Variation in the performance and emission characteristics of CI engine with the use of nanofluids as fuel additive in biodiesel

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Abstract

Because of continuous population growth, energy consumption and various other environmental concerns, improvement of CI engines have received significant consideration so as to get energy efficient and less hazardous emissions. In this respect, numerous techniques have been employed for improving the engine characteristics. Alteration in fuel is one of those, where the main purpose is to improve the combustion process to a level where we shall obtain low consumption of fuel with less emissions. The properties like higher density, high fuel consumption, lesser heating value, and emissions, can be reduced by adding fuel additives to the base fuel without affecting its initial properties and performance. Metal-based additives or metal oxide-based additives, antioxidant additives, cetane number additives, and oxygenated additives are the most widely used additives which help in improving the combustion, fuel economy and reducing the emissions. This work presents the study and analysis of biodiesel with the use of nano metal oxide additives to examine its effect on combustion, performance, and emission characteristics of a Compression ignition engine.

1.Introduction

Compression ignition (CI) engines are becoming demanding now a days in various sectors including transportation, agricultural and industrial ones due to its better reliability and good efficiency, which is mainly because of its higher compression ratio. At the conflicting side, CI engines are also evolving as the main source of air pollution, as exhaust gases coming out of CI engines are affecting the climate and also responsible for greenhouse effect which certainly affects all living organisms. As per current scenario, consumption is overtaking the discovery and the world is going towards industrial adversity. Due to fast diminution of petroleum products and also due to stern rules that are conveyed by the government to vehicle manufacturers and consumers to follow the emission norms for environment safety from pollution coming out of CI engine exhaust has led to the boom in research in finding out substitute techniques for CI engine for improving the performance and controlling the emissions. Researchers have mainly targeted three areas to reduce the emissions in diesel engine, mainly engine design modification, fuel adulteration and exhaust gas treatment. In this regard, Biodiesel has been observed as a renewable and environment-friendly fuel, with benefits such as lower emissions of CO and unburnt hydrocarbons, but the major disadvantage of using biodiesel is that won't absorb the fuel emissions generated while growing the crops and preparing biodiesel. To reduce these drawbacks various types of additives can be added to biodiesel. Among all the fuel additives those are recently examined to biodiesel, the nanoparticles as additive has appeared to be the better option for achieving supreme improvement in the performance characteristics of engine with lowest level of exhaust emissions too. Metal-based additives, oxygenated additives and cetane number improver additives are the other widely used additives in biodiesel blending as they can help in reducing emissions of oxides of carbon, unburnt hydrocarbon and NOx by reducing ignition delay period, thereby increasing heat release rate, which increases the peak pressure and hence overall efficiency of the engine also.

2. Nanoparticles requirements as additive in Biodiesel

Nanoparticles are actually acting as a fuel catalyst which certainly reduces the delay period, thereby increasing the heat release rate, resulting in lower emissions and better efficiency, which is mainly done by improving few fuel properties such as fire point, viscosity, flash point etc. Few of its expected requirements are:

- Mixture's chemical stability should not be affected with the addition of nanoparticles in any case.
- Adding nanoparticles should reduce the exhaust emissions, specially CO and unburnt hydrocarbons, thereby increasing the oxidation intensity of the engine.
- It should brake increase thermal efficiency for constant power condition with the reduction in brake specific fuel consumption.

2.1 Preparing Nano fluids

2.1.1 Single step method

For reducing accumulation of nano particles, a one-step method was developed by Eastman [8], which is a physical vapor condensation method for preparing nanofluids like ethylene glycol nanofluids. This process involves simultaneous preparing and separating the particles in the fluid. Here, few processes such as drying, transportation, storage and dispersion of nanoparticles are evaded, so that accumulation of nano particles can be minimized, thereby increasing the stability of fluids. This method is mainly preferred with fluids having low vapor pressure, which adds to its one limitation.

2.1.2 Two-step method

Most commonly used method is two-step method for preparation of nanofluids. Nanoparticles or other nano fibers which are used in this method are at first formed as dry powders by any physical, chemical methods. After that, with the help of ultrasonic agitation, magnetic force agitation and ball milling, the nanosized powder is dispersed into a fluid in the second processing step. For large scale production of nano fluids, this method is the most economic one. As the nano particles have high surface area, hence these particles have the tendency to cumulative. Using surfactants is the important technique that can improve the stability of nano particles in the fluids. However, if we consider high temperature applications, then surfactants functionality is a big concern.

3. Literature Review

In this particular section, we shall discuss the detailed study which was done by analyzing different work done by different researchers in this field and thereby showing their results showing the outcome of various nano additives on CI engine performance characteristics.

C. Syed Aalam [1] conducted various experiments on four-stroke single cylinder common rail direct injection diesel engine with B20 blend of mahua biodiesel by adding two variants of aluminium-oxide nanoparticles as additive. He has used ultrasonicator and homogenizer where cationic surfactant was taken as cetyl trimethyl ammonium bromide (CTAB), used for biodiesel blending and aluminium oxide nano particles. Given below Fig. 1 is the Scanning electron microscope (SEM) of nano particles of aluminum oxide. The experimental set up used by him is also given below in Fig.2

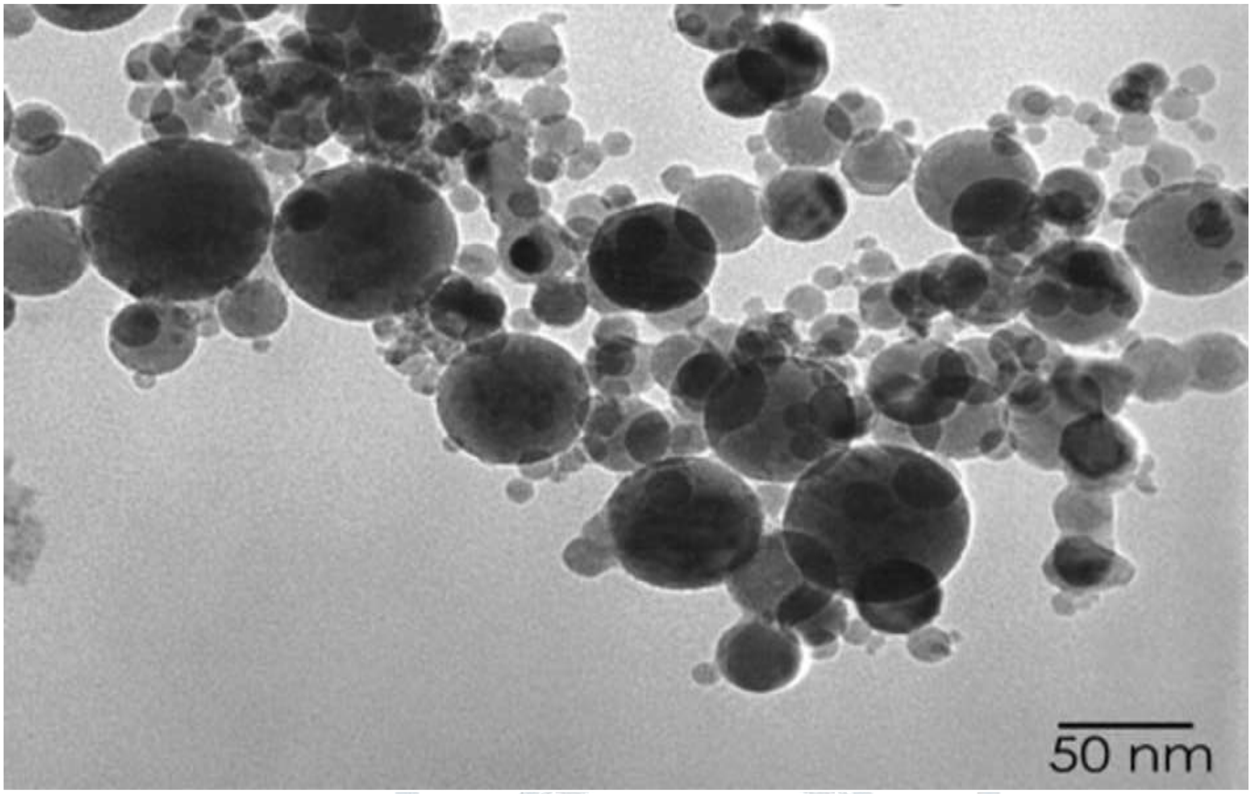


Fig. 1 SEM of aluminium oxide nanoparticles.

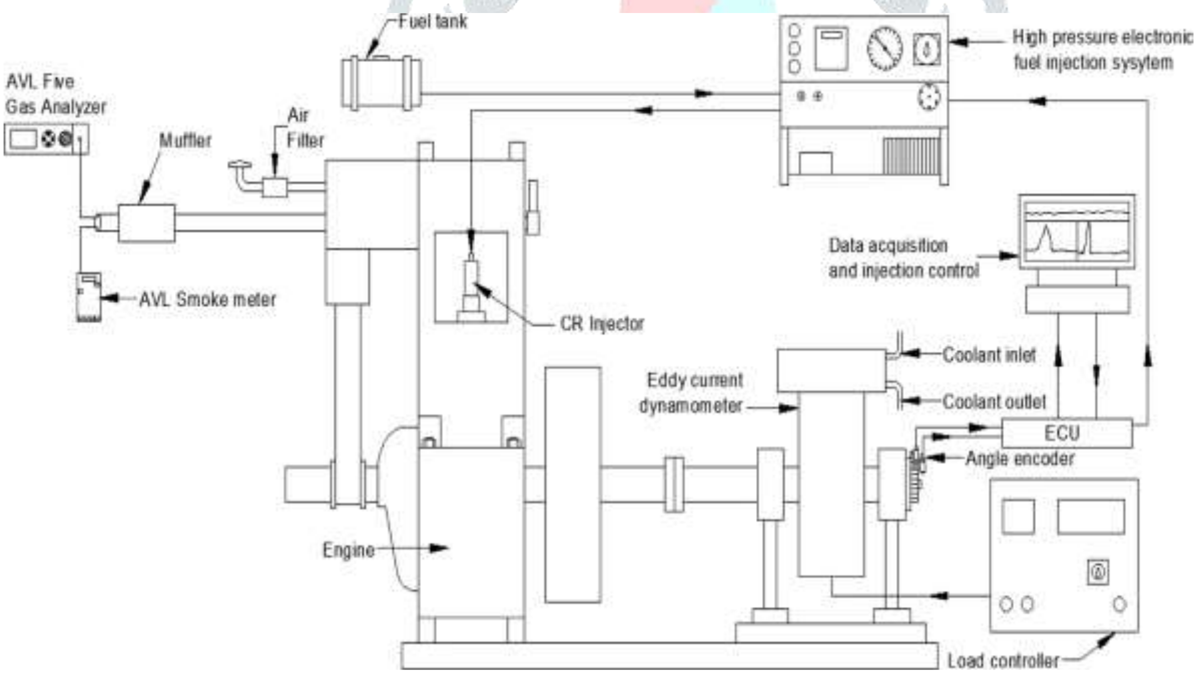


Fig.2 Set up for experiment

Further he found that there was substantial reduction in pollutants such as carbon oxides, unburnt hydrocarbon and smoke, which increased the brake thermal efficiency of the engine as well. In addition, operation of common rail direct injection (CRDi) diesel engine was found to be smooth where he used mahua oil biodiesel blend of B20 when it is added with different proportions of aluminium nanoparticles as an additive to the biodiesel.

A.Prabu[2] in his work has used single cylinder CI engine which was of direct injection type. In which he has used three different fuel series consists of biodiesel-diesel which is B20, biodiesel-diesel-nano particles which is B20A30C30 and biodiesel-nano particles which is B20A100C100. In his work he has used two types of nano particles consists of alumina (Al_2O_3) and cerium oxide (CeO_2), amount of each was 30ppm and ultrasonicator was used for mixing with the above blends so as to attain proper suspension.

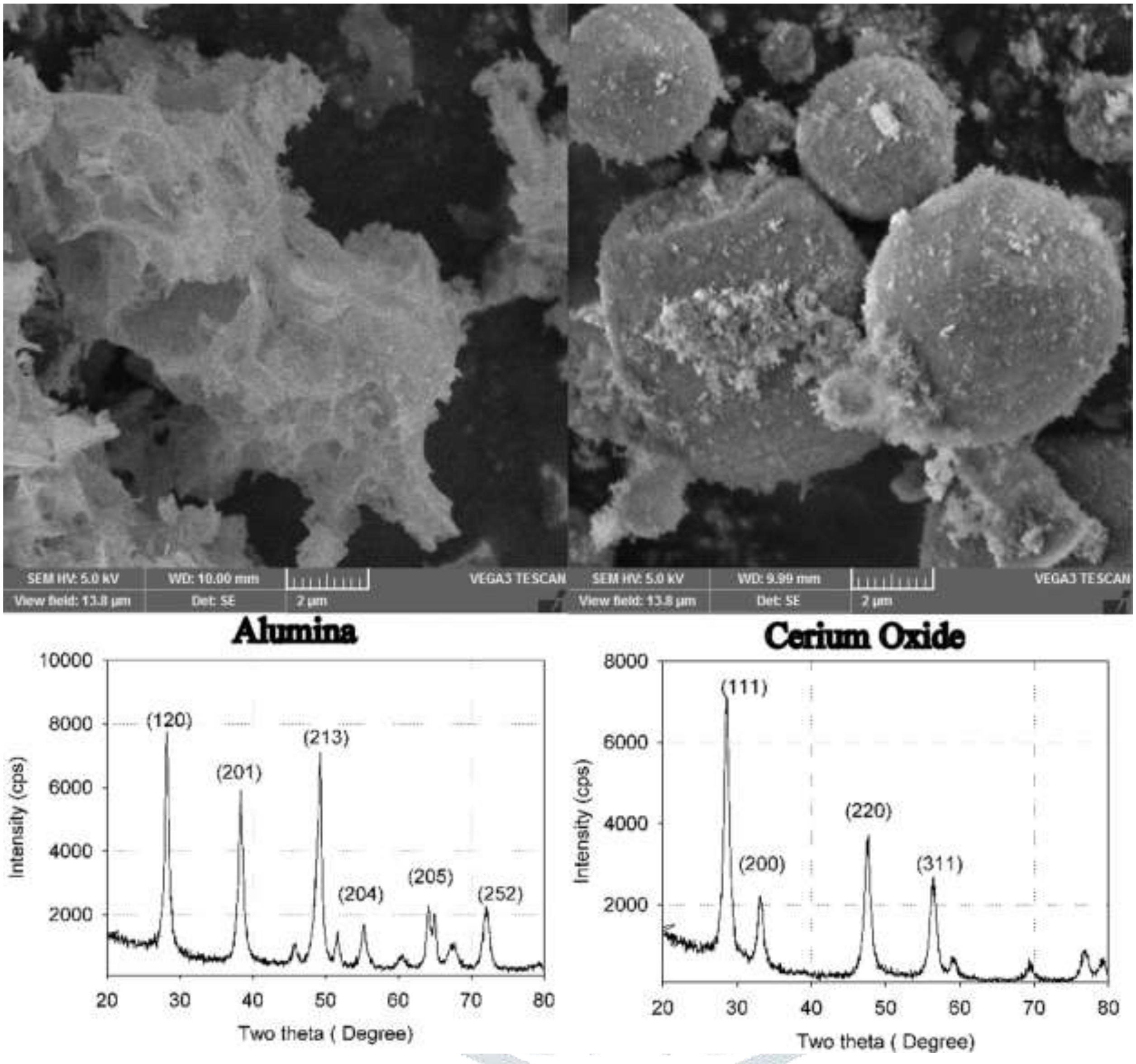
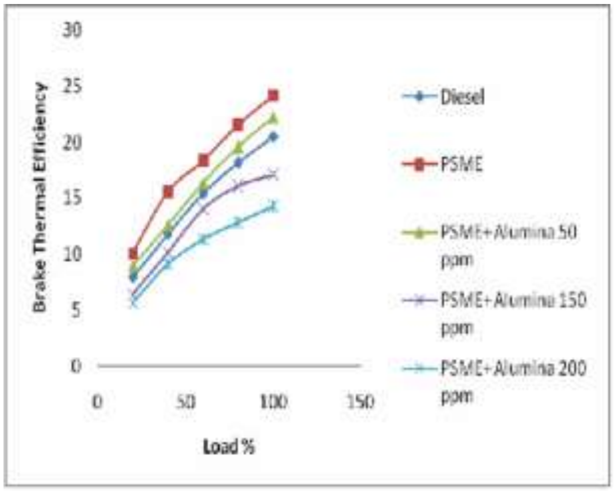


Fig.3 SEM and XRD images of alumina and cerium oxide nanoparticles

Results showed that for B20A30C30 brake thermal efficiency was improved by 12%, with reduction of 30% in NO emission, while there was 60%,44% and 38% reduction in carbon monoxide, hydrocarbon also smoke emissions respectively as compared to that of B100.

K.Krishna [3] in his work examined on single cylinder water cooled DI diesel engine and at 1500rpm(constant) speed with palm stearin methyl ester (PSME) as fuel of B100 blend and aluminium oxide(Al_2O_3 -Alumina) nano particles as additives where he examined the effects of the metal additives in biodiesel.



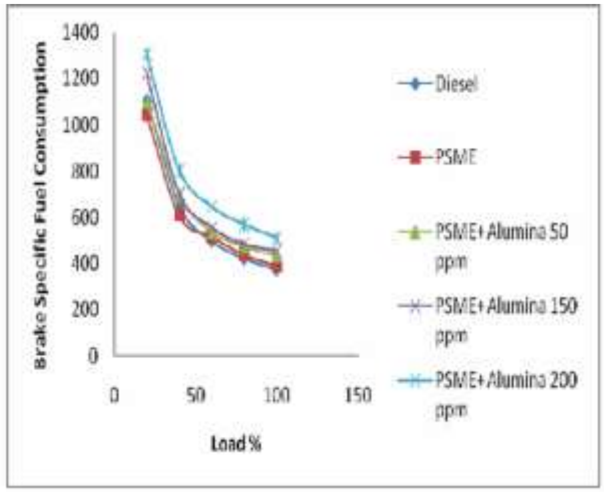
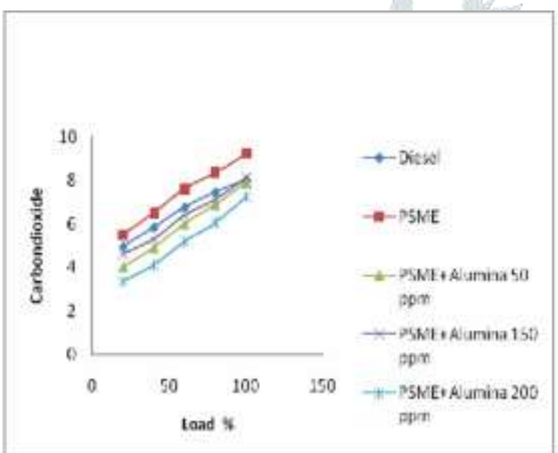


Fig.4 BTE Vs Load variation

Fig. 5 BSFC Vs Load variation

From the Fig. 4 we can see that brake thermal efficiency has increased with load for all fuels i.e. PSME, PSME+50ppm, PSME+150ppm, also PSME+200ppm, whereas due to the higher cetane number , BTE of PSME and PSME+50ppm shown improved results than that of other blends and pure diesel also. Further we can see that there is a reduction in BTE for blends of PSME+150ppm and PSME200ppm by comparing with diesel, again due to oxygen content being high in the alumina nano particles. Further from Fig. 5 we can find that there is decrease in bsfc with increase in load. Also, it was found that bsfc is minimum for case where pure diesel being used, also with the addition of alumina nano particles, there was some increase in bsfc again due to the more viscosity.



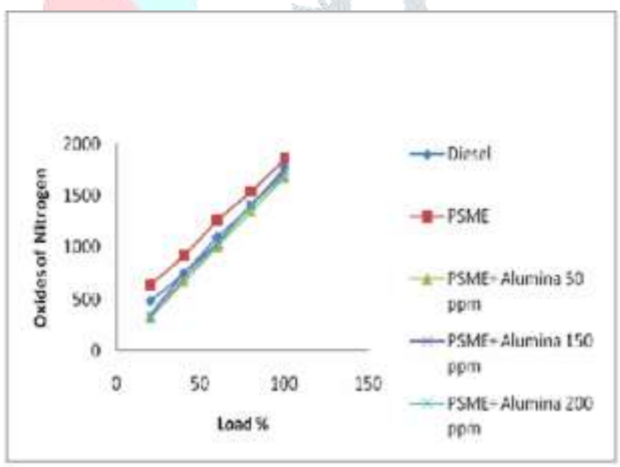
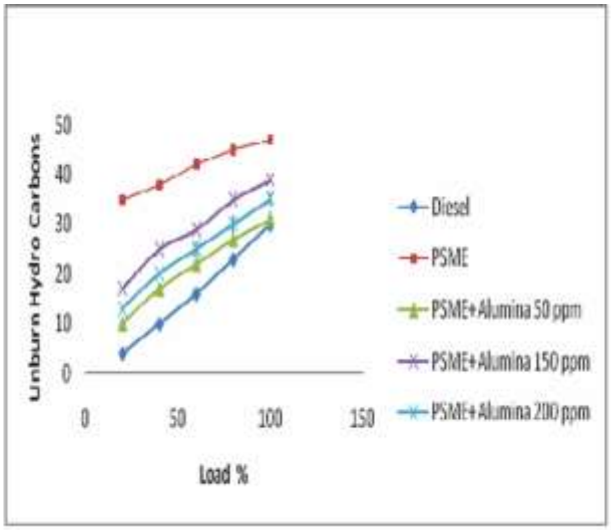


Fig. 6 CO_2 Vs Load variation

Fig. 7 NOx Vs Load Variation

From Fig. 6 we can find CO_2 emissions variation with variation in load for all used blends at different loads of 20% to 100% with increment of 20% and It was found that for all conditions there was steady increase in the CO_2 emissions with increase in load. In most of the cases emissions of carbon dioxide were reduced as compared to pure fuel except PSME where the case is opposite because of less energy release. Considering Fig. 7, we found that there was increase in NO_x emissions with biodiesel, for which the main reason can be its reactive nature and also because of presence of oxygen in structure which reacts at higher temperature and results in NO_x formation. But as we add alumina nano particle in it, which acts as oxygen buffer, he has found that NO_x emissions got reduced. Eventually, with 50ppm alumina, there was 9.70% less production of NO_x as compared with diesel.



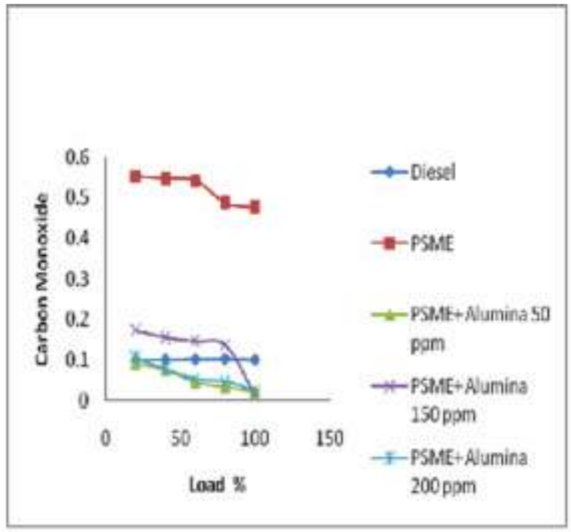


Fig. 8 UBH Vs Load Variation Fig. 9 CO Vs Load Variation

From Fig. 8, we can see unburned hydrocarbon (UBH) emission variation with increasing load of 20% up to 100% load, where unburned hydrocarbon (UBH) emission for PSME comes to be higher than that of PSME+150ppm and PSME+200ppm blended fuel. Reason can be their lower thermal efficiency, which results in partial combustion. For carbon oxide (CO) emissions, we can see Fig. 9, where it was seen that for 50ppm alumina, there was on an average 39.21% less formation of CO than diesel.

M. Mirzajanzadeh [4] in his work examined the performance of CI engine by using. Nano catalyst (CeO2-MWCNT), prepared by mixing Cerium oxide and multi walled carbon nanotube confirming to 46% of Ce and the Fourier-transform infrared spectroscopy (FTIR) spectra has confirmed that fabrication of the nano catalyst was successful (Fig.1)

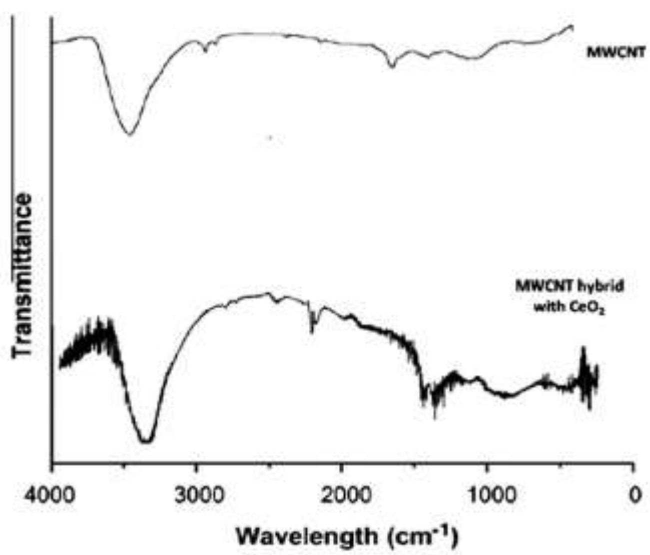


Fig. 2 The Fourier-transform infrared spectroscopy spectra of the MWCNTs and the amidated CeO2-MWCNts

Further, he has used fuel blends of B5 and B20 with three catalyst concentrations where the extreme torque was 1500 rpm at condition of full load and found that power produced was changing directly, approximately linear to the nano catalyst amount which was applied. Further, nano catalyst was added at 3 different proportions of 30ppm, 60ppm and 90ppm respectively which resulted in increase in power production of 0.58%, 1.79% and 3.52% for B5 and 2.28%, 5.72% and 7.81% for B20, respectively. Overall, all major pollutants i.e., nitrogen and carbon oxides, also unburnt hydrocarbon were significantly decreased by 18.9%, 38.8%, 71.4% respectively, in B20 of 90 ppm amount.

Rakhi N. Mehta [5] examined the performance of engine having specification of single cylinder, direct injection CI engine which was running at constant speed of 1500rpm where stable suspensions of nano particles of Aluminium (Al), Boron(B) and Iron (Fe) were used as additives. Initially tests were performed with pure diesel at both the conditions of full load and no-load condition, after which nano fuels were added through different feed line. Result shows that nano fuels of Al, Fe and B has early ignition with increased evaporation rates at 0.2s of time as compared with diesel which was 1.2s, which suggests ignition delay. Further these nano fuels have shown longer sustenance. Specific fuel consumption (sfc) was also seen to be lowered by 7%. Eventually the emissions of hydrocarbons and oxides of carbon also got reduced. However, NOx emissions were marginally increased having 5% hike with Al and 3% with Fe.

V. Selvan [6] in his work studied about VCR engine where the optimal compression ratio was taken as 19:1, with the use of diesterol which is diesel-castor oil biodiesel – ethanol blend and CeO_2 – CNT (cerium oxide -carbon nano tube) blends. In his work he has used Cerium oxide (CeO_2) and carbon nano tube (CNT) of each having concentrations of 25, 50 and 100 ppm respectively. These are added with diesterol blends. Further it was seen that there was increase in thermal efficiency by 7.5%, with the reduction in hydrocarbon and smoke emissions by 7.2% and 47.6% respectively with the addition of these nano particles in diesterol blends as compared with diesterol blends without these particles.

Prabakaran [7] in his work investigated about the effect of adding zinc oxide nano particle to diesel-biodiesel-ethanol blends. His study was mainly having three steps involving solubility test, property testing and finally addition of ZnO nano particles. Out of 18 total blends, there were 5 blends which were stable in all three temperatures ie. 5ºC,15ºC,>25ºC. The oxide of zinc was added in 250 ppm amount. Blended fuel was tested and result shown that there was an increment in fuel's calorific value because of adding nano particles. He has done testing on a single cylinder four stroke CI engine which was of direct injection type and was running at 1500 rpm (constant) speed. He has found that bsfc got increased and cylinder's pressure also. Further he found that there was increase in Brake thermal efficiency while comparing with biodiesel-diesel-ethanol blend taken at full load.

4. Future Scope

We have not utilized the use of nanoparticles yet to its full. As there are lot of problems which are required to be scrutinized in order to cope up with stability of engine, in addition safety part is also equally important which should be considered as well in future. Few parameters that can be focused are nano particle size, which can be varied to see different variations in the result. Secondly, experimentation can be done on engines with different compression ratios. Combustion analysis and flame characteristics can also be focused using various visualization techniques.

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5. Conclusion

Based on above study, we can be concluded that Biodiesel and its blends certainly reduce CI engine emissions, thereby becoming a good option for alternative fuel. Further with the use of nano additives, results are even improved. These additives act as fuel catalyst to promote the combustion to its competition in faster rate with least delay, thereby increasing the efficiency and lowering the fuel consumption also. Further, these nanoparticles have got activation energy due to which carbon deposits within combustion chamber get burns off which eventually lowers unburnt hydrocarbon and smoke emissions. Nano particles addition in the fuel enhances the properties of fuel like cetane number, calorific value etc. as they got high value of surface to volume ratio and thermal conductivity. In many cases, it is found that adding nano particles results in lowering of NOx emissions whereas, in most of the cases there is reduction in CO emissions because of complete fuel combustion except the case of adding magnetic nano fluid, where CO level was found to be increased.

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