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NANO-ADDITIVES, CI ENGINE EMISSION AND PERFORMANCE CHARACTERISTICS – A REVIEW

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ABSTRACT

Fuel reserves are declining because of high standard of urban class, have led to an energy crisis and an enormous increase in the demand and cost of the fossil fuels. The US Energy Information Administration (EIA) has predicted that the global fuel consumption mainly liquid fuel, will rise from 86.1 million bbl/day to 110.6 million bbl/day by the year 2035 and the global sales of passenger cars are forecasted to hit 78.6 million vehicles in 2017. The consumption of petroleum products can carry the key environmental impact that may be regional or global in scale, including air pollution, climate change, and oil spills. The dependency of world energy on conventional fuels such as petroleum-based products, coal, and natural gas has elevated to two-thirds of the global energy demand. Biodiesel is an unsurpassed alternative fuel source intended to extend the value to fossil fuels, and the longevity and cleanliness of diesel engines. It reduces the dependence on the foreign fuels and reduces the greenhouse gas emissions due to its closed carbon cycle. The present work summarizes the literature from most recent articles on nanoparticles as a liquid fuel additive. The effect of dispersion of several nanoparticles on the enhancement in the performance characteristics and reduction in emission of a CI engine fuelled with diesel-biodiesel blends are discussed. Nevertheless, few obstacles and challenges which have been recognized in this review must be addressed before they can be fully put into practice in the industrial applications.

Keywords: Biodiesel, Diesel Engine, Transesterification, Nano-additives, Emission, Performance

1. INTRODUCTION

The decline in the fuel reserves, population growth and high living standards of the urban class have led to an energy crisis and an enormous increase in the demand and cost of the fossil fuels. The US Energy Information Administration (EIA) has predicted that the global fuel consumption mainly liquid fuel, will rise from 86.1 million bbl/day to 110.6 million bbl/day by the year 2035 and the global sales of passenger cars are forecasted to hit 78.6 million vehicles in 2017. The consumption of petroleum products can carry the key environmental impact that may be regional or global in scale, including air pollution, climate change, and oil spills. The dependency of world energy on conventional fuels such as petroleum-based products, coal, and natural gas has elevated to two-thirds of the global energy demand. The fuel importing developing Asian countries are in a severe economic disparity due to unequal distribution of fuel prices. Engine exhaust comprises of volatile organic compounds (VOCs), which represent unburned fuel emissions and other VOCs produced as by-products of incomplete combustion. Few VOCs described as being of health concern are acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde, and naphthalene. Petrol and diesel-powered automobiles are the major sources of VOCs in urban areas. A severe problem related to diesel emissions is the presence of polycyclic aromatic hydrocarbons (PAHs). Numerous PAHs are known to be mutagenic and/or highly carcinogenic towards humans.

Biodiesel is normally produced from the transesterification of vegetable oil. However, in Brazil, about 20% of the biodiesel produced comes from animal fat. The production of biodiesel involves the transesterification of a triglyceride molecule with three molecules of methanol or ethanol to afford three molecules of fatty acid methyl or ethyl esters, the biodiesel themselves, and a molecule of glycerol or glycerin, produced as by product. The world forecast of glycerol production form biodiesel points to an increasing supply, with net global production around 1.2 million tons by 2012. In Brazil, the estimated amount of glycerin production with the implementation of B4 is 260 thousand tons per year, but this production will increase in 2010 with the introduction of B5. By contrast, the present glycerin consumption in Brazil, mostly for personal care, cosmetics and food usage, is about 30 thousand tons per year. Therefore, it is imperative to find new applications for the excess of glycerin produced from biodiesel.

The vegetable oils and animal fats are used in transesterification process in order to reduce viscosity. There are four methods to reduce vegetable oils viscosity they are direct use and blending process, microemulsion process, pyrolysis process (thermal cracking) and transesterification process. Out of four transesterification is apreeminent method for edible and non-edible oil. Non-edible oils are used for biodiesel production this is due to nonedible oil seeds availability, edible oil value and also environmental concerns. Metal based nano particle has such properties: nano particles takes high specific surface area, nano particles contains higher thermal conductivity and nano particles exist high reactivity. While adding cerium oxide nano particles with biodiesel which increases cetane number and fuel efficiency of diesel engine. Aluminum oxide nano particles blended in biodiesel which enhances performance and reduction in emissions and also increase heat release rate of combustion. Addition of nano particles will increases combustion efficiency and reduction in emissions, and by varying the nano particle size combustion rate will be increased, high heat release rate. In earlier paper, a metal based nano additive was investigated. In the present paper, organic nano particles as coconut shell were prepared and it is blended with biodiesel and tested in diesel engine.

2. LITERATURE REVIEW

Nazia Hossain et al. researched on the use of microalgae for the production of biofuels has been investigated because of its rich energy content, inflated growth rate, inexpensive culture approaches, the notable capacity of CO2 fixation, and O2 addition to the environment. Addition of nano additives has been observed as an significant innovation. Different types of nano additives such as nano-fibres, nano-particles, nano-tubes, nanosheets, nano-droplets, and other nano-structures had been surveyed, to accommodate microalgae growth for the utilization in the biofuels. Addition of nano-additives in the biofuels for the growth of microalgae showed great improvement. It was observed that use of this fuel had complete and clean combustion, mixed with conventional fossil fuel in the spark ignition engine, compression ignition engine and direct injection engine. The addition of nano particles which increased the microalgal biofuel, showed reduced CO, smoke, soot, CO_2, HC, NO_x emission by 72% and increased combustion efficiency. Application of solid nano-additives such as alumina (Al2O3), CERIA, carbon nano-tubes (CNT), Co3O4, ZrO2, La2O3, CeO2, SiO2, Ni2O, TiO2, ZnO, Fe2O3, CuO, Ce*x*Zr(1–*x*)O2, and amide-doped MWCNTs-CeO2 boosted the engine power, torque, and brake thermal performance of biodiesel (extracted from microalgae and other biomass) in CI and DI engines up to 11%. It was also observed that mixing of nano particles blended with biodiesel and blend of biodiesel-diesel had outstanding performance [1].M.S. Gada et al. deduced biodiesel from jatropha oil by acid esterification and then trans-esterification. The mixing percentage were 20% Vol% of jatropha biodiesel mixed with diesel and biodiesel oil. Nano additives were added to improve the fuel performance by adding as CNTs, TiO_2, and Al_2O_3, having 25,50 and 100ppm blend ratio was created. Test results established that nano Al_2O_3 as J20-Al100 improved the thermal efficiency by 6.5% compared to other fuels. Jatropha biodiesel blend with CNTs as J20C50 produced higher decreases in CO and NOx emissions by about 35 and 52%, respectively compared with all fuels. TiO_2 as J20-T25 reduced the hydrocarbon and smoke emission by 22 and 50% [2]. Vijayakumar Chandrasekaran et al. investigated on fuel modification in a diesel engine. Initially the diesel engine was operated with different fuel blends i.e. 20MEOM (mahua oil), 40MEOM, 60MEOM, 8MEOM and 100MEOM, under varying load conditions and at constant speed. 20MEOM was the best blend compared to other blends. Then in the same fuel 20MEOM blend, nano particles od copper oxide were added. It was observed that the brake thermal efficiency was improved by 2.19% compared to 20MEOM without additives. Smoke, carbon monoxide and HC were reduced [3]. Paulo H.R. Silva et al. studied glycerol acetals from butanal, pentanal, hexanal, octanal and decanal were prepared with the use of Amberlyst-15 acid resin as catalyst. Hydrocarbon chain size changes with glycerol conversion decreases. This fact has been associated with formation of micelles and aggregates of the aldehyde to minimize the interaction between the polar glycerol molecule with the hydrocarbon chain. Acetal isomers distribution changed with the reaction time, mainly for long chain aldehydes. Pour point was reduced from 18 to 13^0C for biodiesel (animal fat) by adding 5vol.% butanal-glycerol [4].A. Murugesanresearched on the performance of DI compression ignition engine run on waste cooking oil biodiesel blend 20% and compared its performance wit and without nano additives. Aluminium oxide and cerium oxide nano particles were disseminated at different weight in the biodiesel blend. Better combustion was observed with the presence of highly reactive surface. Nano particles in the biodiesel blend improve the brake thermal efficiency and specific fuel consumption by 1.6 and 8%. Carbon monoxide (shown in figure 1), unburnt HC and smoke was reduced and NO_x reduced by 8%. Engine characteristics further improved by the addition of 500 mg/l of aluminum oxide and 500 mg/l of cerium oxide [5].

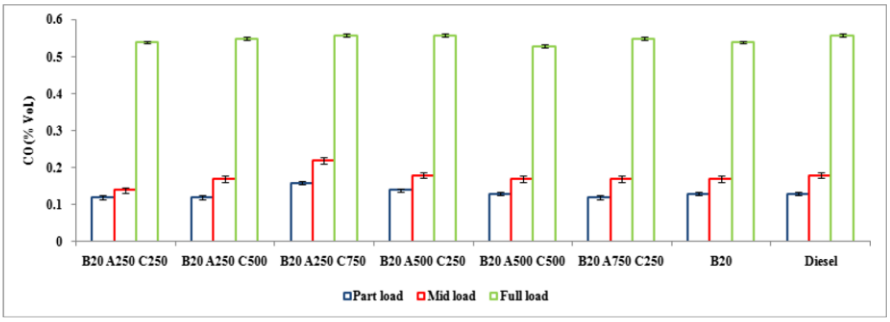


Fig. 1. Variation of CO under load [5]

Manzoore Elahi M. Soudagar et al. researched on the use of additives to improve the diesel-biodiesel fuel emission. The additives could be oxygenated, metallic, non metallic, organic and a combination. Heat transfer rate and thermophysical properties were improved at the same time fuel mixture was stable. Also, there was an increase in the engine performance parameters and reduction in the exhaust emissions depending on the dosage of nanofluid additives. Dispersion effect of nano particles and its effect on performance and emission reduction were discussed. Figure 2 shows the micro explosion and atomization effect [6].

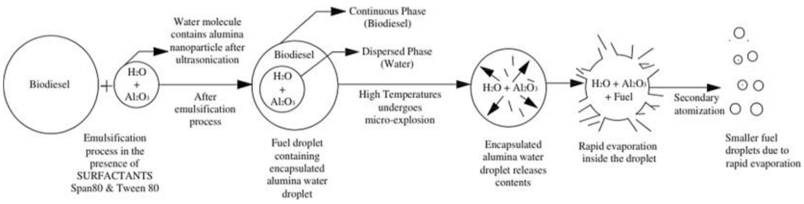


Fig 2. Schematic of microexplosion and secondary atomization effect of the biodiesel emulsion fuel [6]

Harish Venu et. Al Studied the effect of polanga biodiesel on emission, combustion and performance on a single cylinder engine. Biodiesel was added with nano-additives at 25ppm and 50ppm concentration. The test was carried out at 25%, 50%, 75% and 100% engine load and experimental results were compared to baseline diesel fuel in a agricultural single cylinder, having compression ratio of 17.5 at a speed of 1500rpm. Polanga biodiesel was blended with nano additive of Al_2O_3using ultrasonicator and magnetic stirrer. Experimentation results revealed that the addition of the nanoparticles in PBD improved the combustion and emission characteristics of base fuel due to higher surface area to volume ratio of nano-additives. Brake thermal efficiency was enhanced by 6.58% and brake specific fuel consumption was lowered by 7.38% by the use of Al_2O_3 nano-additives. HC, CO, smoke opacity and NO_x emission improved by the use of nano-additives in the fuel which also helps in improving the combustion efficiency. PBD + 25 ppm Al2O3 resulted in lowest ignition delay (ID) while PBD + 50 ppm Al2O3 resulted in the highest mass fraction burnt (MFB). Al_2O_3 +50ppm showed the best result by improving the combustion and minimum emission [7].

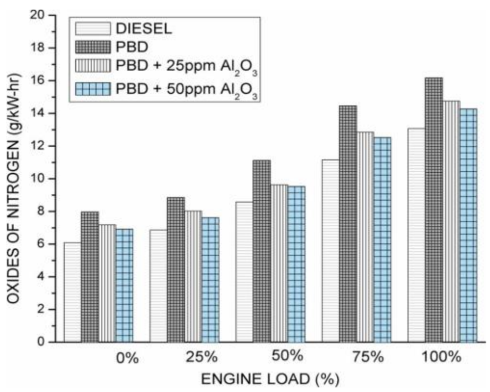


Fig 3: Variation of oxides of nitrogen (NOx) with respect to engine load [7].

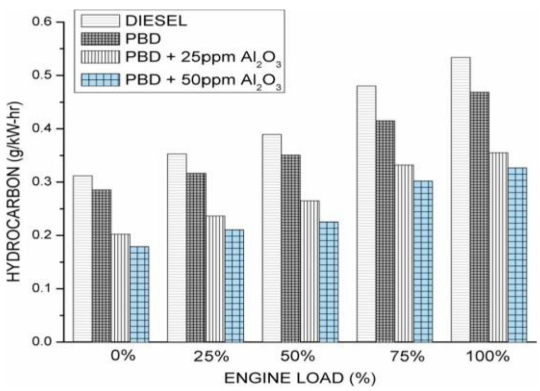


Fig 4: Variation of hydrocarbon (HC) with respect to engine load [7]

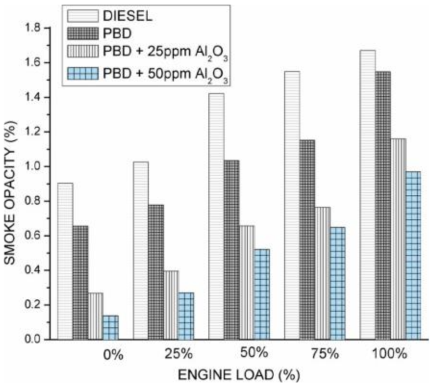


Fig 5: Variation of smoke opacity with respect to brake power [7]

L.Jeryrajkumar et al. Researched on the use ofpolangabiodiesel in compression ignition engine for benefiting the environment. Particulate matter, CO and HC emission reduced by the use of biodiesel but the NO_x emission and fuel consumption increased, no change in the engine. Introduction of nano particles in the biodiesel decreased the NO_x emission and thermal efficiency was better than only biodiesel. Cobalt oxide and Titanium dioxide Nano additives were used with Calophylluminnophyllum biodiesel and its effect on emission and performance was characterized on a 4-stroke single cylinder, water cooled CI engine. Hydrothermal process was used to prepare the nano additives. The nano attitives were in the size range of 100nm, scanning electron microscope, zeta potential and X-ray diffraction were used for characterization of nano particle. Ultrasonicator and Magnetic stirrer, dispersed the nano particles(150 ml/l) in the biodiesel. it was observed that if the additives are combined in the right amount, it can lower the emission of PM, CO and UHC but increase the NO_x emission. In HC emission cobalt oxide showing 80% reduction at full load. Titanium dioxide resulted that 70% reduction in 75% load. It also helps in engine performance and combustion. It also helps in reducing the fuel consumption and improves the thermal efficiency [8].

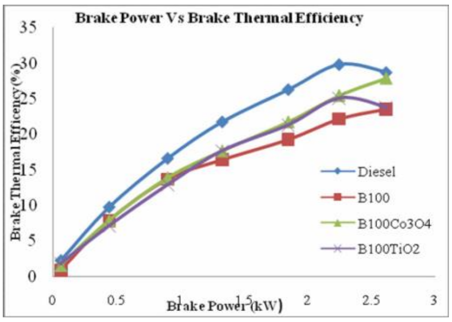


Fig 6: Variation of Brake Thermal Efficiency with Brake Power [8]

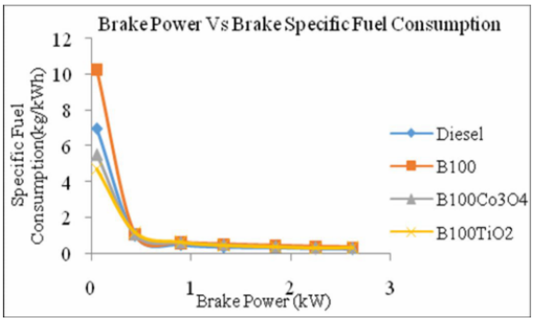


Fig 7: Variation of Brake Specific Fuel Cosumption with Brake Power [8]

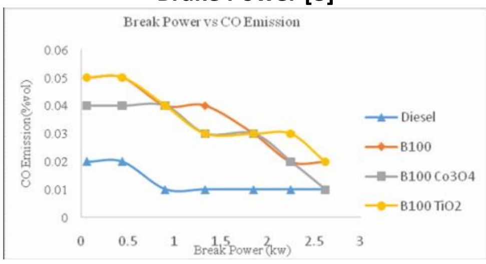


Fig 8: Variation of Carbon Monoxide with Brake Power [8]

Fig 9: Variation of Hydrocarbon Emissions with Brake Power [8]

Harish Venu et al. Studied on the use of nano additives in the compression ignition engine to reduce the exhaust emissions. Biodiesel could be used in diesel engine as low as 10% but the only disadvantage is higher NO_xemission and this could be reduced by the use of EGR. Hydrocarbons, smoke and carbon monoxide riser with the use of EGR. Palm biodiesel was used with diesel in a ratio of 30/70 respectively with EGR and 25ppm titanium dioxide nano-particles were mixed. By the use of EGR it was observed that BSFC, CO and HC reduced but EGT increased. NO_x emission were similar for both the conditions of use of additive with EGR and without additive with EGR. Smoke emission were lower for biodiesel with additive and EGR. Higher heat release rate was observed and slightly lower cylinder pressure seen when the EGR percentage was increased [9]. **Harish Venuet al.**Focused on the effect of nano additives, injection timing and combustion chamber geometry in a single cylinder CI engine fuelled with diesel-biodiesel- ethanol blends. The fuel was doped with aluminium additives. The fuel was tested in combustion chambers with different geometry and it was observed that torroidal re-entrant combustion chamber geometry was the optimum geometry. BTE is lowered for HPF-TRCC21 and HPF-TRCC24 by 4.53% and 1.22% while highest BTE of about 33.8% is achieved for 22obTDC in comparison with other blends such as DIESEL-HCC23 (32.75%), HPF-TRCC21 (31.41%) and HPF-TRCC24 (32.53%). Brake specific energy consumption was lowest for HPF-TRCC22. HC was 9.18% and CO was 16.83% lower for HPFTRCC22 compared to HPFTRCC23. NO_x was reduced by 22.53% with HPF-TRCC21, at the same tiome reducing HC and CO emission by 6.13% and 20.51 compared to HPFTRCC23. DIESEL-RK theoretical simulation were compared to experimental result and was found to be similar [10]. **S. Janakiramanet al.**found that automotive sector was the main consumer of energy compared to other sectors. It was also stated that India imports about 70% of its non renewable energy.

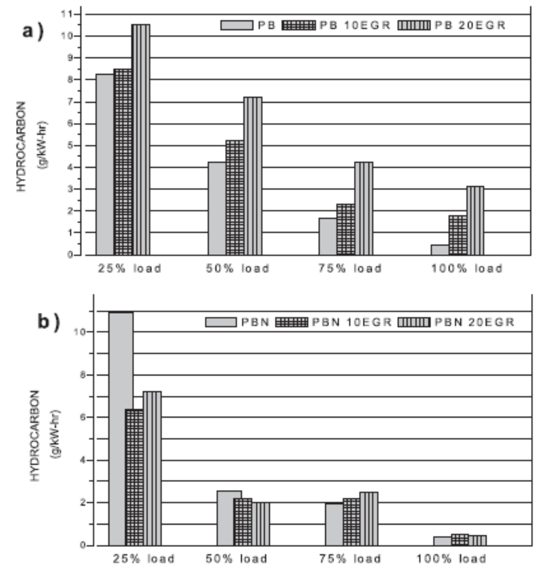


Fig 10: a Variation of total hydrocarbon (THC) emission with respect to engine load for PB-EGR b Variation of total hydrocarbon (THC) emission with respect to engine load for PBNEGR.

Cerium oxide (CeO2), Zirconium oxide (ZrO2) and Titanium oxide (TiO2) additives with 20% biodiesel (i.e 20% Garcinia gummi-gutta biodiesel) and 80% diesel were compared by experimentation in a single cylinder engine. sol-gel combustion, TEM, XRD and SEM analysis were used for the characterization and synthesis of nano particles. 25 ppm faction nano particles were prepared and magnetic stirrer was used for 30 minutes for blending it with B20 followed by 10min ultrasonication. Similar performance, low UBHC, co and smoke emission was observed with B20 (Garcinia)þTiO2(25 ppm) fuel blend compared to diesel. NOx and CO2 emission increased with increase in peak load [11]. **K. Vinukumaret al.** Researched on the reduction of emission from compression ignition engine run on biodiesel and diesel blend with coconut shell nano particles. The coconut nano particles were prepared by mechanical ball milling process. Coconut Nano particle size was 20nm in diameter. 20%BD80%DF with coconut shell at maximum load reduced the NO_xemission by 18.56%, in comparison to 100% diesel fuel. CO and CO_2 emission was reduced for all load conditions [12].

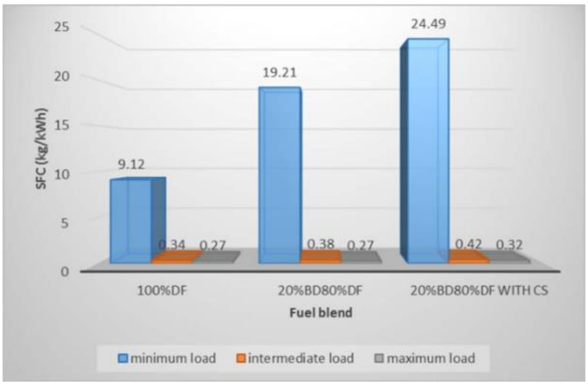


Fig 11: Results of specific fuel consumption for different fuel blends at the constant speed of 1500 rpm and minimum, intermediate and maximum load [12].

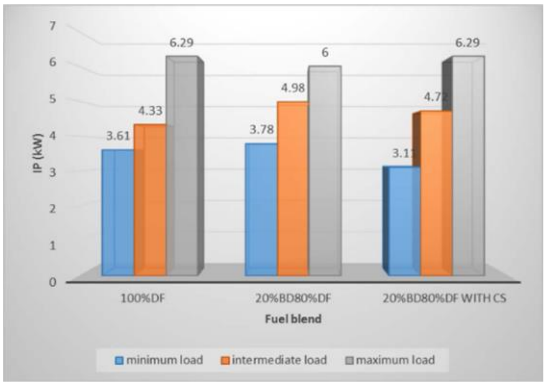


Fig 12: Results of power generated by different fuel blends at the constant speed of 1500 rpm and minimum, intermediate and maximum load [12].

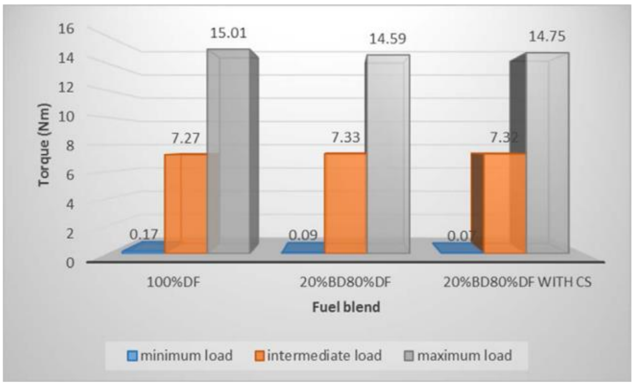
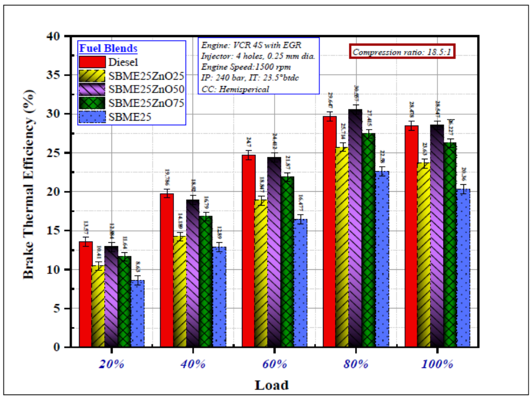
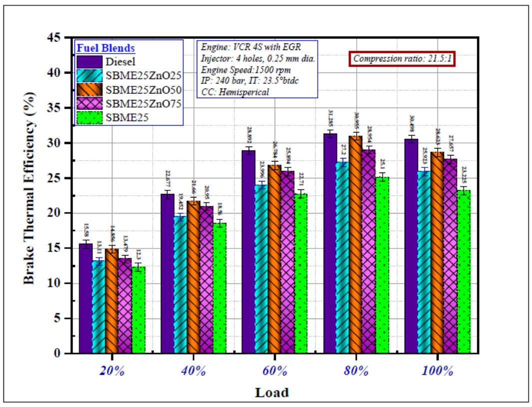


Fig 13: Results of torque generated by different fuel blends at the constant speed of 1500 rpm and minimum, intermediate and maximum load [12].

Rakhamaji S. Gavhane et al. synthesized zinc oxide nanoparticles and blending with soybean biodiesel. zinc oxide were blended to improve the fuel properties of SBME25 blend and improve the characteristics of variable compression ratio diesel engine. Soybean biodiesel was prepared by transesterification reaction. To check the shape and size of zinc oxide nanoparticles, several characterization test were accomplished. Dosage of nano particles were 25, 50 and 75ppm with sodium dodecyl benzene sulphonate. Nanofuel blend showed better fuel properties against SBME25. The fuels were tested at different compression ratios (18.5 and 21.5). Fuel blend SBME25ZnO50 and compression ratio (CR) of 21.5 illustrated an overall enhancement in engine characteristics. Beak thermal efficiency increase by 23.2%, HC, CO, smoke and CO_2 was reduced by 32.23%, 28.21%, 22.55% and 21.66% respectively. Ignition delay was reduced as well as HRR and mean gas temp was improved. Though NO_x emission was higher for all the nano fuel blends and increased combustion chamber temperature [13].



(a)



(b)

Fig 14: The variation of BTE at compression ratios of (a) 18.5 and (b) 21.5 [13].

Harish Venuet al. Experimented on combining nano additives with ternary fuel in a single cylinder engine with different combustion geometry and injection timing. HPF-TRCC22 resulted in lowest BSEC. HC and CO was reduced by 9.18% and 16.83% respectively as compared to HPFTRCC23. HPFTRCC21 reduced the NO_x emission by 22.53% but at the same time increased the HC, CO emission by 6.13% and 20.51%, compared to HPFTRCC23 [14].Harish Venu et al. Compared by experimental study the use of biodiesel-ethanol mixed with nano additives like titanium oxide, zirconium oxide and Diethyl ether. Test fuel was BD80%, Ethanol20% with 25ppm Titanium oxide nano-particle, 25ppm Zirconium oxide nanoparticle and a blend of BE 50ml Diethyl ether. Oxidation was increased, light-off temperature was reduced using nanoparticles which creates large contact area and enhances the combustion, reducing the emission. It was observed that CO and BSFC was reduced by using titanium oxide but at the same time smoke, NO_x and hydrocarbon increased. Zirconium increase hydrocarbon and BSFC at the same time CO and CO_2 was lowered in comparison to biodiesel ethanol blend [15]. S. Karthikeyan et al. Researched about hybrid Nano catalyst, which could help in reducing emission of CI engine fueled by biodiesel blends. Prosopis juliflora oil was used to produce biodiesel, by transesterification. cerium oxide nano catalyst on multi was nanotube was in investigated with 50 and 100ppm biodiesel blend. Emission was reduced using nano particles because of high surface area and their distribution of particles with catalytic oxidation helped it [16]. S. Manigandan et al. In this study titanium dioxide and zinc oxide additives were blended with corn biodiesel and pentanol in a CI engine. For increasing the efficiency of the engine ZnO 5%, TiO_2 5%, 2% of pentanol and 1% of nonionic surfactants Span80 were mixed in corn oil methyl ester. Diesel, CVOME, CVOMEZ50, CVOMEZ100, CVOMET50, and CVOMET100 were the fuels used in the experiment. Experiment was conducted in water cooled Diesel engine and it was observed that emission was reduced, CO by 26%, HC by 37% and NO_x by 19% because of ZnO and TiO_2. Emission was reduced because of the high oxygen content in the fuel because of additives [17]. **P. T. Saravankumar et al.**Studied on the use of corn oil biodiesel as a substitute of conventional diesel and use silicon dioxide nano additives in the fuel. SiO_2 additives were blended in 50, 75, 100 ppm. Biodiesel 20% blend with SiO_2 additive blend was used in a single cylinder four stroke direct injection engine. Different concentration was used for the additive was experimented for the effect on emission. Nano particle had positive effect on emission characteristics [18].**Mina Mehregan et al.**Researched on the use of nano additive(Mn_2O_3 and Co_3O_4) with biodiesel-diesel on Compression ignition engine with urea-SCR system, evaluate its performance and emission characteristics. Base fuel had 20% waste cooking oil biodiesel and 80% diesel. Manganese oxide and cobalt oxide nanoparticles with 25 and 50ppm concentration was used in this study. NO_x and CO emission were appreciably decreased by the use of nano particles in the engine compared to base fuel [19]. S. Karthikeyanet al. Botryococcusbraunii algal oil was converted to biodiesel by transesterification reaction. Samples were created with 20% blend and CeO2 nano particles were added to the blend in 50,75 and 100 ppm by ultrasonicator. It was observed that the emission were reduced by blending nano additives [20]. **Ganesan.s et al.**researched on the use of biodiesel to reduce NO_x, CO_2, HC and Co and increase the fuel consumption. It was observed that nano particles reduced the fuel consumption and at the same time improved the thermal efficiency. cerium oxide in Mentha longifolia biodiesel improved the performance and emission characteristics of single cylinder engine [21].Harish Venuet al. Researched on improving emission and performance of a CI engine run on biofuel blend (40% biodiesel, 40% Diesel and 20% Ethanol (BE)). Alumina nano particle and diethyl ether was blended in different concentration for the experiment. Alumina was added in 25ppm and 50ppm whereas diethyl ether was added in 10% concentration. NO_x emission was reduced but at the same time HC, CO, BSFC and CO_2 was increased by the addition of DEE and Al_2O_3. This could be attributed as DDE resulted in high latent heat of evaporation and low temperature combustion, were as in the case of Al_2O_3surface area to volume ratio of mixture during rapid combustion process, higher catalytic combustion and reduced evaporation. BE with 5 % DEE showed highest peak pressure and low heat release rate, BE with 10% DEE showed lowest peak pressure. In the case of Al_2O_3 additive, particulate matter formation was highest at 75% load and 100% load. BE with 5 % DEE and BE with 25 ppm Al_2O_3 showed better performance compared to conventional diesel [22].K. Ramarao et al. Determined the emission and performance of a single cylinder direct injection fuelled by diesel-biodiesel (cotton seed) blend and Nano-additives (cerium oxide). Flash point, Fire point & Calorific values were tested for these blends. Nano additives ranging from 30nm to 50nm were blended with neat diesel fuel. SFC, BTE, EGT, CO, air fuel ratio, HC and NO_x emission were observed. BTE increased with increase in load of biodiesel with nano additives. The NOx emissions with cotton seed oil and their different blend accepts B20 + 0.04 and B20 + 0.08 gm with addition of Nano additive decrease as compared to diesel fuel.CO emissions are less at lower loads for all blends compared to diesel fuel, but CO emissions are nearly equal with that of diesel fuel at higher loads [23].S. Karthikeyanet al. study Botryococcusbraunii algal oil was converted to methyl ester by transesterification reaction. Biodiesel 20% + diesel 80% was blended with cerium oxide nano particles at 50ppm, 75ppm and 100ppm dosage with the help of ultrasonicator. CO, CO_2, O_2, NO, and UHC were measured during the experiment for different fuel blends. UHC reduced and NO_x increased with increase in nano additive concentration in the biofuel blend [24].

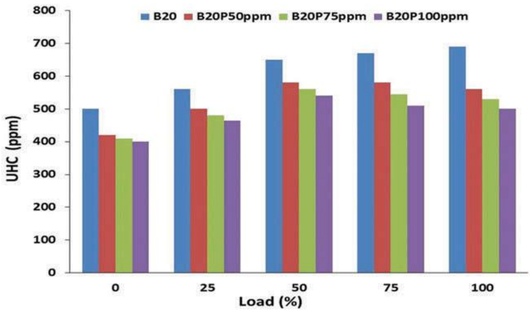


Fig 15: Variation of UHC with load [24]

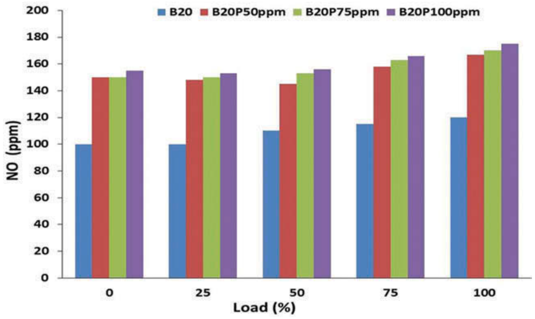


Fig 16: Variation of NO with load [24]

3. CONCLUSION

Clean environment is a need of every one and is the major concern. The energy source used nowadays are non-renewable. Increasing urbanization, increase the demand and also increase the emission from the conventional fuels which created a demand for efficient and alternative energy source. In the Alternate fuels, Biodiesel is extremely popular because of non-toxic, biodegradable, carbon neutrality and renewable and same properties like diesel, it could be replace conventional fuel little modification or no modification. There are a lot of advantages of using biodiesel with additives. Following could be concluded on the use of biodiesel with additives in compression ignition engine:

- nano-technology applications showed the capability of amplifying microalgal-biofuel combustion efficiency and reduced soot, NOx, smoke, HC, CO2, and CO emission to the environment up to 72%. Application of solid nano-additives such as alumina (Al2O3), CERIA, carbon nano-tubes (CNT), Co3O4, ZrO2, La2O3, CeO2, SiO2, Ni2O, TiO2, ZnO, Fe2O3, CuO, CexZr(1–x)O2, and amide-doped MWCNTs-CeO2 boosted the engine power, torque, and brake thermal performance of biodiesel (extracted from microalgae and other biomass) in CI and DI engines up to 11%.
- Jatropha biodiesel mixed with nano particles achieved improvement in engine performance and emissions reductions compared with the other tested fuels.
- Polanga biodiesel was blended with nano additive of Al2O3 improved the combustion and emission characteristics of base fuel due to higher surface area to volume ratio of nano-additives. Brake thermal efficiency was enhanced by 6.58% and brake specific fuel consumption was lowered by 7.38% by the use of Al2O3 nano-additives. HC, CO, smoke opacity and NOx emission improved by the use of nano-additives in the fuel which also helps in improving the combustion efficiency.
- Titanium dioxide resulted that 70% reduction of emission at 75% load. It also helps in engine performance and combustion.
- NO_x emission was reduced but at the same time HC, CO, BSFC and CO_2 was increased by the addition of DEE and Al_2O_3.
- Zirconium increase hydrocarbon and BSFC at the same time CO and CO_2 was lowered in comparison to biodiesel ethanol blend.

These are some of the probable facts through which the study on the inclusion of nanoparticles in the diesel-biodiesel blends can be accomplished by the researchers. Also, there is a necessity in the investigation of the use of the nanoparticles with the waste cooking oil biodiesel fuel blend. Furthermore, a cost-effective method for developing nanoparticles, and the environmental damages and health risk on exposure of nanoparticles on humans, should be investigated.

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