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Review Article

Role of Emulsion and Nanotechnology in Alternative Fuel for Compression Ignition Engine: Review

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Abstract

The main reason for using alternative fuels in compression ignition engine is that the consumption and demand of petroleum products are increasing every year due to urbanization, increase in vehicular density and power requirement is going up and to reduce emission produced by today's diesel engine, which in turns require a clean burning fuel that perform well under the variety of operating conditions. Using an emulsion of diesel in water as a fuel has been a recent field of study in this field. Water/diesel emulsified formulations are reported to reduce the emissions without compensating the engine's performance. Conventional fuels have been found rather inadequate in improving emission characteristics which is the very first need of impeding emission regulation. Nanofluids could decrease the emission parameter and can improve combustion efficiency by improving the ignition delay and fuel properties. Nanofluids had the potential as the next generation fuel for lowering emission and combustion efficiency improvement. Although nanofluids have displayed enormously exciting potential applications, some vital hinders also exist before commercialization of nanofluids.

Keywords: *Alternative fuels, Nnanofluids, CI Engines*

1. Introduction

Diesel engine plays a vital role in power generation, transportation and industrial activities. The main advantages of the diesel engine over the gasoline spark ignition engine include its durability, reduced fuel consumption and lower emission of carbon monoxide and unburned hydrocarbon. Due to higher efficiency, diesel engines are of high interest in light duty vehicles. India stands 6th in the world of oil consuming countries with an oil utilization of 2,438,000 barrels per day and its pollution problem appeared many years ago. Pollution Conservation Research Association reported that the transport sector solely ingests more than 50% of the entire oil consumption in the country **(Sood, 2012)**. Health impacts of poor air quality ranges from irritation of eyes to some serious problem such as impaired lung function, decreased resistance to infection, increased incidence and severity of lung cancer, reproductive problem, birth defects and premature death mainly due to respiratory and heart condition**.(Bhandarkar, 2012; Shrivastava *et. al,* 2013)**

1.1 Need of Alternative Fuels

Increasing liquid fuel prices and impending emission regulations have sharpened the automotive industries to focus on efficiency. Moreover the rapid depletion of fossil fuels due to widespread use has forced to search for some low emission and renewable sources. The environmental concern, emission from motor vehicle have become an impute begetter of air pollution. Emissions of diesel-fueled vehicle have high concentration of NOx and particulate matter. The mixture contain carbon particle that are exceptionally small in size, less than one micron. These particle may be deeply inhaled into the lung and carry with them a collection of attached hazardous compound. Euro III diesel car emits 7.5 times more toxic particulate matter than comparable petrol car **(Bhandarkar, 2012)**. So in order to reduce the vehicle emission it projects the need of improving fuel quality as to minimize the pollutants. Alternative fuels acclaimed for lower emissions so the question is whether converting a significant fraction of vehicle to alternative will help reach such goals.

1.2 Emulsions

An emulsion can be defined as a mixture of two liquids in which one is present in droplets of macroscopic or ultramicroscopic size, distributed throughout the other. Emulsions are made from the constituents spontaneously or by a mechanical way. In spontaneous emulsions, the mixing is easy and spontaneous. But if they don't mix properly then a third chemical called a surfactant is used to bind the molecules of the constituent liquids. Then a mechanical agitator is used to mix the liquids thoroughly. After mixing them for some time, emulsion is formed.

1.2.1 Types of emulsion: Depending upon the type of emulsification technique, the emulsions are classified into two types **(khan *et al*, 2014)**:

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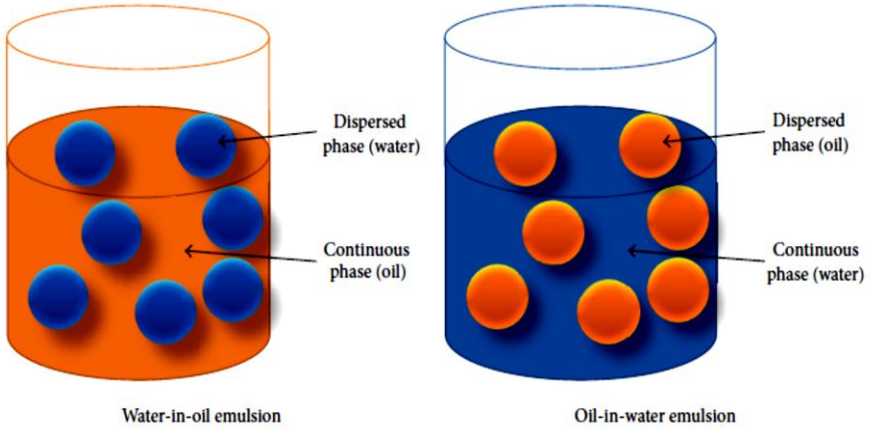

Figure 1.1 Concept of two-phase water-in-oil and oil-in-water emulsion

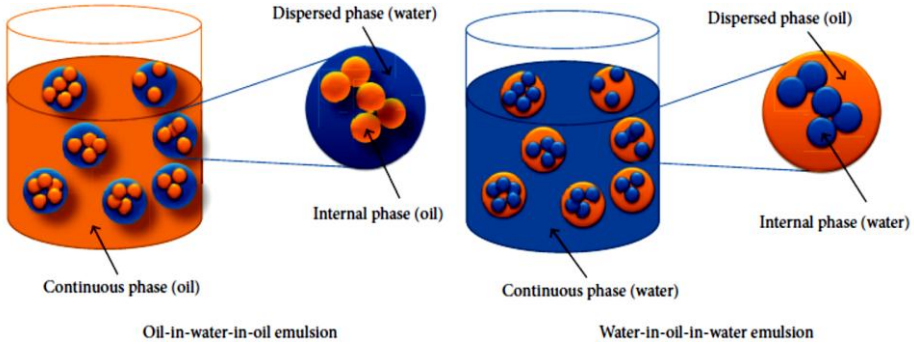

Figure 1.2 Concept of three-phase oil-in-water-in-oil and water-in-oil-in-water

1.2.1.1 Two-Phase Emulsion: Two phase emulsion include one continuous and one dispersed phase liquid and sometime called primary emulsion. There are two basic form of two-phase emulsion as shown in figure 1.1.

Oil-in water emulsions (O/W): The emulsions where oil is the dispersed phase and water is present as the dispersion medium (continuous phase) is called oil in water emulsion.

Water – in- oil emulsions (W/O): The emulsion in which water forms the dispersed phase and the oil is present as a dispersing medium (continuous phase) is called water in oil emulsion

1.2.1.2 Three-Phase Emulsion: Three phase emulsion consist of one continuous phase and two or more dispersed liquid. These emulsions sometimes are called multiphase and secondary emulsion. On the basis of inner and outer phase as shown in figure 1.2 named as oil-in- water-in-oil and water-in-oil-water.

1.2.2 Water diesel emulsion in diesel engine : Stringent emission norms and environmental concerns are prime mover for developing interest in water diesel emulsion. Induction of water has a convincing effect on various component of exhaust escaping to environment, such as nitrogen oxides (including NO and NO2, which are collectively termed as NO_x), particulate matter as well as soot formation. Water diesel emulsions are of more interest due to micro size dispersion of water molecule, which is desirable for better combustion of fuel. The various fuel additives are employed for emulsion fuels, including some light hydrocarbons and triglycerides. The main reason for increasing interest in water diesel emulsion as compared to gasoline is that the high combustion temperature and high pressure that is present in the diesel engine is particularly appropriate for this concept. Use of diesel water emulsions have shown to give several interesting results:

- Reduction of nitrogen oxide NO_x emissions, particulate contents and soot particles in the exhaust and
- Boost combustion efficiency of the engine.

The presence of water in diesel brings about an appreciable reduction in the quantity of NO_x and particulate matters (PM) emissions. However it relates more to diesel fuels than any other fuels. For the fuels with high nitrogen content, such as some residual oils, the NO_x in the exhaust comes mainly from oxidation of nitrogen. **(khan *et al*, 2014)**

1.2.3 Effect of emulsion fuel on combustion efficiency of the engine: Induction of water in combustion chamber through any kind of emulsion has significant effect on the efficiency of engine. As water content increases, yield of

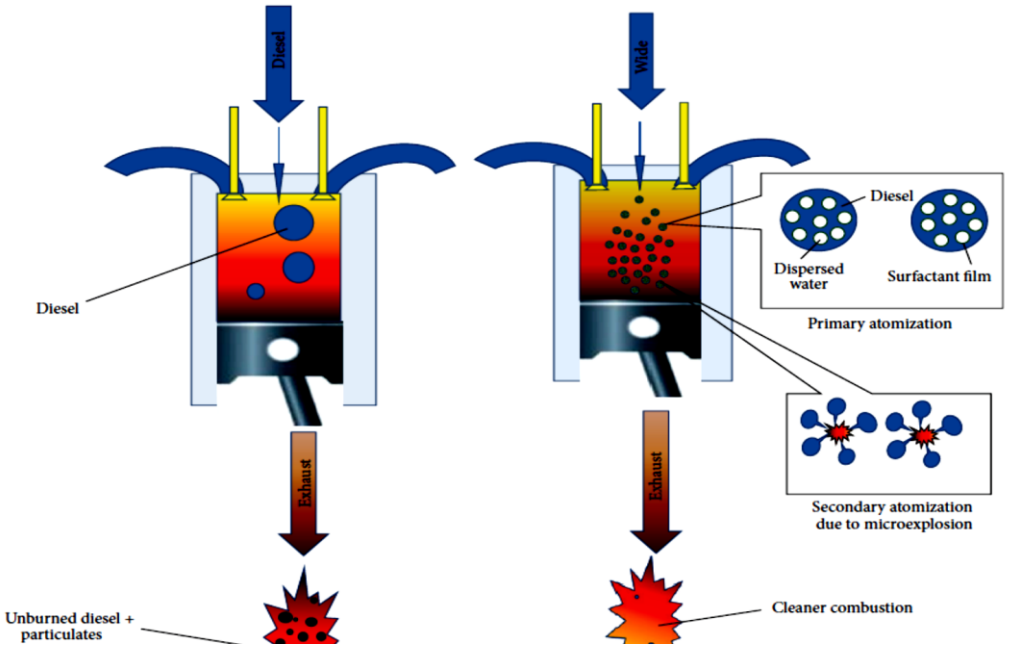

Figure 1.3 Concept of micro explosion phenomenon

torque also increases over the entire operational range. When the charge is injected inside the cylinder, water turned into steam due to very high pressure and temperature. Another basis for the improvement in combustion efficiency is low interfacial tension present in oil-water compound, promotes better atomization for burning of injected fuel. Higher contacts with air facilitated due to better dispersion of oil-water molecules and therefore boost the burning process, which is favorable for the combustion. **(Alahmer *et al*, 2010; khan *et al*, 2014)**

1.2.4 Effect on emulsion fuel on emission parameter of the engine: By using diesel water emulsion in the CI engine as a fuel, reduces the overall temperature inside the cylinder. As soon as the atomized fuel is sprayed inside the cylinder during the compression stroke, the water particles get vaporized owing to the high temperature and pressure inside the cylinder. Hence, water takes away some heat from the cylinder for its latent heat requirements to convert into steam. Thus will lower the local high temperature resulting in the reduction of NO_x Likewise, there is also a micro explosion phenomenon is to facilitate the mixing process which results in reduced reaction time. Further, the reduction in maximum local temperature also reduces the reaction rate. These combined effect reduce the formation of particulate matter, soot and total hydrocarbon in the exhaust. **(Alahmer *et al*, 2010; khan *et al*, 2014)**

1.3 Nanotechnology

Nanotechnology is produced by functional materials, devices, and systems and is controlling matter at the nanoscale level, and the exploitation of their novel properties and phenomena that emerge at that scale. **(Das *et al*, 2007)** There are mainly two approaches that are used in nanotechnology:

Top-down approach: It referred as the synthesis of nanostructures from bulk.
Bottom-up approach: It referred as the formation of nanoparticles from constituent atoms.

2. Influence of Emulsion Fuel on Diesel Engine Performance and Emission

(Sachuthananthan *et al*, 2007) performed the experiments on a naturally aspirated water cooled, kirloskar single cylinder constant speed DI diesel engine to appraise the performance and emission characteristics of constant water-biodiesel emulsion as fuel with blends of diethyl ether . It was found that the brake thermal efficiency increased from with diethyl ether addition. The NO_x level for diethyl ether addition is lower than that of water-biodiesel emulsion and neat diesel modes of operation. Diethyl ether blend gives better performance and lower emissions compared to other blends of emulsion fuel. **(Kannan *et al*, 2009)** examined performance and emission characteristics of water emulsified diesel fuel. The experiments were conducted on a single cylinder four stroke cycle direct injection diesel engine. Sodium lauryl sulphate was used as surfactant to prepare emulsion. The results exposed that brake thermal efficiency was increased when the amount of water in the emulsion increases The brake specific fuel consumption was decreased at all load conditions when the percentage of water in the emulsion was increased The NO_x and hydrocarbon emissions were found to decrease with increase in water percentage in the emulsified diesel. **(Badrana *et al*, 2011)** investigated the performance and exhaust emission of emulsified diesel fuels in a single cylinder, direct injection Diesel engine. The engine torque, power and brake thermal efficiency were increases as the water percentage by volume in the emulsion increases. An increase in the brake thermal efficiency was observed for emulsion fuel, particulate matter and NOx emissions were

decreases as the percentage of water in the emulsion increased. **(Sudrajad *et al,* 2011)** conducted the experiment on direct-injection diesel engine four stroke one cylinder fuelled with emulsion oil. The increasing of SO_2 emissions was higher at high engine load. NO_x concentration was decreased at low engine load. Exhaust gas temperature was slightly decreased as engine load increases. The experimental results prove that w/o emulsions fuel potentially good alternative fuels for diesel engine in the near future because of give a benefit effect on the fuel oil consumption and reduction of pollutants emissions. **(Yang *et al,* 2012)** evaluated the performance and emission of the emulsion fuel in a diesel engine and compared with pure diesel. Glycerin was used as an additive for emulsion oil by mass. It was observed, torque decreases with the increase of water content. An improved brake thermal efficiency was observed for the emulsion fuel. Emulsion fuel was found to reduce the combustion duration. **(kumar,2012),** conducted the experiment on single cylinder direct injection diesel to evaluate the performance and emission characteristics of emulsified diesel fuel It was observed that emulsion given highest brake specific fuel consumption, highest brake thermal efficiency, lowest exhaust gas temperature, lowest CO and the reduction of HC emission occurs due to the use of emulsion fuel. Water contents produce larger differences in NO_x emissions among all the emulsions. **(Kishore *et al*,2012)** evaluated the performance and emission characteristic of straight vegetable oil, micro emulsions using ethanol and butanol (by vol.) ,were compared with diesel on single cylinder, naturally aspirated, compression engine using pump set. Carbon monoxide emission was lower with emulsions as compared to diesel. At full load, unbrunt hydrocarbon emissions were higher with vegetable oil and its emulsions as compared to diesel. Nitrogen oxide and smoke opacity emission was seen to lower with vegetable oil and micro-emulsions as compared to diesel. **(Yang *et al,* 2013)** evaluated an emulsion fuel with nano-organic additives on a four cylinder, four stroke diesel engine. Glycerin and polyethoxy-esters was used as oxygenated additive.NP-9 is was the surfactant to form the stable emulsion. It was observed that better efficiency is achieved with emulsion oil and NO_x emission was found to reduce. HC and CO emission are very low for both the tested fuels. It was found that ignition delay of emulsion fuel is slightly longer; however the combustion duration was shorter **(Scarpet, 2013)** reviewed the diesel-water emulsion fuel to reduce diesel engine emissions. The diesel-water emulsion fuel was contained water and diesel fuel with specific surfactants, to stabilize the system. NOx was reduced due to the reduction of local high temperature due to vaporized water during combustion. The reduction of local high temperature may cause the reduction of reaction rate, which has a possibility of affording a mixing time for better combustion for reducing PM. Smoke emissions was tend to decline as the emulsion ratio increases due to the lower peak temperature in cylinder. Study showed that engine power was decreased with water content, due to lower calorific value of emulsion fuel compared to pure diesel fuel. **(Swain *et al.* 2013),** carried out an experiment on a single cylinder four stroke constant speed direct-injection diesel engine to evaluate the performance and emission characteristics. The blends water with diesel were prepared using surfactant for the stability of the emulsion. From the experimental result reported here that the specific fuel consumption was observed improvement with an optimum value of 15% water. The results revealed that the large reduction of NO_x concentration was observed by using different concentration of water in fuel emulsion. Furthermore improvement of fuel economy and reduction of exhaust smoke were obtained.

3. Application of Nanotechnology in Alternative Fuel

(Kao *et al,* 2007) investigated the combustion of aluminum nanofluid into diesel. It was observed using nanofluid in diesel fuel had lowered the BSFC compared with neat diesel fuel. It was observed that NO_x concentration for nanofluid laden diesel fuel is lower than that of diesel fuel at all loads. The aluminum nanopowder additive mixed in diesel fuel causes a clear smoke reduction for engine speed and NO_x concentration was showing a decreasing trend. **(Selvan *et al,* 2009)** investigated the performance and emission characteristics of compression ignition engine using neat diesel and diesel-biodiesel-ethanol blends with cerium oxide as additive. The performance test were carried on a single cylinder four stroke injection variable compression ratio water cooled engine The lower SFC was observed for Cerium oxide blend of neat diesel. The addition of cerium oxide further decreased the CO, HC emission when compared with neat diesel. The NO emission was lower for the neat diesel comparing to all the fuel blends. **(Basha *et al,* 2009)** investigated the effect of carbon nanotube (CNT) into diesel to achieve better performance and reduced emission .The experiment were conducted on single cylinder four stroke water-cooled DI diesel engine. The brake thermal efficiency and specific fuel consumption was observed to be improved with CNT blends. It was observed that magnitude of emission characteristics such as NO_x, CO, HC, EGT and smoke opacity is comparatively less compared to neat diesel. **(Sajith *et al,* 2010)** evaluated the influence of dose level of cerium oxide nanoparticle in biodiesel. In order to obtain the performance and emission characteristics, performance test were carried out on a single cylinder water-cooled direct injection diesel engine. Increasing trend was observed in the properties of fuel like viscosity and volatility with addition of nanoparticle. The results showed, hydrocarbon emission was found to reduce with increase in dosing level of the additive. The NO_x emission was found to be generally reduced on the addition of cerium oxide nanoparticle to biodiesel. The reduction influence of the fuel additive on carbon monoxide emission was not as prominent. **(Ganesh *et al,* 2011)** investigated the effect of nano fuel additive on the performance and emission characteristics of jatropha biodiesel (B100) in a single cylinder direct injection, air cooled diesel engine. It was observed that at 75% load operation, NO_x reduction is about 47% in case of cobalt oxide nano-fuel additive. The cobalt oxide nano fuel

additive shows a better reduction in NO_x emission at all load when compared with Magnalium nano fuel additive. By adding magnalium, the maximum reduction of about 66% CO emission was observed at 50% load. Also by adding cobalt oxide, there is a 50% reduction in CO emission at 75% load. **(Shafii *et al,* 2011)** performed test on a four cylinder, in-line, four strokes, compression ignition, water cooled engine. A water based Ferrofluid was added to diesel fuel to explore the effects on the engine exhaust emission. Mixture of diesel and ferrofluid having different volumetric proportions of ferrofluid was prepared, yielded emulsion fuel. Results show that adding ferrofluid to diesel fuel decreased NO_x emission. **(Ajin *et al,* 2013)** conducted an experiment to investigate the catalytic activity of cerium oxide, especially in nanosized form. The performance tests were conducted on a naturally aspirated four stroke single cylinder water-cooled compression ignition engine. It was observed that viscosity, flash and fire point increases with addition of nanoparticle. Also found that hydrocarbon emissions were decreased on addition of catalytic nanoparticle. The NO_x emissions were found to be decreased by a maximum of 30%, on the addition of cerium oxide nanoparticle in diesel. **(Lenin *et al,* 2013)** performed the experiments on a single cylinder air cooled Direct Injection diesel engine for evaluation of diesel doped with metal additives. The change in diesel fuel properties (viscosity, flash point and fire point) due to introduction of nano metal oxide additive was observed. The diesel fuel with nano metal oxide additive had presented a marginal increase in performance. Brake thermal efficiency was increased marginally as compared to conventional diesel fuel. For the DI Diesel engine, the hydrocarbon emissions were highest at lower load. **(Fangsuwannarak *et al,* 2013)** evaluated the performance and emission of a Four cylinder, four stroke vertical-in-line, water-cooled compression ignition pickup diesel engine at full load condition using commercial diesel, Palm Biodiesel and nanoparticle blended fuel .The nanoparticle used was TiO_2. It was found that TiO_2 had reduced the specific fuel consumption and increased engine power for pure diesel. However the NO_x emission for commercial diesel blended with nanoparticle fuel is effectively reduced as compared to commercial diesel and B5 blended with nanoparticle. The blend of TiO_2 based additive with diesel does not only provide the minimum CO_2 emission but it was also led to the minimization of fuel consumption in comparison with diesel without additive. **(Tiwari *et al,* 2013)** conducted the test to determine the combustion characteristics, performance and emission characteristics of single cylinder four stoke direct injection diesel engine using biodiesel fuel blended with multiwalled carbon nanotube. Biodiesel used was known as Hinge oil methyl ester [HOME].The result revealed that better thermal efficiency was observed for HOME-MWCNT blended fuel. MWCNT-HOME blended fuel was tends to reduce the smoke opacity as compared to HOME. **(Mehta *et al,* 2014)** Investigated the burning characteristics, engine performance and emission parameters of a single-cylinder Compression Ignition engine using nano fuels which were formulated by sonicating nano particles of aluminum, and boron in base diesel with Span80 as a surfactant for stable suspension. The nano fuels reduced ignition delay, longer flame sustenance and agglomerate ignition by droplet combustion mechanism test. Peak cylinder pressures decreased at higher load conditions. Specific fuel consumption was reduced with Al in comparison to diesel. At higher loads, the emission study showed a decline in CO along with a drop of in hydrocarbon emissions for A1 and Fe nano fuels. **(Karthikeyan *et al,* 2014)** evaluated the performance and emission characteristics of Promolin Stearin wax oil biodiesel blended with diesel and concentration of Zinc Oxide on a single cylinder air-cooled and direct injection diesel. The zinc oxide additive blends improved the calorific value but did not had any significant effect on the other properties. The BSFC was decreased and BTE was increased with the increase in the dosing level of ZnO in the fuel. The CO and HC had appreciably reduced with the increase of the nano particle dose, as compared to blend of biodiesel. The NOx emissions of all blended fuels did not have any considerable effect. **(Selvan *et al,* 2014)** investigated the performance, combustion and emission characteristics of a variable compression ratio engine using cerium oxide nanoparticles and carbon nanotubes as fuel-borne nanoparticles additives in diesterol (diesel–biodiesel–ethanol) blends.The carbon nanotubes was a catalyst to accelerate the burning rate which resulted in decreased ignition delay and cause for the lower heat release and advancement of the peak heat release rate. The Cerium Oxide nanoparticles were an oxygen donating catalyst which provides oxygen for the oxidation of carbon monoxide and absorbs oxygen for the reduction of nitrogen oxides. The activation energy of Cerium Oxide was to burn off carbon deposits and helps to prevent the deposition of non-polar compounds on the cylinder wall resulted in significant reduction of hydrocarbon and smoke emissions. **(Karthikeyan *et al,* 2014)** done the experiments on the single cylinder four stroke stationary air-cooled and direct injection diesel engine. The nano size zinc oxide nano particle mixed in diesel and canola oil methyl ester biodiesel and fueled in diesel engine to check the performance and emission characteristics. The results showed that slight improvement was observed in calorific value and kinematic viscosity. The maximum cylinder pressure was attained for additive added fuel released highest heat among all the blends. The BSFC was decreased with increase in the dosing level of ZnO to the fuel. The BTE of additive fuel was improved at higher load. It was observed that minimum CO and HC measured with the ZnO blend fuel compared to other blends while the maximum NO_X emission was recorded with the use of ZnO blended fuel.

Conclusion

There has been plenty of research done so far on emulsion production method, stability and diesel engine performance and emission analysis by varying the water content in diesel engine. Simultaneously, effect of the surfactant on the stability has been reported by many researchers. Due to advent of nanotechnology many

researchers investigated its impact on the engine performance and emission characteristics. A lot of work is being done using diesel, biodiesel as a base fuel and nanoparticle as a catalyst, additive over compression ignition engine. The effect of dose level on the fuels properties and performance has been depicted by many scientists. Very little work has been done on the influence of nanoparticle as an additive/ catalyst on water-diesel mixture is demonstrated for lower content of water. Based on literature it is concluded that a comparative study can be performed on effect of cerium oxide nanoparticle dose level in higher concentration of water in water-diesel emulsion based on their performance and emission characteristics in a four cylinder, four stroke diesel engines. The effect of dose level can also be analyzed.

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