Effect of nanofluid additive and after treatment devices on engine emission - A review

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Abstract. This research paper summaries the research carried by various researcher in the field of Nanofuids and after treatment devices on performance and emission of CI engines. Basically there are two methods of reducing the emission in the engines. First method is completely burn the fuel i.e. converting hydrocarbon and eliminating the emission. Suppose if the fuel is not completely combustible and it produces emission but it can be reduced by treating it before it enter the atmosphere, this is another way of reducing exhaust emission. The major exhaust emission are NOx and PM i.e. particulate matter. It is evident from many research papers that combustion can be improved by adding Nano additives to reduce the emission. Researcher have used various nano particle of various size and material to improve the performance of the engine and reduce emission. Also they have used various after treatment device reduce emission.

Keywords. Nanofluids, Emission, after treatment devices

1. Introduction
Use of diesel engine is more for various application such as transportation, generator, and agriculture as it is cheap compared petrol. The higher fuel efficiency and power density of diesel engines are their advantages over gasoline engines. The major emissions from diesel engines are particulate matter (PM), smoke and NOx. The NOx exposure to sunlight release ozone. The stringent emission norms and greenhouse gas emission like CO 2 emission make mandatory to use exhaust after treatment devices and search for alternative fuels for passenger cars to secure the energy requirement. The recently many researchers have investigated the various biofuels and after treatment devices to reduce environmental effect of CI engine. However, the NOx emission was dominant emission in biofuel fuelled engines. Also, low atomization, and lower efficiency are major problems. Hence, to improve the performance of biofuels, fuel modification techniques was studied by many researchers. The recent development in nano technology have added advantages in fuel modification techniques. Also, recently many after treatment devices like SCR, DPF, diesel oxidation catalyst was helpful to reduce the pollution.

In CI engines, NOx and PM emission have tread off between each other and reduction of one may results in increase of other vice versa and hence very difficult to reduce. Emissions like NOx can be reduced either by retarding the injection timing or by including the exhaust gas recirculation (EGR) system, using selective catalytic reduction technique (SCR). However, use of after treatment devices was increased in smoke and specific fuel consumption. The use of fossil fuel in combustion systems will affects the shortage of fossil fuel and also, economic growth of country. As these fuels are imported
from outside the country. Hence, need to search for alternative biofuels with less effect on environment is future challenge. In the recent development in biofuels in CI engine, considerable efforts are made with its blends in diesel. The feedstock which produces biodiesels are Edible oil like palm oil, rapeseed oil, coconut oil, sunflower oil, olive oil, Soybean oil and nonedible oil like Karanj, Jatropha, Neem. The use of biodiesel increases in transportation sector due to its comparative properties with diesel and its renewable nature. Even though many researchers are concentrated on biodiesel, difficulties in cold starting, sticking of oil, poor atomization due to higher viscosity and NOx emission are major challenges.

The improvement of properties and quality for better usability of biodiesel can be obtained using fuel additives such as antioxidants, cetane number improver, corrosion resistant additives and cold flow property enhancer etc. Also, many researchers have used the metal and metal oxide additives in microsize powders. However, microsize additives are settle do, higher reactivity, promoted n quickly. Hence, these are not that much effective. The recent development in nano technology promoted the use of nanoparticles in fuel which are more stable, higher reactivity, and good heat storing and releasing capability. Also, these particles have more surface-area to volume ratio, good radioactive heat transfer properties, and better ignition characteristics. However, more analysis and investigations are necessary on nanoparticles in liquid fuels to find effects on exhaust after treatment devices. Till date very few efforts have been carried out to study combined effect of adding nano-materials in fuels to investigate the performance and emission characteristics in the CI engine with exhaust after treatment devices.

2. Nanofluids additives for CI Engines.
There are various types of nano particle such as carbon based like carbon nanotubes, metal based like Al, Mg, Zr, Ti, Ni and ceramics based nano particles [1]. Venkatesan et al [2] Used ultrasonicator for preparing a aqueous cerium oxide containing 50 cc per liter dispersed into the blend of diesel and biodiesel. Yuvarajan, D., et al [3] Prepared biodiesel and diesel blend of mustard oil biodiesel with TiO2 nano particle having average size 50nm to investigate the effect of formation of CO (carbon monoxide), HC (hydrocarbon), NOx and Smoke emission. Nanthagopal, K., et al[4 ] has studied the effect of nanoparticle such as zinc oxide and titanium dioxides in proportion of 50 ppm and 100 ppm with distilled water added as additives in a blend of biodiesel of Calophyllum inophyllum on a liquid cooled engine with direct injection diesel engine. Karthikeyan, S et al. [5] prepared a blend in proportion of 80:20 of diesel and methyl ester along with nano particle additives of the cerium oxide. Cerium oxide was used in this blend by adding of 50 ppm and 100 ppm in it with the help of Ultrasonicator. D’Silva, Rolvin, et al[6] Nano fluid additives for CI engine is prepared by using nano particles of titanium oxide and calcium carbonate by dispersed in a blend of diesel and biodiesel of ester pongamia pinnata oil in a proportion of 80: 20 with a aid of ultrasonicaor. Wu, Qibai, et al [7] An attempt was made to investigate the effect of diesel and bio diesel with the addition of carbon coated aluminum nano particle in a mass fraction of 30 ppm with a aid of ultrsonicator. Debbarma, S et. al. [8] explored blend of diesel and bio diesel along with a iron nanoparticles as additives concentration of 40 ppm and 120 ppm iron particles in CI engine. This sample was prepared with ultrasonicator. Balaji, G et. al. [9] reported the results of experiments carried out using carbon nanotubes additives on the performance of the engines and also emission blended with methyl ester of neem oil in direct injection diesel engine.

3. After treatment devices for CI Engines
There are various types of diesel particulate filter, exhaust gas recirculation, catalytic convertors etc. Azam, Ali, et al.[10] designed a combine unit of exhaust gas recirculation consisting of counter flow heat exchanger, an oil bath cleaning unit to control the emission caused by the combustion of fuel in engine. Mehregan, Mina [11] Investigated the effect on NOx emission by adding nanoparticle and urea selective catalyst reduction as an after treatment device. Şahin, Havva Hande [12] To reduce exhaust emission caused by engine there are many alternative ways author used selective catalytic reduction to
reduce emission. Loganathan et al. [13] studied the effect of the addition of cerium oxide nanoparticle on the major physiochemical properties and the performance parameters of diesel engine. Kurien et al. [14] A composite regeneration system with the application of microwave energy is proposed in this paper. Vedagiri, Praveena, et al. [16] Biodiesel blend consisting of diesel and grapeseed oil biodiesel along with cerium oxide (CEO) and zinc oxide (ZnO) in proportion of 100 ppm each were used to investigate the performance of the engine, combustion of the fuel and its effect on the exhaust emission. B. Jothi Thirumal et al. [17] examined the effect of nano particle additive of Cerium oxides (CeO2) along diesel on performance of the engine and the physiochemical properties of the blend. Kim, Hwanam et. al. [18] explored the effect of the different particle size, the reactivity of nanoparticles as a catalyst, and the exhaust pollutants on a common rail direct injection (CRDI) diesel engine fuelled with diesel biodiesel blends. Liu, Z. Gerald, et al. [19] explored the effect of copper zeolite based SCR system and exhaust after treatment device on the polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) emission from CI engine. Wittka, Thomas, et al. [20] Combination of various after treatment devices consisting of lean NOx trap, selective catalyst reduction (SCR) was used investigate the effect of NOx emission from an engine.

4. Performance of I C engines

4.1. Effect on brake specific fuel consumption

In a sample consisting of Diesel + biodiesel and Carbon nanotude there is an 6.25% decrease in the mean specific fuel consumption in compare to diesel only [2]. Due to micro explosion behavior and catalytic effect of nano particle there is reduction in brake specific fuel consumption in a bio diesel blend consisting of Calophyllum inophyllum biodiesel (CIBD) along with nano additives of inc oxide and titanium oxides. [4] There is a reduction in brake specific fuel consumption with a bio diesel blend of rice bran oil along with cerium oxide as compared to blend of only biodiesel without nano particle additives and pure diesel [5].

BSFC reduces by 5.7% at most of the loads for a blend of titanium dioxide calocium carbonate anlong with pongamia pinnata methyl ester 20% and diesel 80% [6]. There is an improvement in BSFC for blend of biodiesel blend with nano particle additives of aluminium coated with carbon [7]. The lowest BSEC of 3.3% for the biodiesel blend of INP50PB30 was obtained [8]. It is observed that ther is decrease in brake specific fuel consumption adding nano additive [9]. The Enhanced oxidation reaction and improved combustion efficiency helps in reduction of BSFC for a nano fluid blend of grape seed bio diesel [16]. There is an increase in BSFC [20]

4.2. Effect on brake thermal efficiency

In a sample consisting of Diesel + biodiesel and Carbon nanotube the results showed an increase of 5.81% increase in the Brake thermal efficiency compare to diesel only [2]. Catalyst effect of nano particle present in the emulsion cause increase in brake thermal efficiency of CIBD dosed with nano additives of Zinc and titanium oxides as compared to CIBD blended with diesel and pure diesel [4]. There is an improvement in brake thermal efficiency with a bio diesel blend of rice bran oil along with cerium oxide as compared to blend of only biodiesel without nano particle additives and pure diesel[5]. Brake thermal efficiency increase by 2.05% for a blend of titanium dioxide calcium carbonate along with pongamia pinnata methyl ester 20% and diesel 80% [6]. The negligible variation in BSFC for the blend of diesel-biodiesel-ethanol was found out [7]. Brake thermal efficicney (B_the) of engine was incremented by 3% for iron nano particles bio diesel blend [8]. Addition of nano additive increase the B_the [9]. brake thermal efficiency for cerium oxide was increased by 6% for blend of bio diesel [13]. B_the of GSBD was lower by 3.3 % as compared to diesel. The Addition of CeO2 and ZnO at a concentration of 100ppm in fuel samples increases the B_the to 30.2% and 30.51%, respectively [16]. The BTE of the engine, for CeO 50 ppm, was noted to be 6% higher than diesel [17]. Reduction in NOx
is observed to a larger extent is observed by using Combined LNT + SCR Diesel Exhaust After treatment [20]

5. Emission characteristics

5.1. Effect on NOx emission

With the addition Carbon nanotube along with the blends there is an 17% decrease in the NOx emission as compare to diesel only [2]. NOx emissions for MOME, MOME with TIO 100 and 200 was higher than diesel at all operating conditions due to longer delay period of biodiesel producing higher fuel ignition temperature [3]. Catalyst effect of nano additives of zinc oxide and titanium oxide and high latent heat of vaporization of water molecules present in CIBD emulsion, there is a significant reduction in NOx emission from 7 to 29 % for the various proportion of the blends as compared to CIBD blend with diesel and pure diesel only [4]. Cerium oxide nano particle blened with diesel and rice bran oil shows lower NOx emission as compared to bio diesel blend and pure diesel [5]. There is slightly increase in NOx emissions when TiO2 nanoparticles are used. [6] The average reduction in NOx emission was 6% for B10E4N30, and an average decrement in CO emission, compared to B10 was 19%. [7]. Addition of iron nano particle as an additive in the fuel blend of diesel palm oil blend reduces the NOx emissions of NOx by 2%[8]. The NO emissions were reduces by adding nano additive to the neat biodiesel [9]. Reduction in NOx emissions was observed up to 24.8% [10]. As the peak pressure increase there is an enhancement in heat transfer which result in lower emission of NOx in case of bio diesel blended with manganese oxide and cobalt oxide nanoparticles [11]. NOx emission diesel engine is reduce by the addition of nano fluid additives [12]. A full load condition it is observed that there was a reduction in NOx emission by 62% for the nano additive blended fuel as compared to pur diesel [13]. Lower flame temperature resulted in more reduction of NOx [15]. Water content in the blend of bio diesel blend evaporates due to high temperature in the combustion chamber thereby reducing the NOx emission [16]. At full load condition emissions such as NOx, 62.7% lower than diesel at full load condition, respectively [17].As the oxygen content of the fuel is increased there is an increased NOx emissions [18]

5.2. Effect on hydrocarbon (HC) emission

With the addition Carbon nanotube along with the blends there is a 31.48% decrease in the concentration of HC, as compare to diesel only [2]. Yuvarajan, D., et al [3] HC for MOME, MOME with TIO 100 and 200 was lower than diesel at all working conditions due to its more oxygen content which result in oxidation of TiO2 and Zinc oxide particle causes reduction in emission of HC in blend of CIBD blended with diesel and titanium oxide and zinc oxide as compared to CIBD blended with diesel and pure diesel [4]. Cerium oxide nano particle blened with diesel and rice bran oil shows lower HC emission as compared to bio diesel blend and pure diesel [5]. The unburnt hydrocarbons found to be less in case of fuel sample with TiO2 nanoparticles [6]. HC emission are reduced for biodiesel aluminum coated nano additives as compared to biodiesel blend and pure diesel [7]. Addition of iron nano particle as an additive in the fuel blend of diesel palm oil blend reduces the HC emissions by 22% [8]. The HC emissions were reduces by adding nano additive to the neat biodiesel. [9]. HC emissions were reduced by 42.9% due to the implementation of Heat exchanger-Oil Bath Cleaner Unit and EGR on the engine [10]. By shortening the ignition delay and catalytic activity of nano additive and secondary atomization there is a reduction in HC emissions [12]. HC emission was 56.5% lower than diesel at maximum load condition [13]. Complete combustion was observed so lesser HC emission [15]. Flame temperature is higher due to addition of nano additives which causes lesser emission of CO in grape seed biodiesel as compared to pure diesel [16]. Whereas emissions such as HC, observed to be 35.65% lower than diesel at full load condition, respectively [17]. The use of biodiesel–diesel blends reduced the HC [18].
5.3. Effect on carbon monoxide (CO) emission
With the addition Carbon nanotube along with the blends there is a decrease in the CO emission as compare to diesel only [2]. CO for MOME, MOME with TIO 100 and 200 was lower than diesel at all operating conditions as a result of more oxygen content [3]. The oxidation of TiO2 and Zinc oxide nano particle causes reduction in emission of CO in blend of CIBD blended with diesel and titanium oxide and zinc oxide as compared to CIBD blended with diesel and pure diesel [4]. Cerium oxide nano particle blend with diesel and rice bran oil shows lower CO emission as compared to bio diesel blend and pure diesel [5]. The unburnt hydrocarbon are found to be less in case of fuel sample with TiO2 nanoparticles [6]. Addition of iron nano particle as an additive in the fuel blend of diesel palm oil blend reduces the CO emissions by 45% [8]. The CO were reduces by adding nano additive to the neat biodiesel [9]. CO emissions were increased by 14.3 [10]. The CO emissions decrease slightly with the use of nanoparticle additives,[12]. Whereas emissions such as CO were observed to be 35.65% lower than diesel at full load condition, respectively [13]. Complete combustion thereby releasing lesser CO [15]. HC and CO emissions in GSBD was lower than diesel. However, it reduces further with inclusion of nano additives, due to higher flame temperature and longer flame sustenance [16]. Whereas emissions such as CO were observed to be35.65%, lower than diesel at full load condition, respectively [17]. The use of biodiesel–diesel blends reduced the CO [18].

5.4. Effect on Smoke emission
Smoke opacity was found to be decreased by 10.5% in a sample of Carbon nanotube along with the blends as compared to diesel only. [2]. Smoke emissions for MOME, and MOME with TIO 100 and 200 was lower than diesel at all working conditions owing to its inbuilt oxygen content [3]. There is reduction in smoke opacity in case of fuel sample with TiO2 nanoparticles [6]. The smoke emissions were reduces by adding nano additive to the neat biodiesel [9]. The smoke emission were 15% lower than diesel at full load condition, [13]. This may be due to High surface area volume ratio of nanoparticles resulting higher combustion rate and reduces the smoke intensity [16]. Whereas emissions such as, smoke, were observed to be 15%, lower than diesel at full load condition, respectively [17]. Smoke emissions were reduced by 50% with the use of bioethanol–diesel blends [18].

6. Conclusion
It can concluded that the performance of CI engines in term of brake thermal efficiency is found to be improved when a bio diesel blend is used as compare to diesel only. However if the nano additives are added it further increase the brake thermal efficiency. Reduction in brake specific fuel consumption is observed to a larger extent in case of nano additives bio diesel blend compared to bio diesel blend and pure diesel. Hence it can be concluded that use of nano additive must be added in the fuel in order to improve the performance of the engine. In most of the cases it is observed that the NOx emission are reduced due to addition of nano additives but there are some nano additive it is observed that there is an increase in NOx emission as the temperature inside the combustion chamber is high which is favourable the NOx formation.

Due to high temperature inside the combustion, combustion of the fuel takes in a greater manner i.e. more combustion efficiency. Hence it is observed that the percentage of unburnt hydrocarbon is less and formation of Carbon monoxide is less as there is adequate amount of oxygen in blends of Bio diesel and diesel.
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