proportions (25,50 and 100 ppm). After the addition of aluminium oxide nanofluid, it is shaken well. And then it is poured into signification apparatus where it is agitated for about 30–45 min in an ultrasonic shaker, making a uniform HpOME20-ANP blend. The properties of Simuroba oil methyl ester (SOME) , Hippe oil methyl ester and ANPs blended Hippe oil methyl ester blend are determined as per ASTM standards and is listed below.

Table 1: Properties of Diesel, biodiesel and biodiesel nanoparticles blended samples.

Description	Viscosity @40^{0}c(Cst)	Density (kg/m^{3})	Calorific value(MJ/kg)	Flash point (^{0}C)
Diesel	3.4	830	42.86	63
SOME 10	2.68	827	42.46	60
SOME 20	2.83	831	41.45	67
SOME 30	3.07	836	40.90	70
SOME 40	3.92	840	39.46	75
HpOME 10	3.52	831	42.43	74
HpOME 20	3.59	833	41.62	76
HpOME 30	3.79	836	41.78	77
HpOME 40	3.84	840	41.25	77.5
HpOME20+ANP 25	3.42	825.75	41.65	74
HpOME20+ANP 50	3.37	827.5	41.66	71
HpOME20+ANP 75	3.34	828	41.67	68

IV. EXPERIMENTAL SETUP

The experiments have been conducted in series on fully computerized Kirloskar TV1, four-stroke, single cylinder type, water cooled diesel engine. The rated power of the diesel engine has been 3.7 kW. The engine has been operated at a constant speed of 1500 rpm by maintaining the magnitude of injection pressure from 210 to 220 bar at numerous load conditions. The engine was at the commence fuelled with neat diesel to provide the baseline data, and then it was fuelled with SOME, HpOME biodiesel blends and then HpOME20, HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20 + ANP75. The scrupulous details of the engine specification are given in Table 2. Eddy current dynamometer has been employed for loading the engine. HG-540 AIRREX (approved by ARAI) five-gas analyzer has been used to measure HC, CO and NOx emissions. In-cylinder pressure and heat release rate has been measured by the use of data acquisition system interfaced with dual core processor. The experimental setup is shown in Fig. 4.

Table 2: Engine Specification.

Sl. No.	Parameter	Specification
1	Engine Supplier	Apex innovations Pvt. Ltd Sangli, Maharashtra, India
2	Type	TV1 (Kirloskar made) VCR
3	Software used	Engine soft
4	Nozzle Opening Pressure	200-205 bar
5	Governor type	Mechanical centrifugal
6	No. of cylinder	Single cylinder
7	No. of strokes	Four stroke
8	Fuel	H.S Diesel
9	Rated power	3.7 kw (5HP)
10	Cylinder diameter (bore dia)	87.5 mm

11	Stroke length	110 mm
12	Compression ratio	17.5
13	Speed	1500 rpm
14	Arm length	180 mm

Fig. 4: Experimental Setup.

V. RESULTS AND DISCUSSIONS

The operation of diesel engine using Simuroba oil methyl ester, Hippe oil methyl ester blends and ANPs added to Hippe oil methyl ester fuel blends has been found to be very even through the rated load, without any operational problems. The performance features viz., brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), volumetric efficiency and the emission characteristics such as NOx, HC, CO have been plotted against the brake power. Based on the pertinent combustion data, cylinder pressure and magnitude of heat release rate are plotted against crank angle. Primarily experiments have been conducted with neat diesel, SOME10, SOME20, SOME30 and SOME40, and correspondingly for HpOME10, HpOME20, HpOME30 and HpOME40. In both the cases blend B20 (SOME20 and HpOME20) found better than their counter partners.

A. Engine performance

a. Brake thermal efficiency

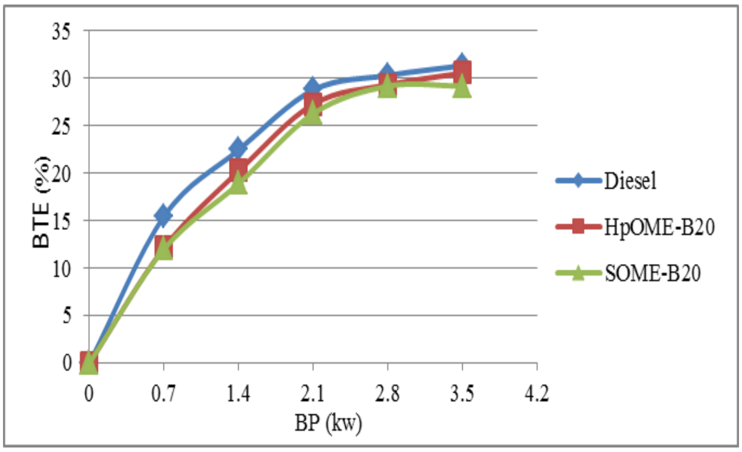

Fig. 5(a) BTE (%) against Bp (kw) for Diesel, SOME20 and HpOME20.

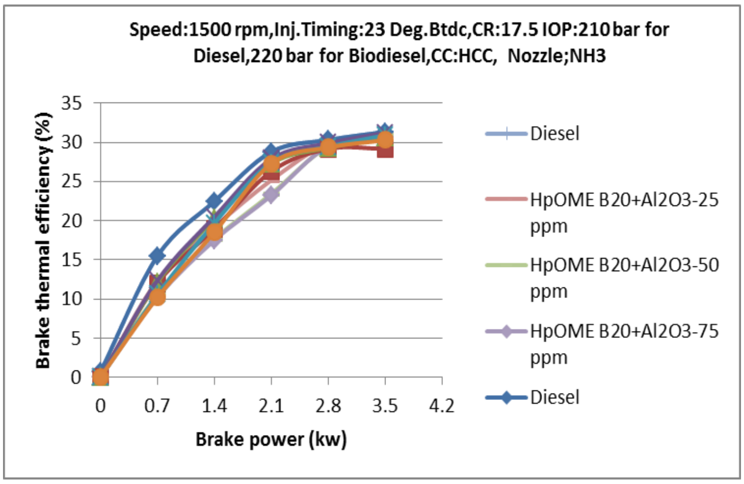

Fig. 5(b): BTE(%) against Bp (kw) for Diesel, HpOME20 +ANP25,HpOME20+ANP50 and HpOME20 + ANP75.

From Fig. 5(a), it can be observed that, the brake thermal efficiency (BTE) increases with the load for diesel, SOME and HpOME biodiesel. The BTE of HpOME20 (30.54 %) is better than that of SOME20 (29.16 %) at full load. From Fig. 5(b), it is observed that BTE is further improved with addition of ANP25 PPM to HpOME20 (31.2%) this could be attributed to the better combustion characteristics of ANP. The catalytic activity of ANP might have improved because of the existence of high active surfaces.

b. Brake Specific fuel consumption (BSFC)

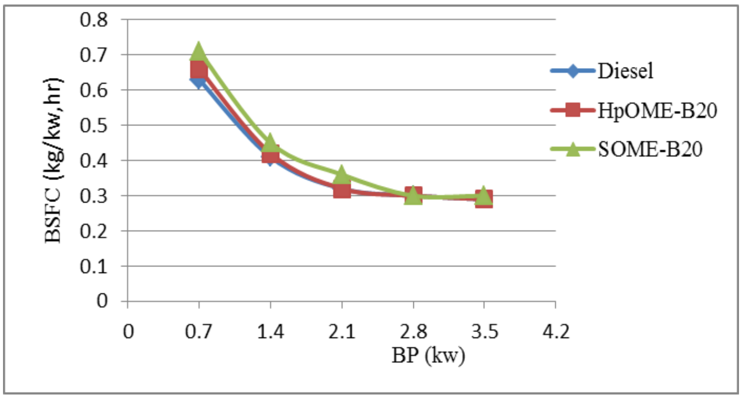

Fig. 6(a) BSFC against BP for Diesel, HpOME20 and SOME20 biodiesel.

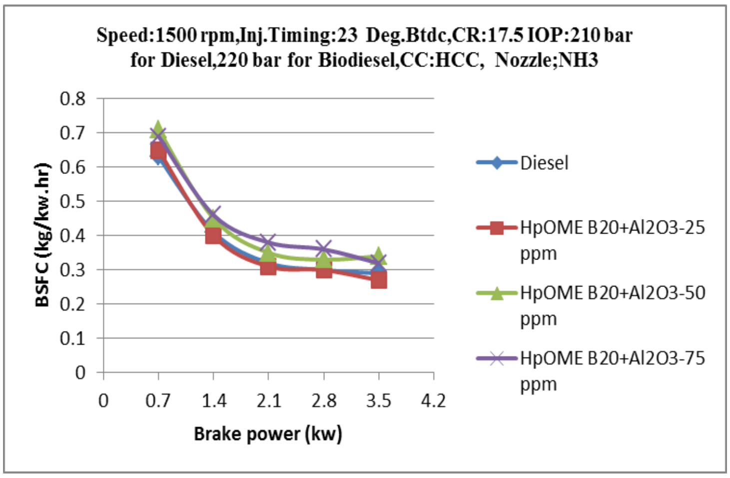

Fig. 6(b): BSFC against BP for Diesel, HpOME20 + ANP 25,HpOME20 + ANP 50 and HpOME20 + ANP 75.

BSFC has been observed to be increased with increasing proportion of biodiesel in the fuel. Brake thermal efficiency of pure biodiesel was highest among the fuels used It is observed from the above Fig. 6(a) the BSFC for HpOME20 is less than SOME20 and same as that of Diesel at full load condition. It is observed from Fig. 6(b) that with addition of ANP to HpOME20 there is marginal decrease in BSFC. For ANP25 BSFC is less compared to ANP50 and ANP75 at full condition.

c. Volumetric efficiency

Variations in the volumetric efficiencies of fuels with respect to change in load are shown in this section.

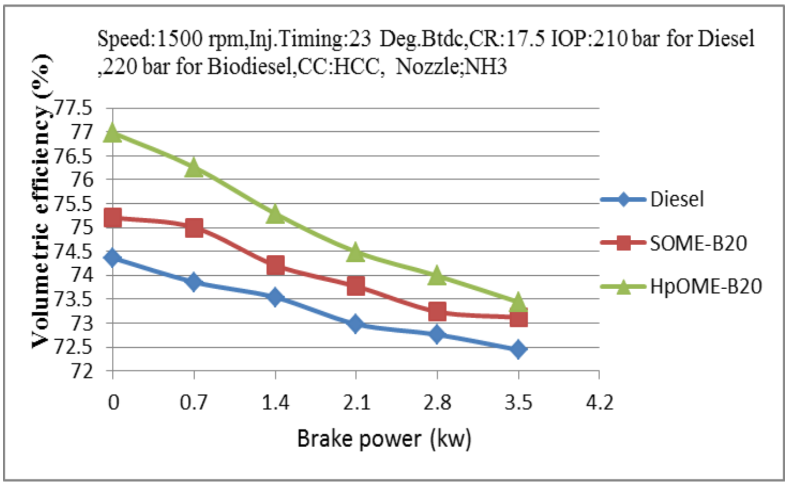

Fig. 7(a): Volumetric efficiency against BP for Diesel, SOME20 and HpOME20 biodiesel.

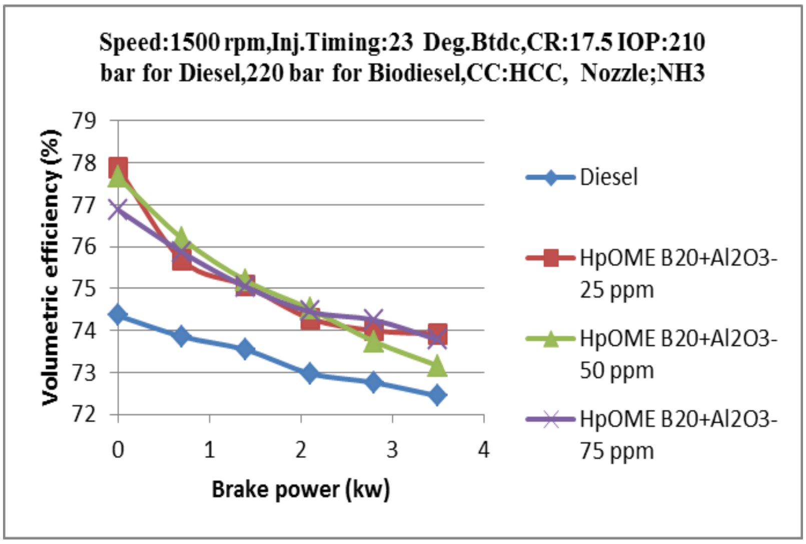

Fig. 7(b): Vol. efficiency against BP for Diesel,HpOME20 + ANP25,HpOME20 + ANP50 and HpOME20 +ANP75 ppm.

It is observed from Fig. 7(a) and Fig. 7(b) that the Volumetric efficiency for HpOME20 is more than SOME20 at all load conditions and also HpOME20 + ANP25 ppm has maximum efficiency at full load conditions when compared to other blends.

B. Emission parameters

a. Hydrocarbon (HC)

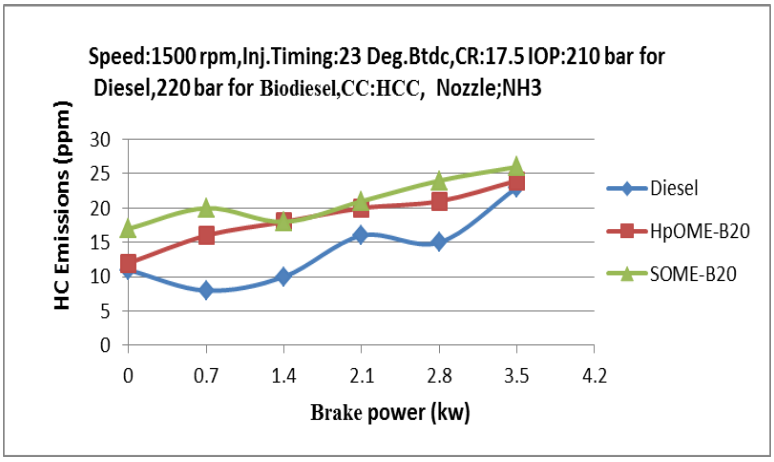

Fig. 8(a): HC emissions against BP for Diesel,SOME20 and HpOME20 biodiesel.

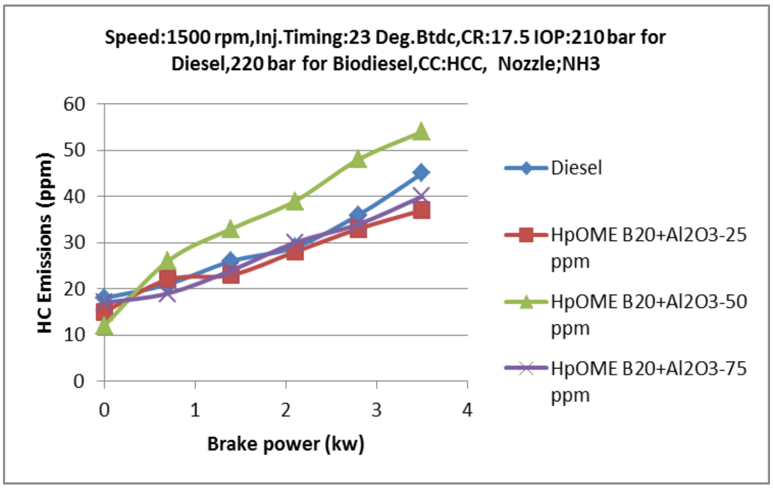

Fig. 8(b): HC emissions against BP for Diesel,HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20 + ANP75 ppm blended biodiesel.

It is observed from Fig. 8(a) and Fig. 8(b), that as the magnitude of load augments, the HC emissions steadily increases for all relevant cases. Many authors' results depict that, a noteworthy reduction in HC emissions when replacing diesel fuel with biodiesel [17, 31]. The higher cetane number of biodiesel blend (HpOME20) decreases the combustion delay period and the lessening has been connected to decreases in the HC emissions. Extra adding of aluminium oxide nanoparticles reduces the hydrocarbon emissions, since ANP supplies the oxygen for the oxidation of hydrocarbon and CO during combustion.

b. Carbon monoxide (CO)

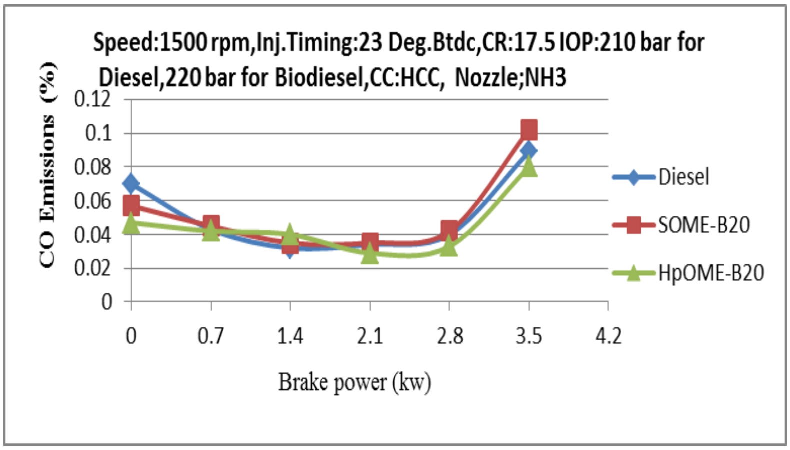

Fig. 9(a): CO emissions against BP for Diesel, SOME20 and HpOME20.

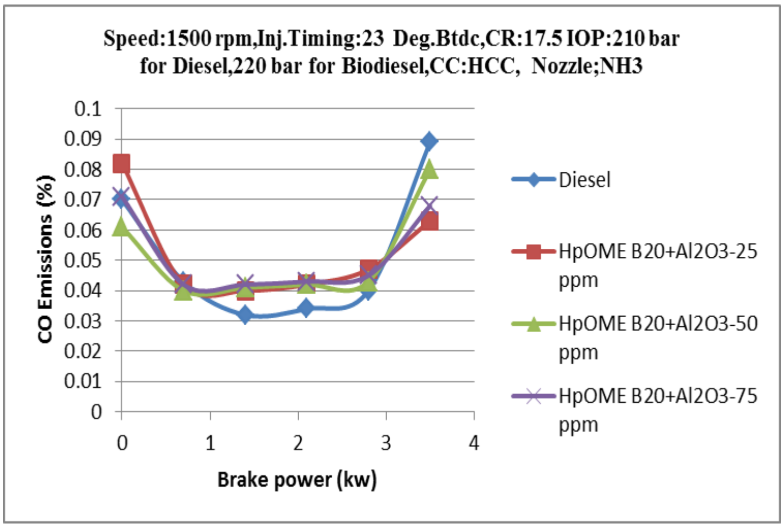

Fig. 9(b): CO emissions against BP for Diesel, HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20 + ANP75 ppm blended biodiesel.

It is observed from Fig. 9(a) that, the CO emissions of HpOME20 is low SOME20 and is almost same as diesel at full load. The consequences of ANP with a biodiesel blend (HpOME20) on the carbon monoxide emission at different engine loads have been shown in Fig. 9(b). ANPs have high surface contact areas which advance the chemical reactivity which uninterruptedly shortened the ignition delay period. From Fig. 9(b) it shown that CO emission found slightly less than diesel for HpOME20 + ANP25 ppm.

C. Oxides of nitrogen (NOx)

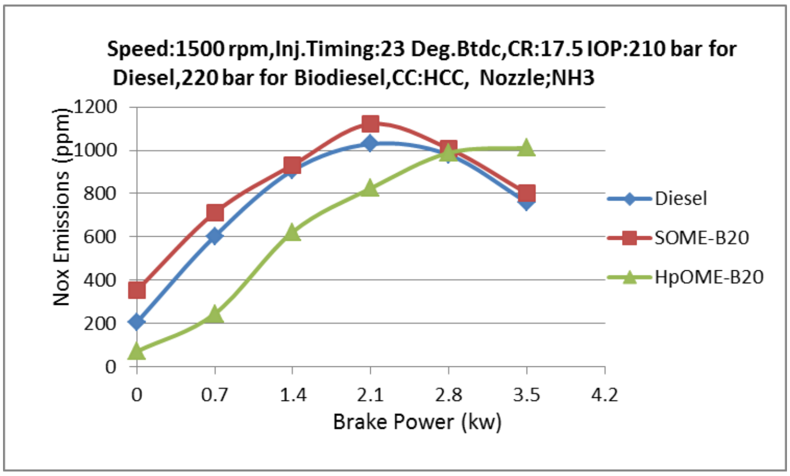

Fig. 10(a): No_X emissions against BP for Diesel, SOME20 and HpOME20.

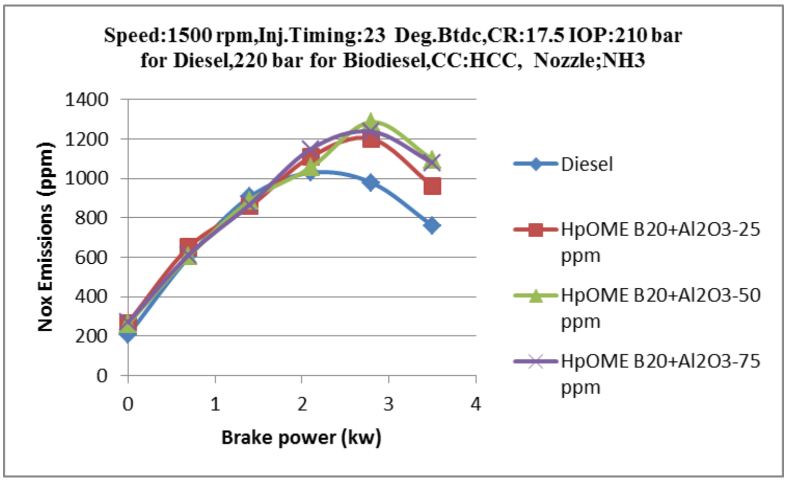

Fig. 10(b): No_X emission against BP for Diesel, HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20+ANP75 ppm.

The reduced ignition delay and combustion timing have been obtained when using the biodiesel blend. It is extensively accepted that the shorter ignition delay may give to marginally increased NOx emissions with biodiesel blend (HpOME20). The toting of nano metal oxide particles leads to completeness in combustion because of the aluminium oxide nanoparticles acting as an oxygen-donating catalyst. NOx emissions increased for ANP blend due to maximum magnitude of heat release rate and high peak pressure during the combustion. NOx emissions of the engine at different nanoparticle absorptions with a biodiesel blend with engine loads are shown in Fig. 10(b). From the figure, it is clear that, the NOx emission strikingly increases by the use of aluminium oxide nanoparticle additives.

B. Combustion characteristics

a. Cylinder pressure

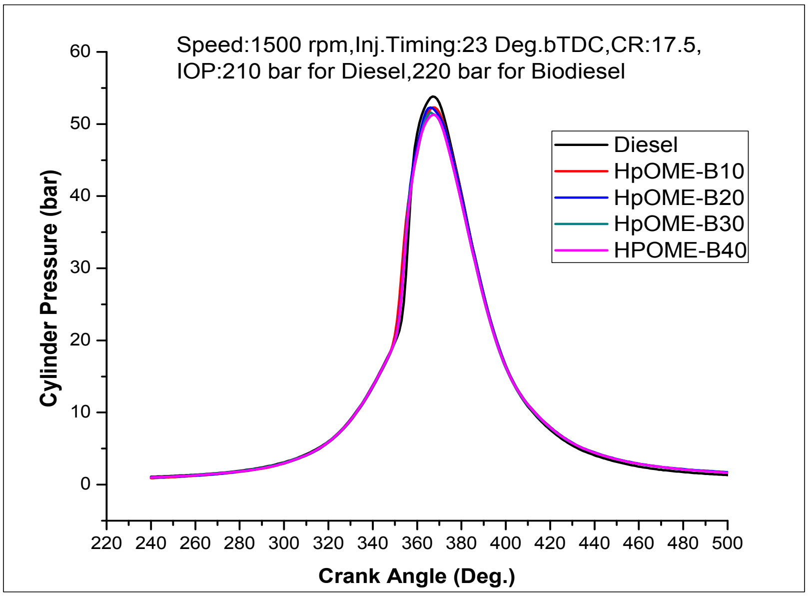

Fig. 11(a): Cylinder pressure against crank Angle for Diesel and HpOME biodiesel.

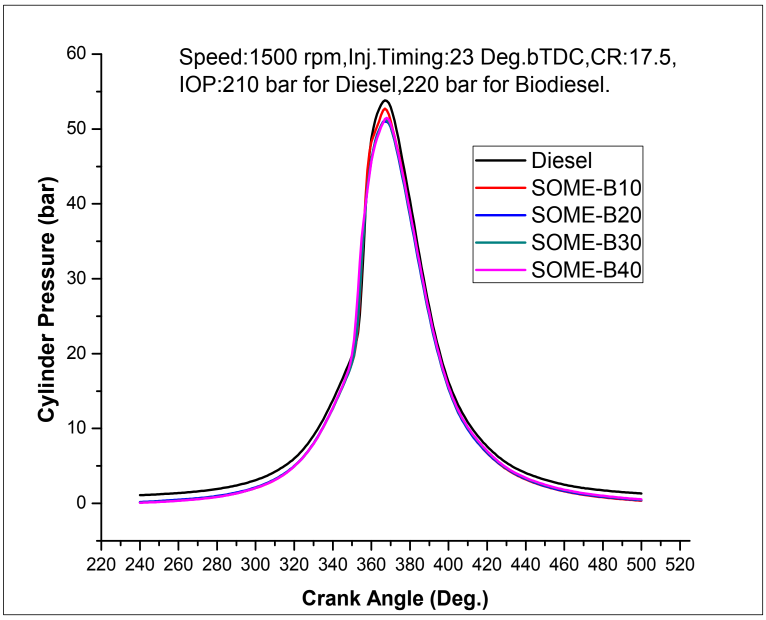

Fig. 11(b): Cylinder pressure against crank Angle for Diesel and SOME biodiesel.

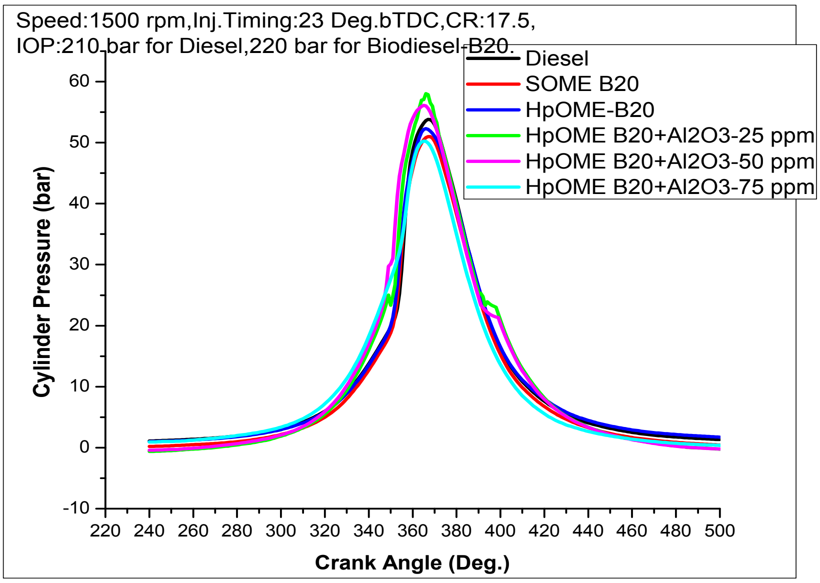

Fig. 11(c): Cylinder pressure against crank Angle for Diesel and HpOME20 with different blends of ANP(25, 50 and 75 ppm) biodiesel.

Fig. shows the variation of the in-cylinder pressure of the engine with crank angle. From the figure 11(a), it is seen that the maximum pressure at 366^o crank angle is 52.18 bar is obtained for HpOME20. From the figure 11(b), it is seen that the maximum pressure at 366^o crank angle is 51 bar is obtained for SOME20. From the figure 11(c), it is seen that the maximum pressure at 366^o crank angle is 58.0275 bar is obtained for HpOME20 + ANP25 ppm.

b. Heat release rate

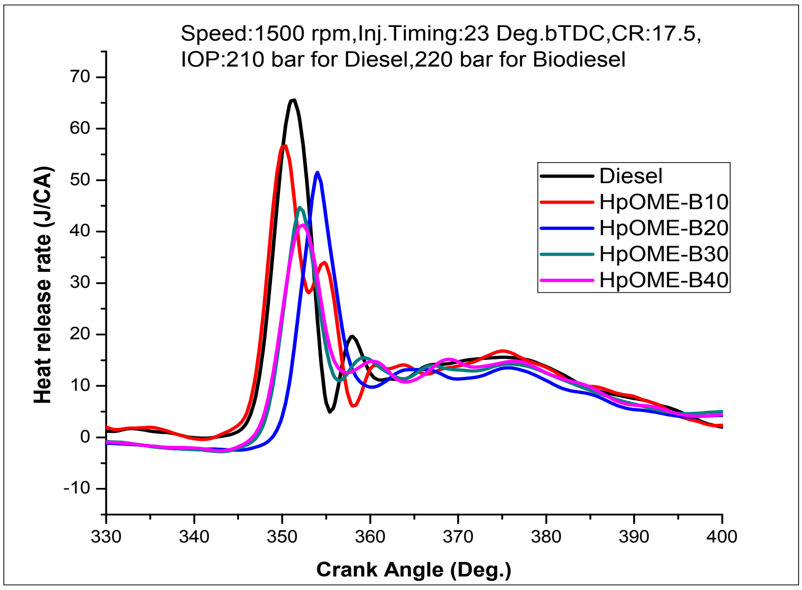

Fig. 12(a): Heat release rate against crank Angle for Diesel and HpOME biodiesel.

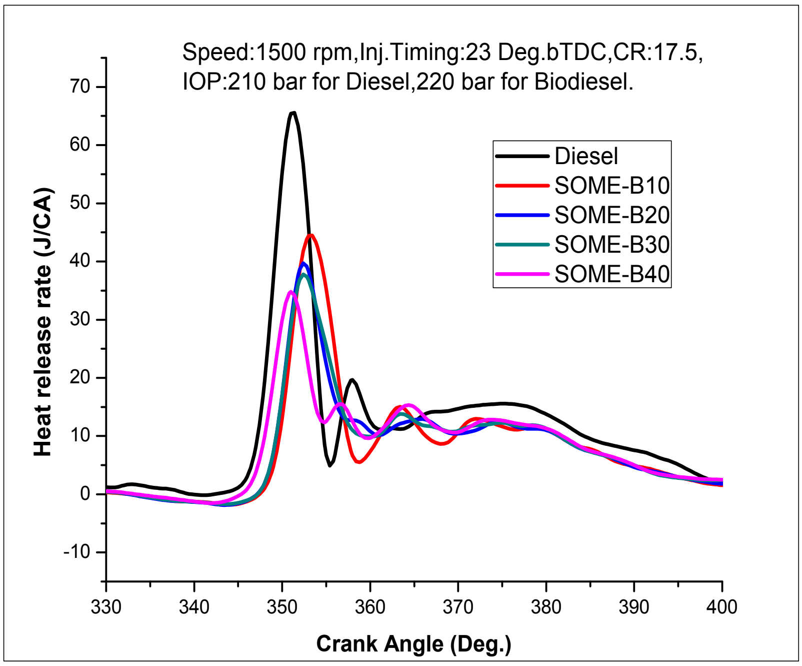

Fig. 12(a): Heat release rate against crank Angle for Diesel and SOME biodiesel.

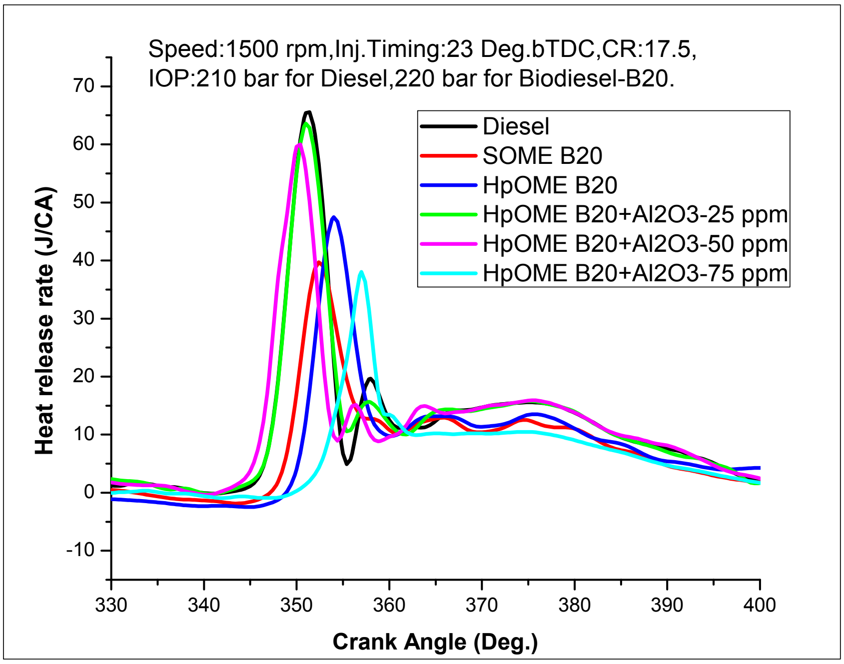

Fig. 12(c): Heat release rate against crank Angle for Diesel and HpOME20 + ANP(25,50 and 75 ppm) blends biodiesel.

Fig. 12(a, b and c) depicts the heat release rate for diesel, Hippe oil methyl ester, Simarouba oil methyl ester biodiesel and HpOME20 + ANP (25, 50 and 75 ppm) blended biodiesel. It can be noticed that, the heat release rate is maximum for neat diesel this is due to high value of calorific value. The heat release rate curves specify the available heat energy, which can be assimilated into useful work. Hippe Oil methyl ester (HpOME) includes a small amount of diglycerides having high magnitude boiling points as compared with the diesel fuel. The chemical reactions during the instillation of the Hippe oil methyl ester blend (HpOME20) at very high temperature eventually resulted in the breaking of the diglycerides. These chemical reactions yield the gases of monoglycerides. Gasification of these monoglycerides in the bobble of the spray spreads out the fuel jet, and the unpredictable combustion compounds present in the fuel are ignited in advance and reduced the ignition delay period. The magnitude of heat release rate in the combustion chamber during the starting of combustion is not enough to completely combust the fatty acids. The addition of ANP considerably aggrandizes the heat release rate of HPOME20.

VI. CONCLUSIONS

In this work, Simarouba oil methyl ester, Hippe oil methyl ester and ANP-mixed Hippe oil methyl ester mixture fuelled diesel engine performance, emission and combustion characteristics have been examined, and based on the experiments the following conclusions have been enumerated:

- It has been found that, HpOME20 has better performance when compared to Simarouba oil methyl ester20 blend.
- ANP-blended biodiesel (HpOME20+ANP25 HpOME20+ ANP50 and HpOME20+ ANP75) portrayed an improvement in the magnitude of calorific value and a lessening in the flash point as compared to HpOME20.
- Biodiesel has higher fuel consumption, because of its lower heating value. With the addition of aluminium oxide nanoparticles, there is a substantial reduction in the value of fuel consumption as compared to biodiesel operation and for HpOME20+ANP25 ppm BSFC has been found to be 6.896% reduction to Diesel.
- A minor decrease in BTE has been observed in all the cases with minimum of 0.38 % (HpOME20 + ANP 25 ppm) with respect to diesel.
- ANP reduced HC and CO emissions up to 17.77% and 29.21% as compared with a biodiesel blend (HpOME20+ANP25), because ANP acts as oxygen buffer catalyst and contributes surface lattice oxygen for the process of oxidation of HC and CO. NOx emissions upsurge with the use of ANP and biodiesel blend compared to the diesel fuel.

- The peak pressure increases with the accumulation of ANP. The totaling of ANP minimizes the ignition delay period. The magnitude of heat release rate also increases with the addition of ANP. The addition of ANP accelerates the hydrocarbon combustion and is the strong reason for the higher heat release rate as compared to neat diesel and biodiesel blend (HpOME20 and SOME2).

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