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Effect of Nanoparticles in HCCI Engine Using Tyre Oil

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Abstract
The main aim of this experiment is to study the effect of nanoparticles in HCCI engine operated in dual fuel mode. Diesel and tyre oil is used as a primary fuel and n-butyl alcohol is used as a secondary fuel. Tyre oil is coming from the waste tyres through pyrolysis process along with the transesterification process. B20 (20% tyre oil and 80% diesel) is the blend composition. The nanoparticles are used to provide excess amount of O_2 (oxygen) for maximum combustion rate, MoO_3(Molybdenum trioxide) is the material which was undergone wet chemical purification and roasting process to convert into nanoparticles which is blended with B20 fuel in 50ppm compositions by using the Ultrasonicator. n-butyl alcohol is varying by 10%,20% and 30% to it. Therefore, it results in decrease of Oxides of Nitrogen (NO_x) and smoke emissions by increasing the thermal efficiency of the engine

Keywords: Nanoparticle, HCCI, Tyre Oi.

Introduction

More use of fossil fuel in engine lead to increase the global warming because the emission of nitrogen oxide and carbon dioxide. Research of scientist get a new engine is called HCCI engine. Homogeneous charge compression ignition engine is one of the most efficient and environmentally friendly combustion modes. HCCI engine has been higher thermal efficiency and less emission of nitrogen oxide, unburn hydrocarbon and carbon dioxide. Homogeneous charge compression ignition engine have low combustion temperature because HCCI engine have lean mixture with burned gases due to that the generation of nitrogen oxide is getting decreases and it is reduce the heat release rate. In HCCI engine intake charge is preheated so the intake charge temperature is improved.

Homogeneous charge compression ignition engine have advantage of both the engine, spark ignition and compression ignition engine. Air and fuel are mixed directly in cylinder like SI engine. Then the mixture is compressed in the compression stroke and combustion starts by auto ignition like CI engine. For reduction of soot particle matter and nitrogen oxide emission from the CI engine and spark ignition engine is operate near the stoichiometric ration lead to richer operation due to that harmful emission is happens. To reduce these problem HCCI engine is used. HCCI engine is operating comparatively low temperature combustion than the conventional diesel mode.

R. Rajasekar and S. Ganesan [1] et al.,
In this paper HCCI engine was operated

on dual fuel mode. Biodiesel and Nano particles are the primary fuel supplies and alcohol is the secondary fuel supply. The blends WCOB20 + CaO125ppm have increased the thermal efficiency as 26%. Because of higher surface area to volume ratio due to the addition of nanoparticles. The brake thermal efficiency of nanoparticles added fuel is more than the normal diesel with 3.121%. Specific fuel consumption of lemongrass biodiesel has less than diesel around 10%. The specific fuel consumption is depends upon fuel flow rate. When the load is increase, the fuel consumption is also increases due to that the Nox formation is increased. For the higher loads lemongrass biodiesel has produce less amount of Nox than diesel about 33.8%. The brake thermal efficiency of B3050Zno has more than diesel fuel about 4.5%.

Prabhu Appavu and T. Arunkumar et al., [2] Lemongrass biodiesel mixed with Nano particles has reduces carbon monoxide about 36% than diesel. Because the nanoparticles has the properties that increase the carbon activation and supply proper amount of air fuel ratio and reduce the ignition delay.
Lemongrass biodiesel mixed with nanoparticles had ability to reduce the emission of hydrocarbon about 29% than diesel fuel. Brake specific fuel consumption is reduces by 33.3%, emission of nitrogen oxide is decrease by 25%, emission of carbon monoxide decrease by 61% and emission of hydrogen carbon decreases by 32.5% when zinc oxide nanoparticles is mixed with biodiesel. For the blends B3050TiO2, B3050ZnO and B3050Al2O3 emission of carbon monoxide was decreased by 17%, 39% and 5% respectively. Emission of hydrocarbon is decrease by 3.3%, 32.5% and 1% respectively. It was concluded that lemongrass biodiesel with zinc oxide nanoparticles compare to titanium oxide and alumina has better performance, emission and combustion characteristics about 5%.

M. jaswanth reddy and Jayaprabakar Jayaraman et al., [3]. The TiO_2 nanoparticle is mixed with blends J30D5H, carbon monoxide and unburnt hydrocarbon emission reduce by 20% and 50% respectively and increase the nitrogen oxide emission by 15%. Graphene nanoparticles with diesel in methyl ester blend get increase brake thermal efficiency by 9.14%, reduce hydrocarbon by 15.38%, carbon oxide by 42.85% and nitrogen oxide by 12.71%. It is show that all the load condition pressure in the cylinder is at peak. All the blends show the reduction of carbon monoxide, nitrogen oxide and unburnt hydrocarbon emission than the normal biodiesel. Experiment show that the 50% to 70% loads have the lowest emission. The emission of carbon monoxide is very small with blend 200ppm compare to other blends. Grapheneoxide nanoparticle gives reduction of carbon oxide near 5% to 22% and unburnt hydrogen near 17% to 26% and increase the emission of carbon dioxide from 7% to 11% and nitrogen oxide from 4% to 9%. Finally it is conclude that Nano grapheme oxide can be added in biodiesel fuel.

M. Sunil kumar and V. Praveen kumar [4] et al., At 50% load condition, blends WCOB20 + CaO125ppm show less specific fuel consumption in chamber. It is seen like load is increase from 0% to 25%. There is sudden drop of value, then there is linear variation in specific fuel consumption value. It is decrease as load is increase. Because in single cylinder engine, the turbulence in the single cylinder engine help to increase the speed at the low load, low diesel fuel is consumed. At 50% and 70% load, the blends WCOB20 + CaO125ppm have less smoke emission than other blends. The blends WCOB20 + CaO125ppm biodiesel has increased the atomization due to the addition of nanoparticles. The blends B3050TiO_2, B3050ZnO and B3050Al2O3 have increase the specific fuel consumption by 1.3% over diesel. When titanium oxide nanoparticles was added in J30D5H, then the brake specific fuel consumption was reduced by 12% and brake thermal efficiency was increased by 15% over blends J30D5H.

Ganesh R. Gawale and G.Naga Srinivasulu et al., [5]. In this paper HCCI engine was operated on dual fuel mode by varying different loads. Ethanol and diesel was the primary fuel supplied at the carburettor and Ethanol and Neemoil was the secondary fuel injected at the end of the compression to start the combustion process. Ethanol mass flow rate in the primary fuel was varying by different fuel jets (Jet 40, 60, 70, 80, 90). Increase in ethanol mass flow rate increases the ignition delay and retards start of combustion. It results in in-cylinder pressure, smoke capacity and NO_x was reduced. But increase in HC and CO emissions compared to normal diesel engine. Jet 90 reduces NO_x from 1646ppm to 585ppm and smoke capacity from 32% to 3.89% respectively at 100% load condition. Thermal efficiency of ethanol and diesel dual fuel mode in HCCI engine was 33.5% which is increased by 1.5% compared to normal diesel engine at 100% load condition.

Seyfi Polat et al., [6] In this experiment ethanol and diethyl ether are used as fuel blends. This experiment was conducted on HCCI engine converted from ricardo hydra engine. This experiment was conducted at engine speed of 1200 rpm with the different inlet air temperatures of 333K, 353K, 373K and 393K and different fuel ratios. Indicated thermal efficiency was decreased with the high air-fuel ratio values and increased with the increasing inlet air temperature value. Indicated mean effective pressure increased by about 23% for E40/D60 as compared to E30/D70 inlet air temperature with the addition of ethanol. Among the fuel blends E30/D70 has obtained highest indicated thermal efficiency which is 33.1%. Indicated mean effective pressure decreased with the increasing lambda value and also increase in amount of ethanol in the fuel blends. Increase in the inlet air temperature results in increase in IMEP. Higher emissions were observed from the E50/D50 blend which is rich mixture in both HC and NOx emissions. Negligible NOx emissions were seen in E30/D70 fuel blend.

Ganesh R. Gawale and G.Naga Srinivasulu et al., [7] In this paper HCCI engine was operated on dual fuel mode to find out performance characteristics of engine. In this experiment propanol was supplied along with the air through the carburettor as a primary fuel. Diesel and butanol blend was the secondary fuel injected through the fuel injector into the engine cylinder. Mass flow rate of propanol was varying by using different fuel jets (40, 60, 70, 80, and 90) in the carburettor. Diesel and butanol blends were taken in the ratio of B10, B20 and B30. Effect of butanol blends were examined under constant propanol rate of jet 60 which is (0.401kg/hr) at different loads. It results in increase amount of butanol increases ignition delay and low

NOx and smoke capacity. For the fuel 100%Propanol and diesel NOx emissions was reduced from 1614ppm to 848ppm and smoke capacity was reduced to 4.44HSU with 1% increase in BTE compared to normal diesel engine But low load conditions BTE was reduced. for the (P100 + D) dual fuel HCCI engine maximum 67.64%, diesel heat energy was replaced by propanol fuel reduction in NO_X emission and smoke opacity with 66.47% and 80.17% respectively at all load conditions with negligible losses in BTE compared to normal diesel engine. The propanol ignited by butanol blend sshowed decrease in NOx and CO emissions. BTE was reduced compared to P100+D engine. For different load conditions different fuel blends are given optimised results.

S.V.Khandal, N.R. Banapurmath and V.N.Gaitonde et.al [8] In this paper HCCI engine was operated on dual fuel mode to study its performance characteristics of engine at different hydrogen fuel ratio and at different loads. Hydrogen is the primary fuel supplied along with the air at the time of suction. Diesel and biofuel is secondary fuel which is injected into the cylinder using CRDI. At the 80% load condition engine was operated with severe knocking without exhaust gas recirculation. Engine operated smoothly with EGR and percentage of 50% diesel and 54% biodiesel. Maximum BTE achieved 31.5% with diesel, 30.6% with honge biodiesel and 30.2% with cotton seed biodiesel. HCCI engine fuelled with biodiesel showed that 2%-3.4% lower BTE; 65%-67% lower smoke rate and 98%-99% lower NOx emissions with the HFER 7% and EGR of 54%-80% load compared to the CI mode. It also showed that 11 times higher HC emissions and similar CO emissions like CI mode.

From the literature survey it was absorbed to adding the nanoparticle to increase the efficiency and emission characteristics. In this investigation the biodiesel is using tyre oil and mixing with different proportions of nanoparticle.

Methods Used

Tyre Oil

Increasing world population and rapid industrialization are growing the modern economy and causing more energy demand. Depletion of non-renewable fuel sources, increase in the energy prices and endless exhaust emission pollution caused by internal combustion engine make researchers to be more interested in sustainable and environmentally friendly renewable energy sources. Alternative fuels are being explored to reduce the harmful effects of fuels and their derivatives, which are the basic energy sources required for production. Recycling of waste tyres by cutting or shredding them and making new products such as liquid tanks, mats, road floors, playground covers, sports fields is the best method in terms of economic and environmental results.

Another recycling method is to obtain coal, gas and valuable oil products as a result of pyrolysis of waste tyres. These valuable oils are successfully used in engines due to their light fuel-like fuel properties. Pyrolysis has become important due to its suitability for use in compression ignition engines to evaluate different wastes as an alternative fuel and to facilitate waste management. As a result, pyrolysis is the best way to recycle waste tyres. Approximately 1.5 billion tires are produced each year which will eventually enter the waste stream representing a major potential waste and environmental problem In Bangladesh, total waste tire generation of each year is

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about 90000 tons. Vehicle tires contain long chain polymer (butadiene, isoprene, and styrene-butadiene) which crosslinked with sulphur thus having excessive resistance to degradation. One common way for disposal of these waste tires is land filling. Tires are bulky, and 75% of the space a tire occupies is void, so the land filling of waste tires has several difficulties. Waste tire needs a considerable amount of space because of the volume of tires cannot be compacted. Tires tend to float or rise in a landfill and come to the surface. Under the ground, the void space of waste tires captures various gases such as methane which has
a tendency to burn suddenly with a vast explosion. If the waste tire is scattered on land in vain then it comes with rain water and may be a good place for breeding mosquitoes or others bacteria's. This causes various harmful diseases to human beings. If the scrap tires burn directly in brick fields or any other incineration plant then various harmful gases such as CO_2, CO, SOx, and NOx will be produced which cause environmental pollution. On the other hand, burning of these tires causes excessive damage to human health caused by the pollutant emissions such as poly aromatic hydrocarbons (PAHs), benzene, styrene, butadiene, and phenol-like substances. Conversion of these waste tires to energy through pyrolysis is one of the recent technologies in minimizing not only the waste disposal but also utilizing as an alternative fuel for internal combustion engines.

Pyrolysis is generally described as the thermal decomposition of the organic wastes in the absence of oxygen at mediate temperature about 4500c. The advantage of pyrolysis process is its ability to handle waste tire. It was reported that pyrolysis oil of automobile tires contains 85.54% C, 11.28% H, 1.92% O, 0.84% S, and 0.42% N components.

Pyrolysis process is also nontoxic and there is no emission of harmful gas unlike Incineration. Tire pyrolysis oil has been found to have a high gross calorific value of around (41–44) MJ/Kg. It would encourage their use as replacement for diesel fuel if it is properly distilled. Therefore, these waste tires should be utilized by converting to new and clean energies.

Fig 1: Tyre oil

N-Butyl Alcohol

N-Butyl alcohol is a four-carbon straight chain alcohol that is a clear and highly flammable liquid with a strong alcoholic odor. N-Butyl alcohol is miscible with many organic solvents such as benzene, ethanol, and diethyl ether and readily dissolvable in water.

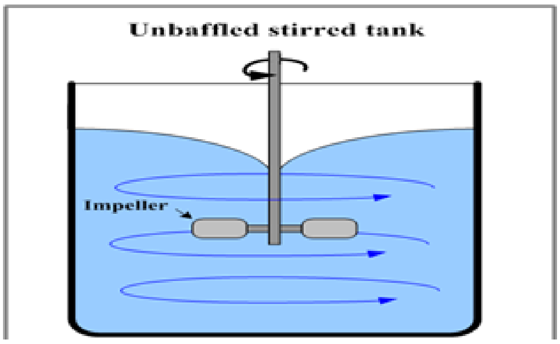

Fig 2: n-butyl alcohol

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Molybdenum Trioxide

Nanoparticles Diesel engines a main source of heavy duty vehicles. They are intimidating environment as they are a main contributor to atmospheric pollution as it emits more HC, CO and NOx. One of the best way to reformulate the diesel by using molybdenum trioxide nanoparticles to reduce emissions. Molybdenum trioxide (MoO3) is a compound of molybdenum (Mo) at its highest oxidation state. It is produced in significantly higher volumes worldwide than any other molybdenum compound, due to the comparative instability of molybdenum oxides of lower oxidation states. Synthesizing these minerals can be complicated and they often exhibit rapid destabilization in air, which limits their realistic areas of application to fine chemical synthesis.

MoO_3 is much easier to manufacture through the wet chemical purification and roasting process. This enables rapid and reliable synthesis of intermediate MoO3 powders for use as catalysts in redox chemistry. It also enables the development of MoO3 nanoparticles with tight control over their crystalline microstructures and size, offering a plethora of benefits for functional coating applications and electronics manufacturing.

Pyrolysis Process

At first, automobile tires are cut into a number of pieces and the bead, steel wires, and fabrics are removed. The tire chips are washed, dried, and fed in a mild steel fixed bed reactor unit. The steps of pyrolysis process

Fig 3: Pyrolysis Process

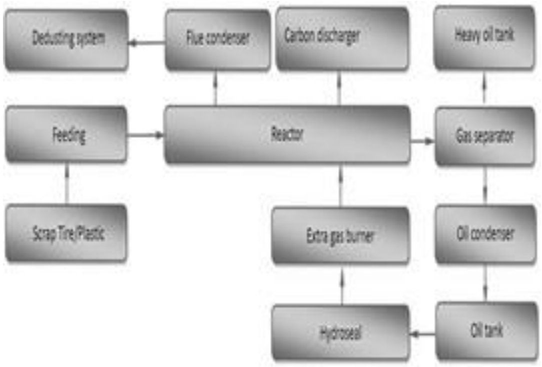

Fig 4: Pyrolysis Process

The feedstock is externally heated up in the reactor in absence of oxygen. The pyrolysis reactor design for the experiment is a cylindrical chamber of inner diameter 110 mm, outer diameter 115 mm, and height 300 mm which is fully insulated. 2 kW of power is supplied to the reactor for external heating. The temperature of the reactor is controlled by a temperature controller. The process is carried out at 450–6500c. The heating rate is maintained at 5 K/min. The residence time of the feedstock in the reactor is 120 minutes. The products of pyrolysis in the form of vapour are sent to a water cooled condenser and the condensed liquid is collected as fuel. Three products are obtained in the pyrolysis, namely, tire pyrolysis oil (TPO), pyro gas, and char. 1.9 kg of feedstock is used to produce 1 kg of tire pyrolysis oil. The heat energy required for pyrolysis process per kg of TPO produced is around 6 MJ/kg.

Mechanical Stirring

In this experiment diesel and tyre oil was mixed with the help of mechanical stirring process in proportions of B20 which means 80% diesel and 20% tyre oil. Mechanical stirring and ultrasonic vibration have also been combined as an alternate route to produce spheroidal starting material. A higher localised fluid flow from the combined effects of vibration and mechanical stirring was noted to have mobilized the insoluble solid nanoparticles and promote more nucleation.

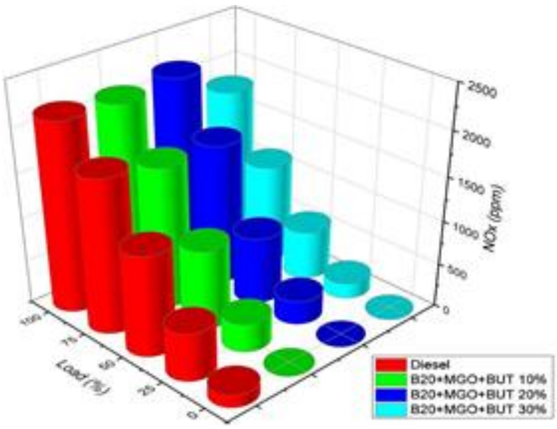

Fig 5: Mechanical Stirring

Ultrasonicators

In this experiment MoO3 (Molybdenum Trioxide) nanoparticles of 50 ppm are doped into the B20 blend with the help of ultrasonicator. Ultrasonication is another method that is used for the preparation of nanoemulsions that has good control over the characteristics of emulsions. It can be used to form a nanoemulsion in situ or to reduce the size of a previously prepared emulsion. When ultrasound waves are transferred through the emulsion, they create cavitation phenomena which comprise the formation, growth, and implosive collapse of micro bubbles/cavities in the medium. These transient collapse conditions generate a localized hotspot region such intense cavitation conditions can initiate the desired physical transformation during emulsification. Ultrasound-based emulsification occurs in two ways, the first generation of droplets occurs in the acoustic field and the second the creation of intense turbulence and micro jets during asymmetric cavity collapse, which causes the break up and dispersion of droplets in the continuous phase. Emulsions with lower droplet size possess long-term stability. Therefore ultrasounds can effectively control the particle size distribution as well as improve the stability of emulsions

Engine Setup

The engine was coupled to a dynamometer to provide load to the engine. A sensor is connected near the flywheel to measure the speed. Air intake was measured by air flow sensor that is fitted in an air box. A burette was used to measure fuel flow to the engine via fuel pump. A thermocouple with a temperature indicator measures the exhaust gas temperature. Emissions such as unburnt hydrocarbon (HC), carbon monoxide (CO) and nitric oxide (NO) were measured by an AVL exhaust gas analyser. Combustion diagnosis was carried out by means of a Kistler make quartz piezoelectric pressure transducer (Model Type 5395A) mounted on the cylinder head in the standard position. Kistler pressure transducer has the advantage of good frequency response and linear operating range. A continuous circulation of air was maintained for cooling the transducer by using fins to maintain the required temperature. Combustion parameters such as mechanical efficiency, brake thermal efficiency, brake specific fuel consumption, ignition delay, and maximum rate of heat release and emission parameters like exhaust gas concentrations and temperature were evaluated. The experiments were carried out by using B20 tyre oil and n-butyl alcohol at different load conditions on the engine keeping all the independent variables same.

Brake Thermal Efficiency (BTE)

Brake thermal efficiency is defined as how efficiently the fuel is burnt inside the combustion chamber and gets converted into useful output. Following graph shows the variation of the BTE with respect to the various blends and diesel fuel. It is evident that the condition of diesel as the only fuel, the efficiency is high. We can clearly observed that BTE with these blends gives higher efficiency compared to normal diesel engines.

Brake Specific Fuel Consumption (BSFC)

As with the obtained values of the experimental study, the graph is plotted with the brake specific enrgy consumption variation with brake power. The variation of the BSEC is regarded with the diesel and its blends. The brake speciific energy consumption is defined as the ratio of energy obtained by burning fuel for an hour to the brake power of the engine.

It is clearly evident that BSFC for thses fuel blends consumes less fuel compared to normal diesel mostly in all cases. Especially for the blend B20+MGO+BUT30% consumes very less fuel.

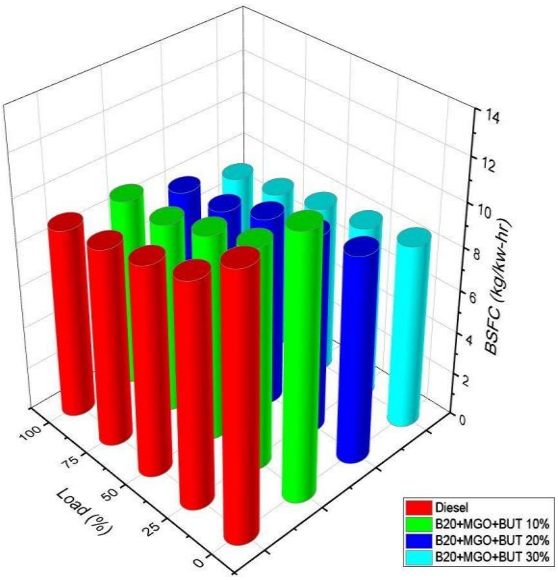

Fig 6: BFC Vs Load

Hydrocarbons (HC)

The following graph represents the hydrocarbon emissions with respect to brake power for various conditions. Blends with various ratios of BUT with B20 emit lesser hydrocarbons when compared to diesel fuel. This is due to the presence of

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oxygen which reduces the formation of hydrocarbon emission.

As the load increases the air to fuel ratio increases, which leads to increase in occurrence of emission. It is noted that the bio-fuel blends have a better reduction in emission. It may be due to the mixing rate of bio fuel blend and availability of the oxygen in it to burn the fuel completely. But here we observe that as load increases HC is also increased compared to diesel.

Carbon Monoxide (CO)

Deficiency in oxygen content is only an intermediate combustion product, which leads in formation of Carbon Monoxide emission. For complete combustion the carbon monoxide has to be fully converted into carbon dioxide. It is noted that CO emissions are more in some load conditions compared to diesel. At the 75% load condition of B20+MGO+BUT20% seems that CO emissions are lesser compared to others.

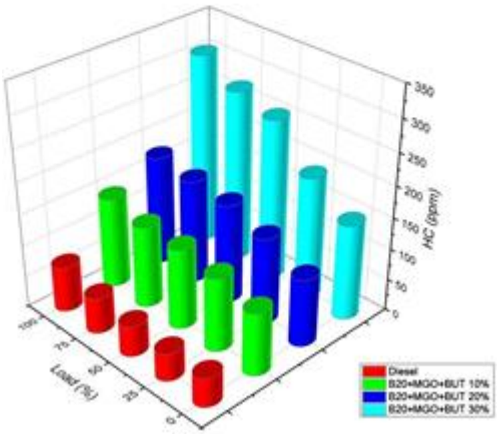

Fig 7: Load Vs CO

Oxides of Nitrogen (NOx)

The oxides of nitrogen occur mainly because of two reasons. The first is the In-Cylinder temperature and oxygen rich in fuels tends to form harmful NOx emissions. Nitrogen combines with oxygen to form oxides of nitrogen. The NOx emissions are higher in diesel engine when compared to petrol engine.

We can clearly notice that NOx emissions are less compared to diesel for all load conditions. Here B20+MGO+BUT30% gives lesser NOx emissions compared to others.

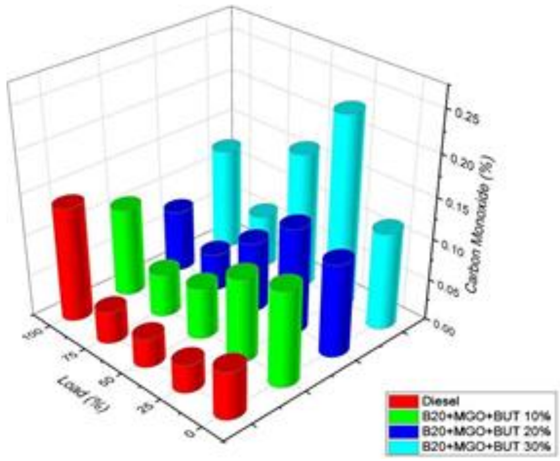

Fig 8: Load Vs NOx

Conclusion

Tyre oil seems to have a potential to use as alternative fuel in diesel engines. Blending with diesel decreases the viscosity considerably. The following results are made from the experimental study,

- The brake thermal efficiency of the engine with tyre oil blend was gives more efficiency than the diesel fuel.

- Brake specific energy consumption is lower for tyre oil blend than diesel at all loading conditions.
- It produced lesser NOx emissions compared to normal diesel fuel.
- Some of the emissioins characteristics CO and HC are higher than normal diesel engine at some load conditions.
- The B20+MGO+BUT20% blend performed decently in each cases compared to other blends.

References

[1] M. Sunil Kumar, R. Rajasekar, S. Ganesan et al., Evaluation of metal oxide nano particles in lemongrass biodiesel for engine performance, emission and combustion characteristics, Material Today Proceedings https://doi.org/10.1016/j.matpr.2020.10.796

[2] M. Jaswanth Reddy, N. Sai Rakesh, J. Jayaraman et al., Effect of novel bio-waste derived nano particles as additives on the performance of diesel engine fuelled with waste cooking oil biodiesel blends, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.09.292

[3] J. Jayaraman, Imtiyaz ul Islam Laskar, K. Dey et al., Investigation on titanium oxide nano particles as additives for operating biodiesel fuelled engine, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.09.291

[4] SS. Hoseini et al. Renewable Energy Performance and emission characteristics of a CI engine using graphene oxide (GO) nano-particles additives in biodiesel-diesel blends 145 (2020) 458-465, https://doi.org/10.1016/j.renene.2019.06.006

[5] Ganesh R. Gawale⁎, G. Naga Srinivasulu, Experimental investigation of propanol dual fuel HCCI engine performance: Optimization of propanol mass flow rate, impact of butanol blends (B10/B20/B30) as fuel substitute for diesel (2020), https://doi.org/10.1016/j.fuel.2020.118535

[6] Seyfi Polat, An experimental study on combustion, engine performance and exhaust emissions in a HCCI engine fuelled with diethyl ether–ethanol fuel blends, Fuel ProcessingTechnology(2016)140–150, http://dx.doi.org/10.1016/j.fuproc.2015.11.021

[7] Ganesh R. Gawale⁎, G. Naga Srinivasulu, Experimental investigation of ethanol/ diesel and ethanol/biodiesel on dual fuel mode HCCI engine for different engine load conditions, Fuel, https://doi.org/10.1016/j.fuel.2019.116725

[8] S.V. Khandal, N.R. Banapurmath, V.N. Gaitonde, Performance Studies on Homogeneous Charge Compression Ignition (HCCI) Engine Powered with Alternative Fuels, Renewable Energy (2018), https://doi.org/10.1016/j.renene.2018.08.035