

Experimental Investigation on CI Diesel Engine Using Simarouba Biodiesel, Hippe Biodiesel and Al₂O₃ Nano Additive Blended Biodiesel

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ABSTRACT: In this present work experiments were conducted to determine performance, emissions and combustion characteristics 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 cetyltrimethyl 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 show a substantial enhancement in the brake thermal efficiency and a marginal reduction in the harmful pollutants (such as CO, HC and Nox) 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 a hundred years ago Rudolf Diesel, the inventor of the C.I 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 scenario with the depletion of the petroleum-based diesel, the demand for alternatives to petroleum-based fuels continues to increase. The increase in the awareness 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 particular 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 alternative automotive fuel. Biodiesel is a fastest growing alternative fuel and India has better resources for its production. Owing to the depletion of the fossil fuels day by day, there is a necessity to find out an alternative resolution to fulfil the energy requirement of the world. Petroleum fuels play a vital role in the fields of transportation, industrial development and

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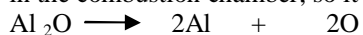
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agriculture[1,2]. Fossil fuels are fast depleting because of increased fuel consumption. Steady with the estimation of the International Energy Agency, by 2025 global energy utilization will increase by about 42% [3]. Many research works are going on to substitute the diesel fuel with an appropriate alternative fuel such as biodiesel. Biodiesel is one of the best available sources to fulfil the energy requirement of the world [4]. Nonedible sources such as cotton seed oil, pongamia oil, Mahua oil, Jatropha oil, and Karanja oil have been investigated for biodiesel fuel production [5]. In the modern years, severe efforts have been made by many researchers to use various sources of energy as feed in existing diesel engines. The make use of straight vegetable oils (SVO) is inadequate due to some unfavorable physical and chemical properties, particularly their viscosity and density. Because of higher viscosity, SVO causes incomplete combustion, poor fuel atomization and carbon deposition on the valve and injector seats ensuing in severe engine problems. When diesel engines are fuelled with straight vegetable oil as fuel, it leads to incomplete combustion. The potential methods to overcome the problem of high viscosity were blending of vegetable oil with diesel fuel in the proper proportions and transesterification of vegetable oils to produce biodiesel [6–8]. The transesterification process has been established worldwide as a successful means for biodiesel production and viscosity reduction of vegetable oils [9]. Transesterification is the process, by means of an alcohol (e.g. either ethanol or methanol) in the presence of catalyst to break the triglyceride molecules of the raw vegetable oil 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 preferred for transesterification process when compared to methanol because it is derived from renewable sources (agricultural waste) and is biologically non-harmful for the environment. Mechanism of transesterification process is shown in Fig. 1. In general, methyl esters of vegetable oil propose the reduction of harmful exhaust emissions from the diesel engine such as CO, HC and smoke but it increased the NO_x emissions [11–17]. The NO_x emission is the most dangerous parameter that has an effect on the environment through acid rain, human diseases, etc. Furthermore, CO and NO are primary pollutants in the formation of atmospheric ozone, which is an important greenhouse gas [18,19]. Many researchers have found that the B20 biodiesel blend gives greater thermal efficiency and emission parameters compared with other biodiesel blends [22]. Among the different techniques accessible to reduce exhaust emissions from the diesel engine while using biodiesel, the use of fuel-borne metal catalyst is presently focused because of the advantage of an enhancement in fuel efficiency while reducing harmful exhaust emissions and health-threatening chemicals [23]. Aluminium oxide nanoparticles at high temperatures dissociate into Al₂O and oxygen:



Al₂O₃ is unstable at high temperatures during combustion

in the combustion chamber, so it also decomposes as follows:



Many researchers found that the combustion behaviour of methyl esters with the addition of nanosize energetic materials as an additive improves the combustion and engine performance of diesel engines. In addition, due to the small size of nanoparticles, the stability of fuel suspensions should be noticeably improved [24–26]. In this investigation, aluminium oxide nanoparticles were added in different proportions (25, 50 and 75 ppm) to a biodiesel blend (HpOME20) which is found to be better than SOME20 to investigate the performance, emission and combustion of the single cylinder, four stroke VCR diesel engine without any Modification.

II. BIODIESEL PRODUCTION

Simarouba oil and Hippe oil which is also known as Mahua oil is heated to a temperature of 100–120 °C to remove water contents present in raw vegetable oil which is followed by filtration. The raw vegetable oil is processed by one base-catalysed transesterification method where it is mixed with 200 ml of methanol and 7 g of potassium hydroxide (KOH) pellets per litre of vegetable oil and placed on a hot plate magnetic with stirring arrangement for 1–1.5 h up to 60 °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 removal of acids and heated above 100 °C to remove the moisture present in the biodiesel.

Process of extracting Biodiesel and Transesterification Process are shown in the following figure.

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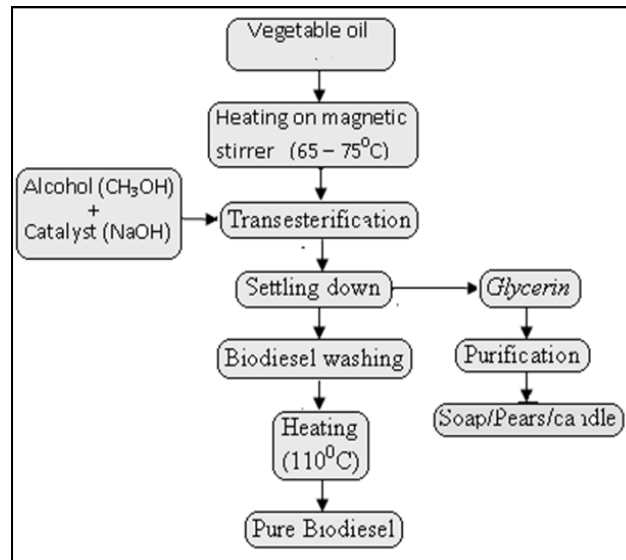


Fig.1 Flow chart of Biodiesel production.

III. BLEND PREPARATION

3.1. 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 Hippé oil methyl ester biodiesel are prepared (HpOME10, HpOME20, HpOME30 and HpOME40).

3.2. Nanofluid preparation.

The unique hybrid biodiesel-nanoparticle blends for the present study were prepared by using with the help of 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 mean size of the nanoparticles varies from 32 to 48 nm. The nanoparticles were diffused in the solvent with the help of a homogenizer. Nanoparticles usually have a high surface contact area and therefore surface energy will be high. Nanoparticles clustered together to form a micro molecule and start to sediment. To make nanoparticles be steady in a base fluid, it should need to surface modification. Cetyltrimethyl ammonium bromide (CTAB) is a cationic surfactant and it creates an envelope on the surface of the nanoparticles and makes the surface as a negative charge. Hence the particle sedimentation was controlled. In order to disperse the nanoparticle to the base, the magnetic stirrer procedure was followed. A known quantity of aluminium oxide nanoparticles (25, 50 and 75 ppm) and CTAB (100 ml for 1Lt) was weighed and poured in the ethanol solvent and magnetically stirred for 2 h. Then it forms an even nanofluid..

IV. EXPERIMENTAL SETUP

The experiments were conducted on fully computerized Kirloskar TV1, four stroke, single cylinder, water cooled diesel engine. The rated power of the diesel engine was 3.7 kW. The engine was operated at a constant speed of 1500 rpm by maintaining the injection pressure from 210 to 220 bar at various load conditions. The engine was at the start fuelled with neat diesel to provide the baseline data, and then it was fuelled with SOME, HpOME biodiesel blends and then

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HpOME20, HpOME20 + ANP25 , HpOME20 + ANP50 andHpOME20 + ANP75. Details of the engine specification are given in Table 1. Eddy current dynamometer was used for loading the engine. HG-540 AIRREX (approved by ARAI) five-gas 16981 analyser was used to measure HC, CO and Nox emissions.

In-cylinder pressure and heat release rate were measured by using data acquisition system interfaced with dual core processor. The experimental set-up is indicated in Fig. 2.

Table.1 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.2.Computerised Engine setup for Experiment

V. RESULTS AND DISCUSSIONS.

The operation of diesel engine using Simuroba oil methyl ester, Hippe oil methyl ester blends and ANPs added Hippe oil methyl ester fuel blends was found to be very smooth throughout the rated load, without any operational trouble. The performance characteristics such as brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), volumetric efficiency and the emission characteristics such as NOx, HC, CO are plotted against the brake power. Based on the combustion data, cylinder pressure and heat release rate are plotted against crank angle.

Initially experiments were conducted with neat diesel, SOME10,SOME20,SOME30 and SOME40,and Simillary for HpOME10, HpOME20, HpOME30 and HpOME40. In both the cases blend B20 (SOME20 and HpOME20) found better than their counter partners.

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Engine performance and Emissions analysis.

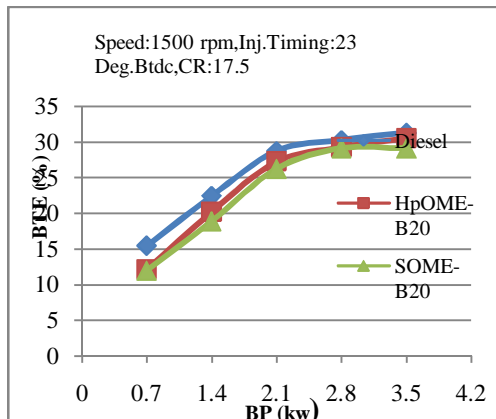


Fig.3. Variations of BTE Vs Bp for SOME & HpOME B20 with Diesel.

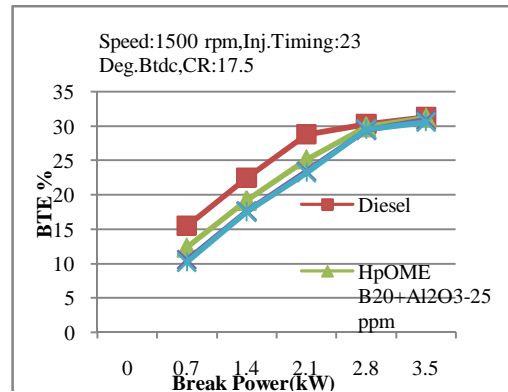


Fig. 4. Variations of BTE (%) against Bp (kW) for Diesel, HpOME20 + ANP 25 ppm, HpOME20 + ANP 50 ppm and HpOME20 + ANP 75 ppm.

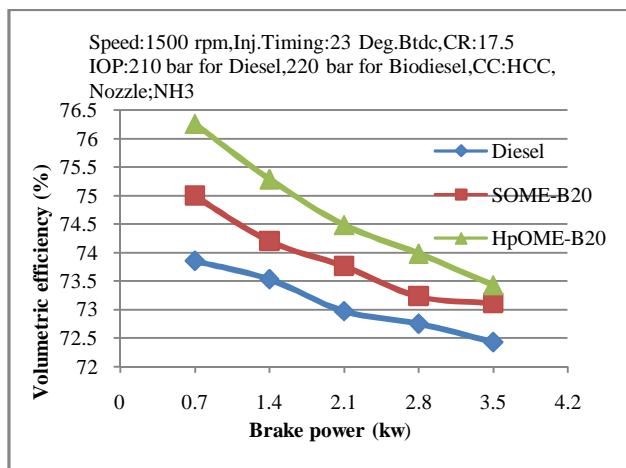


Fig. 5. Variations of Vol. efficiency against BP for Diesel, SOME20 and HpOME20 biodiesel.

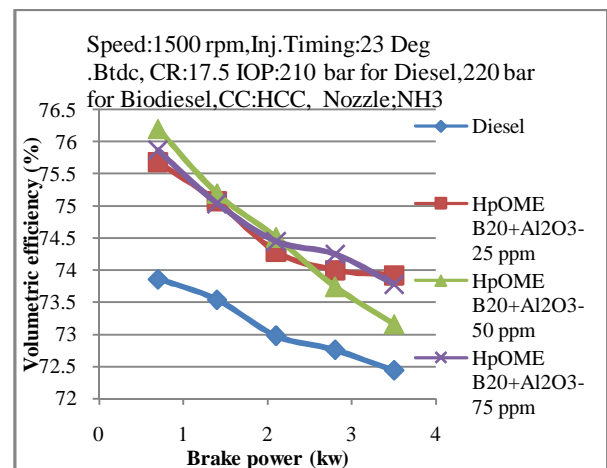


Fig. 6. Variations of volumetric efficiency against BP for Diesel, HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20 + ANP75 ppm.

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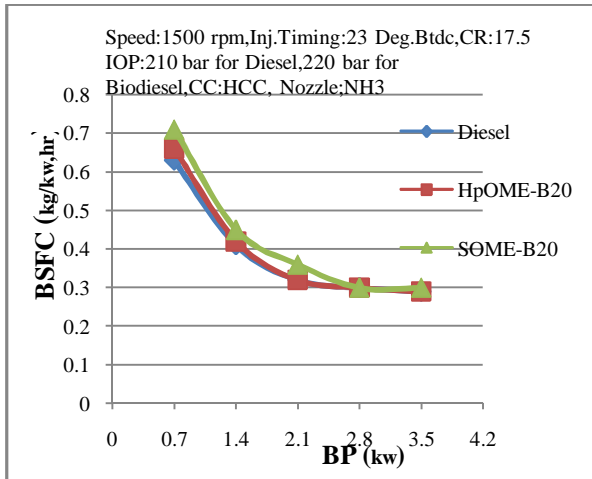


Fig.7. Variations of BSFC against BP for Diesel, HpOME20 and SOME20 biodiesel.

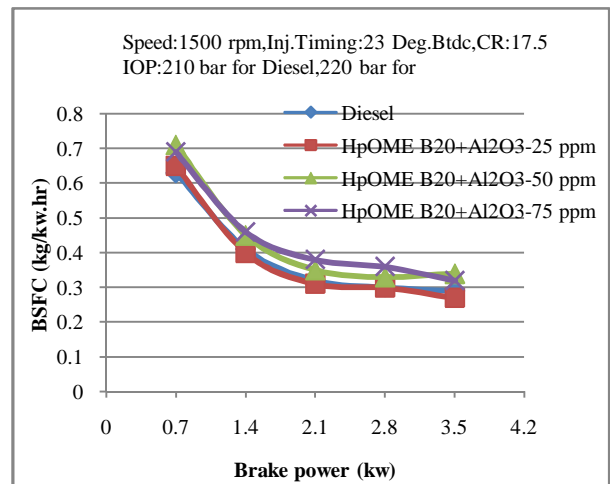


Fig.8. Variations of BSFC against BP for Diesel, HpOME20 + ANP 25 ppm, HpOME20 + ANP 50 ppm and HpOME20 + ANP 75 ppm.

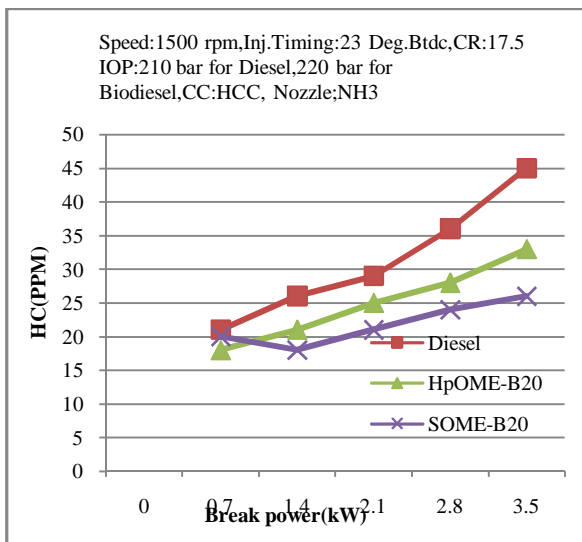


Fig. 9. HC emissions against BP for Diesel, SOME20 and HpOME20 biodiesel.

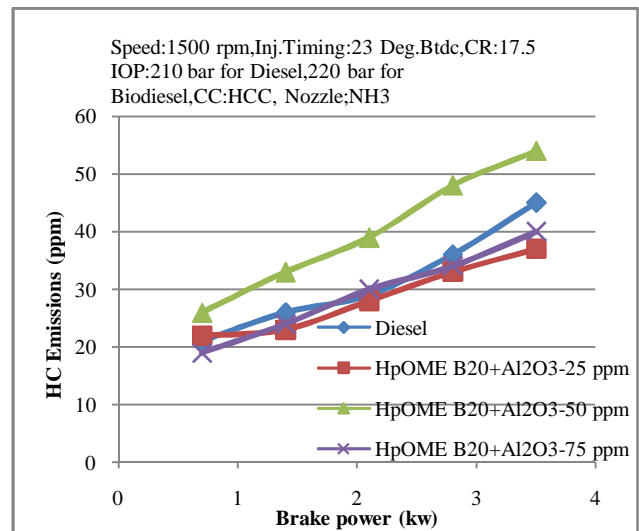


Fig. 10. HC emissions against BP for Diesel, HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20 + ANP75 ppm blended biodiesel.

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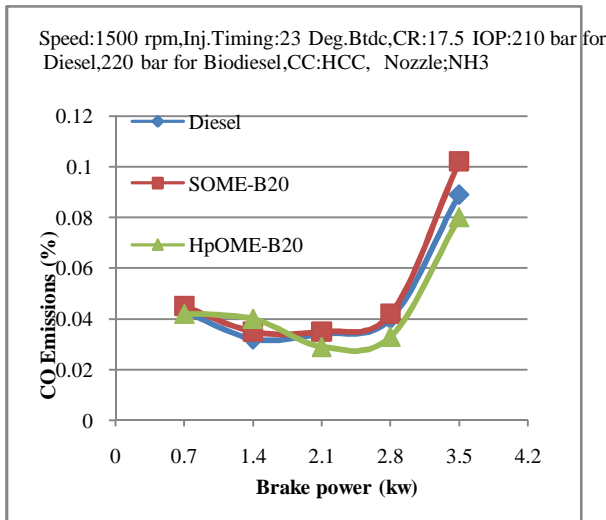


Fig. 11. CO emissions against BP for Diesel, SOME20 and HpOME20

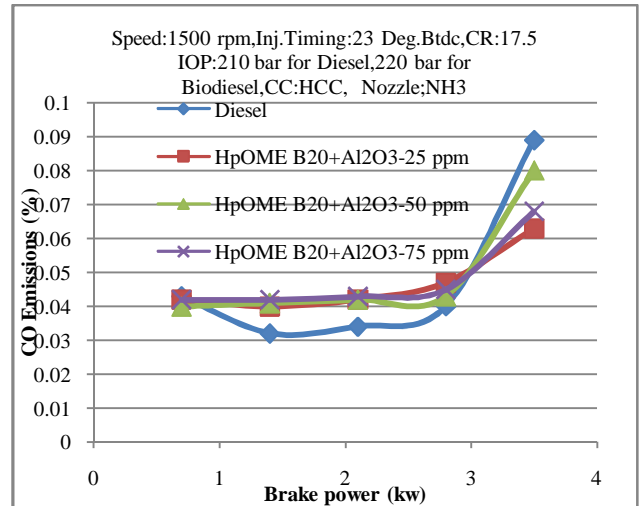


Fig. 12. CO emissions against BP for Diesel, HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20 + ANP75 ppm blended biodiesel.

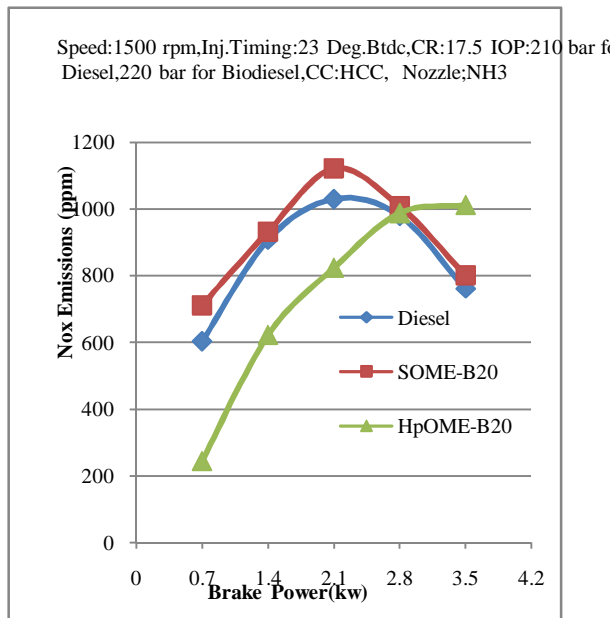


Fig.13.No_x emissions against BP for Diesel, SOME20 and HpOME20.

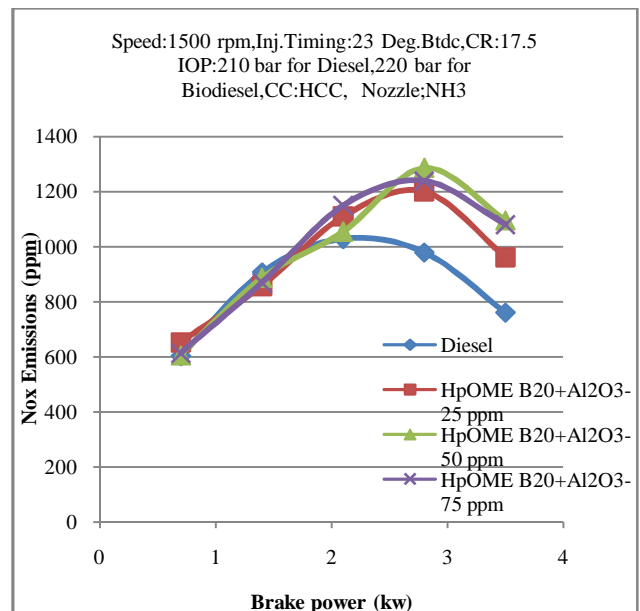


Fig. 14. No_x emission against BP for Diesel, HpOME20 + ANP25, HpOME20 + ANP50 and HpOME20+ANP75 ppm.

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VI.CONCLUSIONS

In this present investigation work, ANP-mixed Hippo oil methyl ester blend fuelled diesel engine performance and emission characteristics were studied, and based on the experiments the following conclusions were drawn:

- It was observed that HpOME B20 shows better performance than SOME B20 blended bio diesel.
- ANP-blended biodiesel (HpOME20+ANP25 HpOME20+ ANP50 and HpOME20+ ANP75) showed an improvement in the calorific value and a reduction in the flash point compared to HpOME20.
- Biodiesel has higher fuel consumption, because of its inferior heating value. With the addition of aluminium oxide nanoparticles, there is a considerable reduction in fuel consumption compared to biodiesel operation and for HpOME20+ANP25 ppm BSFC is found to be 6.896% reduction to Diesel.
- A minor reduction in BTE was observed in all the cases with minimum of 0.38 % (HpOME20 + ANP 25 ppm) when compared to diesel.
- ANP reduced HC and CO emissions up to 17.77% and 29.21% for HpOME20+ANP25 bio diesel blend, compared with to diesel, because ANP acts as oxygen buffer catalyst and donates surface lattice oxygen for the oxidation of HC and CO. NOx emissions increase with the use of ANP and biodiesel blend compared to the diesel fuel.

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