EFFECTS OF CERIUM OXIDE NANOPARTICLE ON COMPRESSION IGNINTION ENGINE PERFORMANCE AND EMISSION CHARACHTERISTIC WHEN USING WATER DIESEL EMUSLION

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CERTIFICATE

I hereby declare that the Dissertation **"EFFECT OF CERIUM OXIDE NANOPARTICLE ON COMPRESSION IGNITION ENGINE PERFORMANCE AND EMISSION WHEN USING WATER DIESEL EMULSION"**. is an authentic record of my study carried out as requirements for the award of the degree of **Master of Engineering** in **Thermal Engineering** at **Thapar University, Patiala** under the supervision of **Mr. Sumeet Sharma**, Associate Professor, Mechanical Engineering Department, Thapar University, Patiala during July 2013 to July 2014. The matter embodied in this report has not been submitted in partial or full to any other university or institute for the award of any degree.

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It is certified that the above statement made by the student is correct to the best of my/our knowledge and belief.

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(Ajay Kumar)

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 (W/D) emulsified formulations are reported to reduce the emissions without compensating the engine's performance. In present work an emulsion was prepared by adding nanoparticle as a fuel additive.

A detailed experiment study has been conducted to evaluate the effect of cerium oxide dose level in 15% water emulsion diesel. The emulsification method was used to produce E15.The span 80 and tween 80 were used as surfactants. The cerium oxide nanoparticle dose level in water emulsion diesel were 40, 60, 80 ppm respectively. The experiments were performed in a 4-cylinder, 4-stroke water cooled diesel engine at constant 1650 RPM, over different load condition. The properties such as viscosity, flash point, and calorific value were also determined as per standards. Experiments were conducted using diesel and different blends of emulsion such as E15, E15Ce$O_2$40, E15Ce$O_2$60, and E15Ce$O_2$80 by varying the load on engine. Performance and emission parameter of different blends of emulsion were compared to pure diesel. Results reported that cerium oxide blended fuels substantially improve the performance and reduce harmful pollutants.

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Nomenclature

ASTM	American society of testing and Petroleum
BMEP	Brake mean effective pressure
BP	Brake power
BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
BTDC	Before top dead centre
CI	Compression ignition
CNT	Carbon nanotube
CO	Carbon monoxide
CO_2	Carbon dioxide
CR	Compression ratio
DI	Direct injection
EGT	Exhaust gas temperature
HC	Hydrocarbon
IC	Internal combustion
NO, NO_2 and NO_x	Oxide of nitrogen
PM	Particulate Matter
PPM	Parts per million
RPM	Revolution per minute
SFC	Specific fuel consumption
TDC	Top dead centre

US	United state
WiDe	Water in diesel emulsion
E15	2% Surfactant + 15% Water + 83% Diesel (% by vol.)
E15 CeO_2 40	2% Surfactant + 15% Water + 83% Diesel + 40 PPM CeO_2 (% by vol.)
E15 CeO_2 60	2% Surfactant + 15% Water + 83% Diesel + 60 PPM CeO_2 (% by vol.)
E15 CeO_2 80	2% Surfactant + 15% Water + 83% Diesel + 80 PPM CeO_2 (% by vol.)

CHAPTER 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 6^{th} 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 [3].

Pollution Conservation Research Association reported that the transport sector solely ingests more than 50% of the entire oil consumption in the country [3].The transport sector contribute to environmental pollution largely and out of these pollutant CO is prime pollutant followed by hydrocarbons emission. In India, transport sector emanate an approximate 261 tones of CO_2, of which 94.5% is subscribe by road transport. The transport sector is accountable for 60% staging of green house gases [4].

Air pollution is not only considered a nuisance, but also a threat to public health. A man on average breathes 22,000 times and he taken 35lbs of air each day [5].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 [2, 4].

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.

1.1 COMPRESSION IGNITION (CI) ENGINE TECHNOLOGY [1]

In operation of a four stroke CI engine only air is inducted into the cylinder during suction while the fuel is injected into the cylinder just before the combustion takes place. If the fuel is injected into a pre-combustion chamber before being introduced into the cylinder then it is comprehend as indirect CI engine. On the other hand when the fuel is injected directly into the cylinder, it is so called direct CI engine. The intake air is compressed and in the process the temperature also rises to about 800K.The compression ratio of CI engine is usually higher than for SI engine. Close to the end of compression stroke; about 20° crank angle before TDC, fuel is injected into the cylinder. The fuel is atomized into droplets and entrains air molecules leading to the liquid evaporating into non-uniform combustible mixture. Because the air temperature and pressure is above the fuel injection point, spontaneous ignition occurs in part of the mixture thus initiating the combustion process. Combustion takes place at an almost constant pressure. The exhaust stroke is the much the same way as SI engine. Because of the high pressure in the cylinder, CI engines are designed to with stand the high pressures and thus tend to be heavier than SI engine.

1.1.1 PERFORMANCE CHARACTERISTICS OF C.I ENGINE [1]

The performance of an engine is an indicated by following factor.

- Brake power developed or BMEP
- Specific fuel consumption (kg/kW-hr)
- Specific power output (kW/kg of engine weight)
- Emission from the engine.

The application of the engine decides the relative importance of these parameters. The specific power output is more important for marine engine whereas specific fuel consumption is more important for industrial engine. The basic parameters which are considered for evaluating the engine performance are:

- Indicated power
- Mechanical efficiency
- Thermal efficiency
- Specific fuel consumption

- Volumetric efficiency
- Exhaust emission

1.1.2 DESIRABLE PROPERTIES OF CI ENGINE FUEL [1]

A few important properties required for safety and convenience in storage, handling and usage are listed below:

Viscosity

Viscosity is defined as resistance to flow of liquid due to internal friction between the liquid molecules. It plays an important role in the performance of the fuel system of engine operating through wide range of temperature. It affects the fuel injection system as the low viscosity can result in an excess wear in injection pump and power loss due to pump leakage whereas high viscosity may result in excessive pump resistance, filter blockage, coarse atomization and fuel delivery rates.

Cloud point and Pour point

The cloud is defined as the temperature at which a cloud or haze of wax crystal appears at the bottom of a test jar when chilled under prescribed conditions. Pour point is defined as the temperature at which fuel ceases to flow. Pour point is always lower than cloud point. Cloud point should be small as possible so that this difficulty will not be experienced even in cold weather

Flash point and Fire point

Flash point is defined as the lowest temperature at which the fuel gives off sufficient vapours and ignites for a moment. The fire point is the temperature at which vapours burns continuously for five seconds. The fire point is always higher than flash point by 5 to 8°C.Flash point is important from safety view point, this temperature should be high. The flash and fire point indicates the temperature below which, oil can handle without any danger of fire.

Volatility

Volatility affects the ignition quality of fuel. It should be sufficiently volatile in the operating range of temperature to produce good mixing and combustion. The volatility characteristics of diesel fuel affect the hydrocarbon emission and smoke density of the exhaust. High volatile fuel also helps in starting the engine easily as it forms the combustion mixture readily

Engine deposits

The deposits in the engine are a very serious problem. Solid carbon matter is deposited on all parts of engine because of incomplete combustion of fuel. The deposits tend to increase with increasing viscosity and decreasing volatility. Sulphur compounds in the fuel tend to promote both deposits and corrosion. Therefore, low sulphur content is most desirable property of CI engine fuel.

Cetane number

Knocking in CI engine is because of delay period which is defined as time lapsed between the injection and start of combustion. As the time lag increases, the amount of fuel accumulated increases and abnormal combustion takes place when actual combustion in the engine starts. Therefore, good CI engine fuels should have low delay period and should ignite more quickly. A high cetane number fuels are generally used to avoid knocking of the CI engines. Cetane number of a diesel engine fuel is indicative of its ignition characteristics. Higher the cetane number better is its ignition properties.

1.2 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 [2]. 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. The diesel fumes are more carcinogenic [2].The World Health Organization estimates that over 700 thousand people die each year in South Asia as result of ambient particulate matter pollution, making $PM_{2.5}$ emission as the sixth largest killer in the region. Many Indian cities fail consistently to meet National Ambient

Air Quality Standards [5].The California Air Resources Board concluded that diesel emission account for the majority of cancer risk created by all outdoor pollution source in the U.S.

In India, vehicle accounts for over half of all NOx emission and about a quarter of fine particulate matter ($PM_{2.5}$) emission resulting into two most problematic air pollutants. One of the primary barriers to progress towards effective vehicle-emission standard in India is the high sulphur content in the diesel fuel and gasoline sold in the country: up to 350 ppm in diesel and 150 ppm in gasoline. At such concentration, sulphur inhibits the proper functioning of advanced after treatment [5].

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.

1.3 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.

1.3.1 Types of emulsion

Depending upon the type of emulsification technique, the emulsions are classified into two types: [6]

1.3.1.1 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

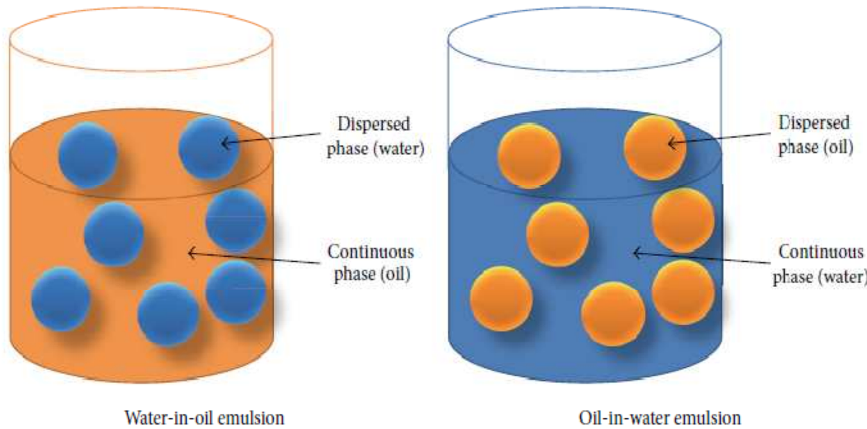


Figure 1.1 Concept of two-phase water-in-oil and oil-in-water emulsion [6]

1.3.1.2 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.

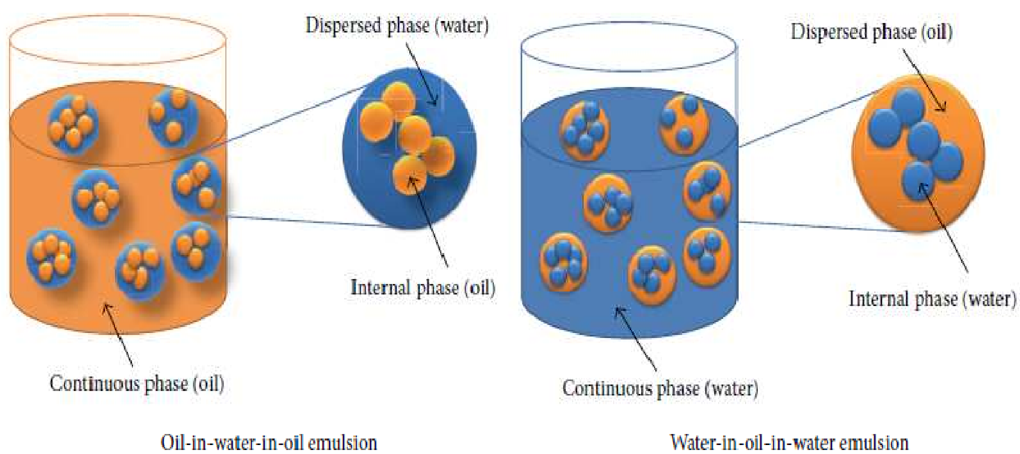


Figure 1.2 Concept of three-phase oil-in-water-in-oil and water-in-oil-in-water [6]

1.3.2 Water diesel emulsion in diesel engine [6]

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 NO_2, 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.

1.3.3 Effect of emulsion fuel on combustion efficiency of the engine [6]

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 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. It has been suggested that water-in-oil upgrade the combustion phenomenon, owing to simultaneous overwhelming of droplets thus providing better mixing of fuel for burning in air.

1.3.4 Effect on emulsion fuel on emission parameter of the engine [6, 7]

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

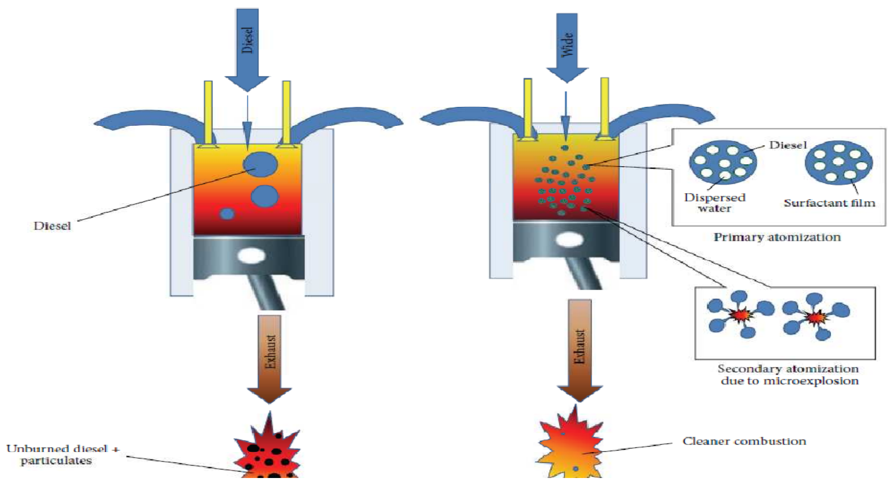


Figure 1.3 Concept of micro explosion phenomenon [6]

1.4 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 [8].

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.

1.4.1 Nanofluids and its structure [8]

Nanofluids are the heat transfer fluids produced by incorporating the very small size particles (average size less than 100 nm) such as metallic, non-metallic and polymeric in to conventional fluid. Yu and Choi, modified Maxwell model with the assumption that the base fluid molecules close to the solid surface of the nanoparticles form a solid-like layered structures. Hence the nanolayer works as a thermal bridge between the liquid base fluid and the solid nanoparticles, and this will enhance the effective thermal conductivity. As seen from Fig. 1, a nanofluid consists of the liquid base fluid, the solid nanoparticles and the nanolayers.

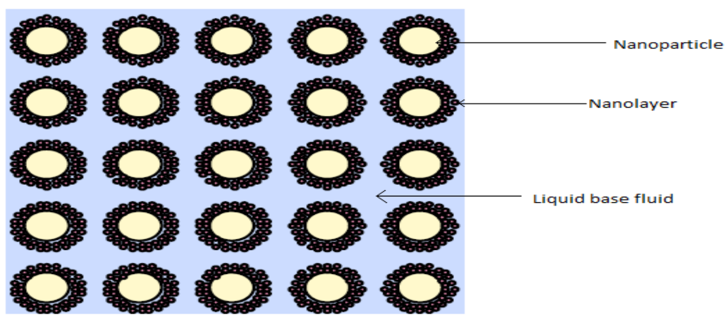


Figure.1.4: Structure of Nanoparticles

1.4.2 Base fluids

Base fluids are also called host fluids. They are single-phase conventional fluids having poor heat transfer properties [8].

Table 1.1: List of base fluids

S.No.	Description	Examples
1	Metallic liquids	Sodium
2	Non-metallic liquids	Water, Ethylene glycol (EG) Engine oil (EO)

1.4.3 Types of nanomaterial [8]

The following types of nanomaterial are listed below in table 1.2

Table 1.2: Nanomaterial Types

S.No.	Description	Example
1	Non-metals	Si, Al2O3, Graphite, Carbon nanotubes
2	Metals	Cu, Al, Ag, Au
3	Nitride ceramics	AlN, SiN
4	Semiconductors	TiO2, SiC
5	Carbide ceramics	SiC, TiC
6	Composite materials	Alloyed nanoparticles, Al70Cu30
7	Oxide ceramics	Al_2O_3, CuO
8	Layered	Cu + C, Al + Al2O3
9	Earth oxide	CeO_2

1.4.4 Challenges of nanofluids [8]

- **High cost of nanofluids:** Higher production cost of nanofluids is among the reasons that may hinder the application of nanofluids in industry. Nanofluids can be produced by either one step or two steps methods. However both methods require advanced and sophisticated equipments. High cost of nanofluids is among the drawback of nanofluids applications
- **Long term stability of nanoparticle dispersion:** Preparation of homogeneous suspension remains a technical challenge since the nanoparticles always form aggregates due to very strong van der Waals interactions. To get stable nanofluids, physical or chemical treatment have been conducted such as an addition of surfactant, surface modification of the suspended particles or applying strong force on the clusters of the suspended
- **Higher viscosity:** As the particle concentration in the suspension increased the viscosity of nanofluid also increased. So, the particle mass fraction cannot be increased unlimitedly.
- **Increased in pumping power and pressure drop:** The pressure drop increases if nanoparticle size increase and hence power required for pumping also increases. The properties of the base fluid like density and viscosity directly influenced the pressure drop. If the viscosity and density of the fluid is increases then pressure drop and pumping power also increases.

References

[1] V.Ganesan , “ Internal Combustion Engine” McGraw-Hill, 4th edition

[2] Shivaji Bhandarkar, “Vehicle Pollution, Their Effect on Human Health and Mitigation Measure”, Vehicle Engineering, Vol.1 (No. 2), 2013

[3] Pranav Raghav Sood, “Air Pollution through Vehicular Emission in Urban India and Preventive Measure”, Energy and Biotechnology, Vol.33, 2012

[4] Shrivastava R.K, Saxena Neeta, Gautam Geeta, “Air Pollution Due to Road Transportation in India: A review on assessment and reduction strategies”, Journal of environmental research and development, Vol.8 (No.1), 2013

[5] T Subramani, “Study of Air Pollution Due to Vehicle Emission in Tourism Centre”, International journal of engineering research and application, Vol.2 (No.3), 2012

[6] Mohammed Yahaya Khan, Z.A. Abdul Karim, Ftwi Yohaness Hagos, A.Rashid A. Aziz, Isa M. Tan “ Current Trends in Water-in-Diesel Emulsion as a Fuel” , The scientific world journal, 2014

[7] A. Alahmer, J. Yamin, A. Sakhrieh, M.A. Hamdan “Engine performance using emulsified fuel” , Energy conversion and management, 2010

[8] Das K Sarit, Choi U.S Stephen, Wenhua Yu and Pradeep T), Nanofluids: Science and Technology. John Wiley & Sons, Inc. New Jersey,2007

[9] Heinz Helser, “Advanced Vehicle Technology” Butterworth-Heinemann, 2nd edition

[10] Willard W. Pulkrabek, “Engineering Fundamentals of the Internal Combustion Engine” Prentice Hall

CHAPTER 2

Literature Review

In the course of “Alternative fuels for compression ignition engine” many journals and books were consulted which are reviewed here reviewed in two parts:

2.1 Review of literature

Yang et al. [1], had evaluated the performance and emission of the fuel in a diesel engine with common rail fuel supply system and compared with pure diesel. Water concentration used in emulsion oil was 10% and 15% respectively. Glycerin was used as an additive for emulsion oil by mass 11.5% and 10% respectively. Unlike other emulsion fuels it was transparent with superior stability. The performance of all the fuels were compared at different speed and working load. 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. Especially for E10, the brake thermal efficiency of the engine was significantly improved by 14.2% compared to pure diesel and NO_x was also reduced by 30.6%

Yang et al. [2], had evaluated an emulsion fuel with 82.4% diesel, 5% water and12.6 nano-organic additives by volume 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. The water droplet size was found to be 100nm in emulsion oil with a typical diameter of 10 µm. Unlike other emulsion fuel it was green in color and very stable. All the fuels were tested by varying the engine speed and load. The results was formulated in comparison of pure diesel It was observed that better efficiency is achieved with emulsion oil and NO_x emission was found to reduced. 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 [3], had reviewed the diesel-water emulsion fuel to reduce diesel engine emissions. The diesel-water emulsion fuel was contained water in the range of 5–15% and diesel fuel with specific surfactants, to stabilize the system. The results showed that NOx was reduced from 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. The phenomenon of micro-explosion, considered as the second atomization which improved fuel combustion and reduces fuel consumption. The heterogeneous results regarding the use of diesel-water emulsion as fuel for diesel engines suggested that experimental work for optimizing the emulsion formulation in terms of water content and internal structure is recommended.

Singh et al.[4], had conducted the experiment on single cylinder direct injection diesel engine working between1500-2700 rpm to evaluate the performance and emission characteristics of emulsified diesel fuel of 0,5,10,15 and 20 water/diesel ratios by volume. The Span 80 in the range of 1% was added to the all emulsion blends and it was stirred using mixing machine at 1500-18000 rpm for several minutes. All the graphs were plotted against the speed. The results shown that the 20%water contents emulsion given highest brake specific fuel consumption among the all blends but emulsion followed .it was seen that emulsion with 20% showed highest brake thermal efficiency. The emulsion with 20% water content had the lowest exhaust gas temperature. The emulsion with 20% water content found to lowest CO and CO2. It had been observed that the reduction of HC emission in the range of 60-93% occurs due to the use of emulsion fuel. Emulsion fuel shown lessens smoke opacity. Much more water contents produced larger differences in NO_x emissions among all the emulsions.

Badrana et al.[5], investigated the performance and exhaust emission of emulsified diesel fuels of 0, 10, 15, 20, 25 and 30 water/Diesel ratios by volume, were used in a single cylinder, direct injection Diesel engine. An experimental investigation was carried out to produce a stable diesel-water emulsion fuel to be used in a diesel engine under different operating conditions. The proper mixing technique and surfactant were used to produce stable emulsion. The stability of these emulsions ranges from one week up to 4 weeks. The physical properties of stable water-diesel emulsions such as density, viscosity and pour point were observed. The effect of water-diesel concentrations, on the performance of a single cylinder diesel engine in terms of engine speed, torque, brake power output, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature and emissions such as NO_x and particulate matter (PM) were studied. The results showed that the water emulsification had a potential to improve the diesel engine performance and to reduce the emissions. The combustion efficiency was found to improve of emulsion during addition of water to diesel. The engine torque, power and brake thermal efficiency were increases as the water percentage by volume in the emulsion increases. The average increase in the brake thermal efficiency for 30% water emulsion is approximately 5% over the use of diesel for the engine speed ranges studied. The particulate matter and NOx emissions were decreases as the percentage of water in the emulsion increased to 30%.

Rao et al.[6], evaluated the performance and emission characteristic of straight vegetable oil (SVO), micro emulsions ESVO-80 (80%, 15%, and 05% of vegetable oil, ethanol and butanol by volume) and ESVO-70 (70%, 20%, and 10% of vegetable oil, ethanol and butanol by volume) compared with diesel on single cylinder, naturally aspirated, compression engine using pump set. Basic properties like viscosity, calorific value, specific gravity were evaluated for all test fuels. It was noticed that at full load, the brake thermal efficiency, with SVO, ESVO-80, ESVO-70 and diesel is about 21.12%, 23.33%, 24.49% and 31.85% respectively. The brake specific energy consumption of ESVO- 70 was found to lower as compared to diesel. The neat vegetable oil reported highest exhaust temperature (402°C) as compared to diesel and emulsions. 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. In extensive period, SVO exposed injector choking, fuel pump damage, fuel filter clogging but emulsions of SVO with alcohol shown lower viscosity, improved volatility, better combustion and less carbon deposits.

Sudrajad et al. [7], had conducted the experiment on direct-injection diesel engine four stroke one cylinder, capacity of 12HP, was operated at 2000 rpm with 25, 50, and 75% engine load using two kind of fuel as 100%diesel oil and 10% emulsion (89% volume DO + 10% water + 1% surfactant).The mixture of sodium hydroxide, calcium hydroxide and chlorine were employed as a surfactant into the experiment work. All the results were plotted against the load. The test were conducted and repeated five times for every kind of fuel, in order to increase the reliability of the test results. The CO emissions were observed for emulsion fuel. The increasing of SO_2 emissions were high at 50% and 75% engine load compare to the 25% engine load. NO_x concentration was decreased from 340 ppm to 280 ppm at 25% engine load. Exhaust gas temperature was slightly decreased from 290 to 2700C, 390 to 360 0C, and 530 to 5100C at 25%, 50% and 75% engine load, respectively. 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.

Swain et al. [8], had 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 of 5%, 10%, 15% and 20% of water with diesel were prepared using surfactant SPAN-60 and TWEEN-60 for the stability of the emulsion. The emulsion was obtained with the aid of a mechanical mixer. From the experimental result reported here that the specific fuel consumption was observed improvement with an optimum value of 15% water. The thermal efficiency was seen slightly better in comparative with the use of neat diesel oil. The combustion efficiency found to increases with water content due to the complete combustion. 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.

Kannan et al. [9], had examined performance and emission characteristics of water emulsified diesel fuel, was prepared by mixing 10% and 20% of distilled water with 90% and 80% of diesel by volume. The experiments were conducted on a single cylinder four stroke cycle direct injection diesel engine at constant speed (1500rpm) with a fuel injection pressure of 200 bars. Sodium lauryl sulphate was used as surfactant and added in the range of 0.1% to prepare emulsion. The mixer was stirred for 2-3 minutes in an electrically operated agitator. All the results were potted against the brake power. From the test results, it was found that the water emulsification has a potential to improve brake thermal efficiency and brake specific fuel consumption. 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. The percentage drop in NO_x was originated 10% and 25% for 10% and 20% water in the emulsion.

Sachuthananthan et al.[10], had performed the experiments on a naturally aspirated water cooled 5H.P kirloskar single cylinder constant speed DI diesel engine to appraise the performance and emission characteristics of constant 30% water-biodiesel emulsion(WBE) as fuel with 5%, 10% and 15% blends of diethyl ether(DEE) . The static injection timing was 23 BTDC and the fuel injection pressure was 200 bar. All the results were described against the brake power. The results indicate that the maximum heat release rate for 30% WBE was found to be 64.1 J/CA degrees which arisen at 11 degrees BTDC and for 5 % DEE it was 54.2 J/CA degrees, for 10 % DEE it was 58.1 J/ CA degrees. It was found that the brake thermal efficiency at full load was increased from 28.3% to 29% with 15% DEE addition. The HC and CO levels were reduced from 75ppm to 40ppm and 0.175 % vol. to 0.1 % vol. respectively at full load when compared to neat water-Biodiesel emulsion. The smoke opacity was observed 4.2 BSU for diesel, 4.5 BSU for biodiesel and 2.5%BSU for 30%water-biodiesel emulsion. With the addition of 15% DEE the smoke opacity was significantly diminished and it was 1.6 BSU. The NO_x level for DEE addition is lower than that of water-biodiesel emulsion and neat diesel modes of operation. At full load the NOx was found to only 568ppm for 10% DEE addition as compared to 651ppm with 30% water-biodiesel emulsion. Use of 15% DEE along with the water biodiesel emulsion the HC emissions was traced only 65ppm at full load conditions which was the lowest level among all the blends. The excess21.6% of oxygen by mass in DEE significantly reduced the CO. Test results indicate that 15% DEE blend gives better performance and lower emissions compared to other blends of emulsion fuel.

Ganesh et al. [11], had 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 operating at 1500 RPM. Cobalt oxide (Co_3O_4) nanoparticle was prepared by Sol-Gel method and Magnalium (Al-Mg) was prepared by Ball Mill process. The obtained particle size range was from 38-70 nm. In order to make nanoparticle stable, CetyleTrimethyl Ammonium Bromide (CTAB) a cationic surfactant was used. Nearly 1% improvement was observed in thermal efficiency for magnalium compare to B100 without additive. The cobalt oxide as additive results in 83% reduction in HC emission at 75% load operation compare to neat biodiesel. A similar trend was noticed with magnalium nano fuel additive. HC emission reduced up to 70% at 50% load. 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.

Ajin et al. [12] had conducted an experiment to investigate the catalytic activity of cerium oxide, especially in nanosized form. Cerium oxide nanoparitcles were prepared by chemical method and added diesel to obtain a stable suspension. The performance tests were conducted on a naturally aspirated four stroke single cylinder water-cooled compression ignition engine, operating at rated speed 1500 RPM. Surfactant used was dodecenyl succinic anhydride which has HLB Value 1.34. Concentration of cerium oxide nanoparticle sample in diesel was 5, 15, 25 and 35PPM. It was observed viscosity, flash and fire point increases with addition of nanoparticle. The load tests were conducted by varying the dosing level of cerium oxide nanoparticle in diesel, which shows that hydrocarbon emission were decreased on addition of catalytic nanoparticle by about 40 to 45%, especially at higher load. The NO_x emission were found to be decreased by a maximum of 30% ,on the addition of cerium oxide nanoparticle in diesel, especially at higher load and further reduction up to 50% with the addition of 5% volume fraction of surfactant treated nanoparticle.

Shafii et al. [13], had performed test on a four cylinder, in-line, four strokes, compression ignition, water cooled engine, operating at 2200 RPM. A water based Ferrofluid was added to diesel fuel to explore the effects on the engine exhaust emission. Concentration used was 0, 0.4, and 0.8 by volumetric proportion of ferrofluid. Synthesis of nanoparticle was based on reacting iron Fe^{2+} and Fe^{3+} ions in an aqueous solution to form magnetite i.e. Fe_3O_4. Furthermore, aqueous tetramethylammonium hydroxide solution is used as a surfactant to create electrostatic repulsion in aqueous environment. The average particle diameter depicted by TEM is 10 nm. Mixture of diesel and ferrofluid having different volumetric proportions of ferrofluid was prepared, yielded emulsion fuel. Results formulated on basis of load variation, which shows that adding 0.4% ferrofluid to diesel fuel decreased NO_x emission by 9 to 15 PPM, adding 0.8% Ferrofluid to diesel fuel decreased NO_x emission by 14 to 24 PPM.

Mozhi et al. [14], had investigated the performance and emission characteristics of compression ignition engine using neat diesel and diesel-biodiesel-ethanol blends with cerium oxide as additive. Cerium oxide nanoparticle size was 32 nm and concentration of 25 PPM were used in the test. Nanoparticle were dispersed in neat diesel and prepared diesel-biodiesel-ethanol Blends. The turbidity procedure was used to assess the stability of the resulting suspension. The performance test were carried on a single cylinder four stroke injection variable compression ratio water cooled engine at the compression ratio of 19.All the results were plotted against brake mean effective pressure (BMEP). 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. The least smoke absorption coefficient was observed as 1.273 for the cerium oxide blended diesel-biodiesel-ethanol blends at the BMEP 0.44MPa.

Basha et al. [15], had 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 with an electrical loading device at constant speed of 1500 RPM using neat diesel and CNT blended diesel without any modification in engine. Carbon nanotube was synthesized by an electric arc discharge method. Concentration of CNT used was 0.5 g/lit, 1 g/lit, 1.5 g/lit by mass fraction. All the results were plotted against brake mean effective pressure (BMEP). 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

Fangsuwannarak et al. [16], had 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,B5 Palm Biodiesel (95% diesel + 5% Palm Oil) and nanoparticle blended fuel .The nanoparticle used was TiO_2. The recommended concentration of the nanoparticle from their producer was used to prepare the blend. All the results were plotted against engine speed. According to his results, exhaust gas temperature was observed to increases with increase of speed. It was found that TiO_2 had reduced the specific fuel consumption and increased engine power for pure diesel by 13.22% and7.78% respectively. 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. In addition, at high engine speed the minimal CO emission less than 55 PPM was obtained for commercial diesel blended with nanoparticle.TiO_2 nanoparticle had the most influence on the diesel fuel for reducing the CO emission with the decreasing fraction by 1% at 1500, 85% at 2000RPM, 80% at 2500 RPM and 76% at 3000 RPM as compared to neat diesel. It had no effective reduction of CO emission for blending in B5 fuel. 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.

Sajith et al. [17], 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, operating at 1500 RPM. The size of nanoparticle 10 to 20 nm and density of 7.13g/mL was used. The dosing level in base fuel was 20PPM, 40PPM and 80PPM respectively. All the results were plotted against the load on the test engine. Increasing trend was observed in the properties of fuel like viscosity and volatility with addition of nanoparticle. The results showed that an average reduction of 25% to 40% in the hydrocarbon emission was obtained for the additive dosing level ranging from 40 to 80 PPM of the additive. The NO_x emission was found to be generally reduced on the addition of cerium oxide nanoparticle to biodiesel. Where average reduction of around 30% was found to occur with dosing level of 80 PPM nanoparticle. The reduction influence of the fuel additive on carbon monoxide emission was not as prominent.

Kao et al. [18], had investigated the combustion of aluminum nanofluid into diesel. The nanoparitcles are made by applying a plasma arc to aluminum nanopowder submerged in water. The average diameter of nanoparticle was about 40-60 nm. An ultrasonicator was used to produce emulsified nano-aluminum liquid. The aluminum nanofluid (AN) additive was added from 30cc to 50cc into 1ltr diesel fuel (D) and then an ultrasonic vibrator was used to vibrate the mixture for 15 min to form the experimental nano-aluminum diesel fuel (AN+D).Combustion curve and emission concentration was determined after 200 sampling combustion cycle. It was observed using AN+D fuel had lowered the BSFC compared with D fuel. The measured concentration of smoke and NO_x with varied values of BMEP at varied engine speeds. For comparison, combustion test at the same condition using pure diesel (D) were also carried out. Experiment performed for both fuel D and AN+D over three different engine speeds. It was observed that NO_x

concentration for AN+D fuel is lower than that of D fuel at all loads at 1200 and 1800 RPM. The aluminum nanopowder additive mixed in D fuel causes a clear smoke reduction for engine speed less than 1800 RPM and NO_x concentration was showing a decreasing trend.

Tiwari et al. [19], had 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].Average particle size, bulk density, surface area and purity of CNT was 10-30nm, 0.05-017 g/cc, 350 m^2g, 95% respectively. The different fuel combination of CNT blended-biodiesel was prepared in mass fraction of 25 and 50 PPM. Using ultrasonicator mixture was allowed to vibrate for 30 min at a frequency of 40 kHz, 120W, and yielded test fuel are known as HOME25MWCNT and HOME50MWCNT respectively. Neat diesel was used for base line data generation ,during the experiment, compression ratio, injection opening pressure, injection timing was kept at 17.5, 205 bar and 23°BTDC for diesel operation and 17.5, 230 bar and 17.5° BTDC for blend of HOME-MWCNT respectively. The entire test was conducted at a constant speed of 1500 RPM and by varying the load .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. The observed smoke opacity for HOME25MWCNT and HOME50MWCNT was 63 and 59 HSU, compared to 78 HSU for HOME and 52 HSU for neat diesel, respectively at 80% load. The NO_x emission for HOME25MWCNT was 600 PPM where it was 750 PPM for HOME50MWCNT, compared to 580 PPM for HOME and 800 PPM for neat diesel, at the 80% load respectively.

Mehta et al. [20], 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 (Al) having 30-60nm, iron (Fe) 5-150 nm and boron (Bo) 80-100 nm in size in base diesel with 0.5wt% and 0.1wt% 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 and were registered as 55, 59, 60 and 62 bars for A1, Bo, Fe and diesel respectively. Specific fuel consumption was reduced by 7% with A1 in comparison to diesel. Exhaust gas temperatures of A1, Fe, and Bo rose by 9%, 7% and 5% respectively, resulting into increase in brake thermal efficiencies by 9%, 4%, and 2% as compared to diesel at higher loads. A wet whatman filter paper was adopted to collect the soot particles and increase in weight by 12%, 9%, and 8% was observed for Fe, Bo and A1 nano fuels respectively as compared to diesel. At higher loads, the emission study showed a decline of 25–40% in CO (vol. %), along with a drop of 8% and 4% in hydrocarbon emissions for A1 and Fe nano fuels respectively. Due to elevated temperatures a hike of 5% and 3% was observed in NOx emission with A1 and Fe-.

Karthikeyan et al. [21], had evaluated the performance and emission characteristics of Promolin Stearin wax oil(B) biodiesel blended with 80% diesel(D) and 50PPM and 100PPM concentration of Zinc Oxide(ZnO) on a single cylinder air-cooled and direct injection diesel engine operating at 1500 RPM. The average diameter of the zinc oxide nano particle was less than 100nm.The experiments were conducted for low, medium and heavy loads at rated speed with injection pressure of 220 bar. All the results were plotted against the break mean effective pressure. 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 BSFC and BTE for B20, D80B20ZnO50 and D80B20ZnO100 were found to be 0.284, 0.278, 0.272 in kg/kw-hr and 28%, 28.8%, 29.96% during experimentation. The CO and HC had appreciably reduced with the increase of the nano particle as compared to B20. The NOx emissions of all blended fuels did not have any considerable effect.

Lenin et al. [22], performed the experiments on a single cylinder air cooled Direct Injection diesel engine for evaluation of diesel doped with metal additives MnO (200 mg/L) and CuO (200 mg/L). Sol–gel method was used for nano fuel preparation. The ranges of nano particle 50-210nm was confirmed with SEM. All the results were shown against the load. 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 by 4% from the conventional diesel fuel. For the DI Diesel engine, the hydrocarbon emissions were highest at lower load. Thus, hydrocarbon emissions during idling condition have been a focus of attention. The diesel fuel with metal additive was found to decrease from the conventional diesel fuel operation during the 25% load tests. At full load it was observed experimentally that 1% decrease in the hydrocarbon emission, it was analyzed that manganese has the stronger effect in reducing the diesel exhaust emissions. The exhaust emission measurements for the fuel with manganese additive showed that CO is reduced by 37%, and NOX is reduced by 4%.

Karthikeyan et al. [23], had done the experiments on the single cylinder four stroke stationary air-cooled and direct injection diesel engine operating at constant speed 1500 RPM under the full load. The nano size zinc oxide nano particle was less than 100nm with 50PPM and 100PMM concentration was mixed in diesel (D) and canola oil methyl ester biodiesel (B) and fueled with various blends such as D80B20, D80B20ZnO50, and D80B20ZnO100 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 and D80B20ZnO100 released highest heat among all the blends as 95.93kj/m^3deg. 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 B20 while the maximum NOX emission was recorded with the use of ZnO blended fuel.

Mozhi et al. [24], had 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. Stability studies were carried out using cerium oxide nanoparticles and carbon nanotubes. Concentration of each were used 25, 50, 100 ppm in the diesterol blends. Blends were subjected to high speed mechanical agitation followed by ultrasonic bath stabilization. The performance, combustion and emission characteristics were carried out at compression ratio of 19:1. Result showed that addition of cerium and carbon nanotube in diesterol blend, the cylinder gas pressure was found to increase when comparing with the neat diesterol 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.

References

[1**]** W.M. Yang, H. An, S.K. Chou, S. Vedharaji, R. Vallinagam, M. Balaji, F.E.A. Mohammad, K.J.E. Chua., “Emulsion fuel with novel nano-organic additives for diesel engine application”, Fuel , 2012

[2] W.M. Yang, H. An, S.K. Chou, K.J. Chua, B. Mohan, V. Sivasankaralingam, V. Raman, A. Maghbouli, J. Li., “Impact of emulsion fuel with nano-organic additives on the performance of diesel engine”, Applied Energy , 2013

[3] Dan Scarpete, “Diesel-water emulsion, an alternative fuel to reduce diesel engine emission .A review”, Machines technologies material, 2013

[4] Nitish kumar, “Experimental investigation diesel emulsion as fuel in small direct injection compression ignition engines”, MIT International journal of mechanical engineering, 2012

[5] Omar Badrana*, Sadeq Emeishb, Mahmoud Abu-Zaidc, Tayseer Abu-Rahmaa, Mohammad Al-Hasana, Mumin Al-Ragheba “ Impact of Emulsified Water/Diesel Mixture on Engine Performance and Environment”. International journal of thermal and environment engg, Vol.3, 2011

[6] Nandkishore D. Rao, B. Sudheer Premkumar and M. Yohan, “Performance and emission characteristics of straight vegetable oil-ethanol emulsion in a compression ignition engine” ARPN journal of engineering and applied Sciences, 2012

[7] Agung Sudrajad, “Experimental study of exhaust emissions of W/O emulsion fuel in DI single cylinder diesel engine”, Modern applied science, 2011

[8] R. K. Swain, Sunita Panda, “Water-in-Diesel emulsion – An eco-friendly fuel for stationary diesel engines”, International journal of scientific & engineering research, 2013

[9] K. Kannan and M. Udayakumar, “NOx and HC emission control using water emulsified diesel in single cylinder diesel engine”, ARPN Journal of Engineering and Applied Sciences, 2009

[10] B. Sachuthananthan and K. Jeyachandran, “Combustion, Performance and emission charachteristics of water-biodiesel emulsion as fuel with DEE as ignition improver in a DI diesel engine, Journal of environmental researh and development,2007

[1] D.Ganesh, G.Gowrishankar, “Effect of Nano-fuel additive on emission reduction in a Biodiesel fuelled CI engine”, Electrical and control engineering conference, 2011

[12] Ajin C. Sajeevan and V. Sajith, “Diesel Engine Emission Reduction Using Catalytic Nanoparitcles: An Experimental Investigation”, Journal of Engineering, 2013

[13] M. B. Shafii, F. Daneshvar, N. Jahani, and K.Mobini, “Effect of Ferrofluid on the Performance and Emission Patterns of a Four-Stroke Diesel Engine”, Advances in Mechanical Engineering, 2011

[14] V .Arul MozhiSelvan, R.B Anand and M. Udayakumar, “Effects of cerium oxide nanoparticle addition in diesel and diesel-biodiesel-ethanol blends on the performance and emission characteristics of a CI Engine”, ARPN journal of Engineering and Applied Sciences, Vol. 4 (No. 7), 2009

[15] J.SadhikBasha and R.B. Anand, “Performance and Emission Characteristics of DI compression ignition engine using Carbon Nanotube Blended Diesel”, Advances in Mechanical Engineering, 2009

[16] Karoonfangsuwannarak and KittichaiTriatanasirichai, “Effect of metalloid compound and bio-solution additive on Biodiesel Engine performance and exhaust emission”, American journal of Applied Sciences, 2013

[17] V. Sajith, C. B. Sobhan, G. P. Peterson, “Experimental Investigations on the Effects of Cerium Oxide Nanoparticle Fuel Additives on Biodiesel”, Advances in Mechanical Engineering, 2010

[18] Mu-Jung Kao, Chen-Ching Ting, Bai-Fu Lin, Tsing-Tshih Tsung, “Aqueous Aluminum Nanofluid Combustion in Diesel Fuel”, Journal of Testing and Evaluation, Vol. 36 (No.2), 2007

[19] Prajwal Tewari, Eshank Doijode, N.R. Banapurmath, V.S. Yaliwal, “Experimental Investigation on a Diesel Engine Fuelled With Multiwall Carbon Nanotube Blended

Biodiesel Fuels", International Journal of Emerging Technology and Advanced Engineering, Vol. 3(No. 3), 2013

[20] Rakhi N. Mehta, Mousumi Chakraborty, Parimal A. Parikh, "Nanofuels: Combustion, engine performance and emissions", Fuel, 2014

[21] S.Karthikeyan,A.Elango,A.Prathima, "Performance and Emission Study on Zinc Oxide Particles Addition with Promolion Stearin Wax Biodiesel of Engine", Journal of Science and Industrial Research, Vol. 73, 2014

[22] M.A. Lenin, M.R. Swaminathan , G. Kumaresan, "Performance and emission characteristics of a DI diesel engine with a nanofuel additive",Fuel ,2013

[23] S.Karthikeyan, A.Elango, A.Prathima, "Diesel engine performance and emission analysis using oil methyl ester with the nano sized zinc oxide particles", Journal of Science and Industrial Research, Vol. 21, 2014

[24] V. Arul Mozhi Selvan, R.B. Anand, M. Udayakumar "Effect of Cerium Oxide Nanoparticles and Carbon Nanotubes asfuel-borne additives in Diesterol blends on the performance, combustion and emission characteristics of a variable compression ratio engine", Fuel, 2014

CHAPTER 3

Research Gap and Objective

Increasing environmental concern and diminishing petroleum resources are the driving force to search for ways and means of developing an alternative fuel. Researcher and scientist concentrate their efforts for developing an alternative to meet power requirement with reduced emission. The various alternative fuels like biodiesel and emulsion oil under the stage of development. Moreover, water-diesel emulsion is more favorable due to its easy availability of water and its abundance in nature. There are various methods of introducing the water in diesel engine. Of all the methods proposed to introduce water into combustion chamber, water-diesel emulsion appears to be most appropriate.

3.1 GAP IN RESEARCH

There has been plenty of research done on 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.

3.2 OBJECTIVE OF RESEARCH

On the basis of the trend of energy consumption and subsequent effect on environment due to combustion, the following points have been carefully analyzed in evolving the objective of the present investigation.

The main objective of this work will be to do a comparative study 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 engine. The effect of dose level will be tested and analyzed.

The literature survey has been done with following aims and objectives:

- Production of water-diesel emulsion fuel
- Blending of Nanoparticle with water-diesel emulsion fuel to prepare different blends in different dose level.
- Performance and emission characteristics analysis of engine
- Correlation of water-diesel emulsion with that of nanoparticle blended water-diesel emulsion is done on the basis of performance and emission characteristics

The parameters of engine to be evaluated and compared were:

- Performance Parameters
  - Brake power (BP)
  - Brake specific fuel consumption (BSFC)
  - Brake thermal efficiency (BTE)

- Emission parameters:
  - Carbon monoxide (CO)
  - Nitrogen oxide (NOx)
  - Unburned Hydrocarbon (HC)
  - Smoke Opacity

CHAPTER 4

EXPERIMETNAL SETUP AND METHODOLOGY

This chapter discusses the methods and procedure required for the preparation of water-diesel emulsion oil and nanoparticle blended water-diesel emulsion oil. In this chapter process adopted for the determination of different properties of water-diesel emulsion oil and nanoparticle blended water-diesel emulsion oil from the four different blends (E15, $E15CeO_2$ 40, $E15CeO_2$ 60, and $E15CeO_2$ 80). These four blends were charged in a compression ignition engine. The performance variable such as brake power, brake thermal efficiency, and brake specific fuel consumption. Exhaust gas is analyzed for carbon monoxide, unbrunt hydrocarbon, Nitrogen oxides, smoke opacity are also assed. These performance and emission variable of emulsion oil are compared to those of pure diesel

4.1 PRODUCTION OF WATER-DIESEL EMULSION OIL

The production of water-diesel emulsion is carried out in two steps with the aid of mechanical agitator.

- In first step, a mixture (2% by vol.) of two non-ionic surfactants span 80 and tween 80 was prepared by using surfactant, with hydrophilic and lipophilic balance value 8.
- In second step, the neat diesel fuel (83% by vol.) is merged with surfactant mixture and agitated by means of mechanical agitator for 15 minute at constant speed of 2500 r.p.m. simultaneously; the water(15% by vol.) is added with the aid of metering pump. The resultant product is the water-diesel emulsion fuel (E15).

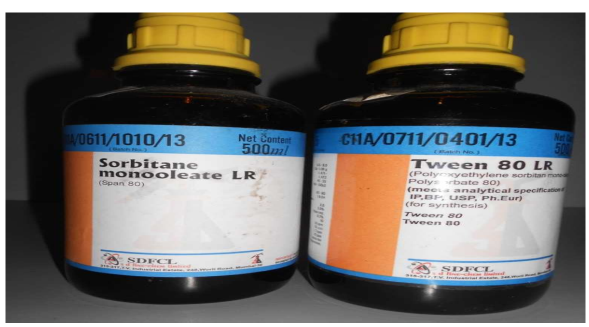


Figure 4.1 Surfactant used for preparing emulsion fuel

Figure 4.2 Surfactant mixture used for emulsion fuel

4.2 PRODUCTION OF NANOPARTICLE BLENDED WATER-DIESEL EMULSION OIL

Cerium oxide nanoparticle is chosen to investigate its effect on water-diesel emulsion oil is purchased from XINYU ADVANCED MATERIALS LIMITED, CHINA. In order to produce nanoparticle blended water-diesel emulsion oil both ultrasonicator and mechanical agitator are used. Various steps used in preparation of nanoparticle blended water-diesel emulsion oil are described below:

- Ultrasonication is used to disperse the cerium oxide nanoparticle (input 40 PPM) in the water for 90 minute in the first step.
- Second, the surfactant mixture is produced in the same manner as it was adopted for E15 emulsion fuel.
- Thirdly, the mechanical agitator is used mix the neat diesel (83% by vol.) and surfactant mixture (2% by vol.) at a constant speed of 2500 r.p.m for 15 minute. At the same time, the (cerium oxide nanoparticle dispersed in water) mixture prepared earlier is added by means of metering pump. The resultant product yields the cerium oxide nanoparticle blended water-diesel emulsion fuel (E15CeO_2 40).
- The same procedure is adopted for dose level of 600PPM, 80PPM which yields E15CeO_2 60 and E15CeO_2 80 respectively.

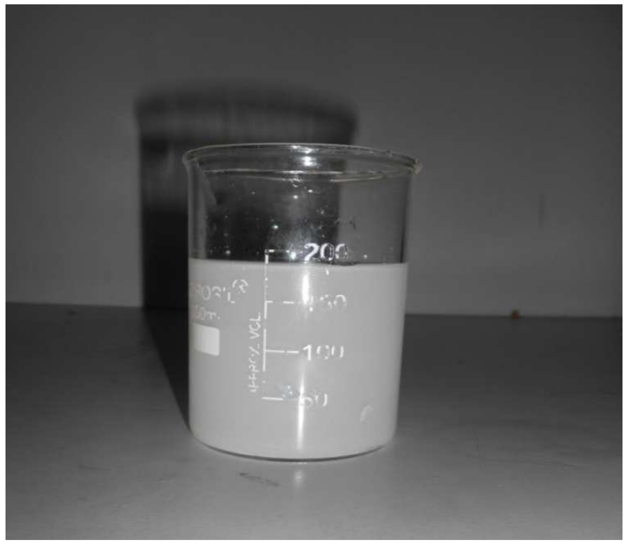


Figure 4.3 Dispersed cerium oxide nanoparticle in water

Figure 4.4 Nanoparticle blended emulsion oil

4.3 DETERMINATION OF PROPERTIES OF THE EMULSION OIL

Evaluation of the following properties of the produced emulsion oil is discussed below:

- Calorific value
- Kinematic viscosity
- Fire point
- Carbon residue

4.4 APPRATUS USED IN ESTIMATION OF PROPERTIES

The following equipments were used for the estimation of the properties of the emulsion oil.

4.4.1 Bomb calorimeter: The wisdom scientific works make isothermal bomb calorimeter (Plate 3.4) was used to compute the gross heat of combustion of an emulsion fuel sample as per IS: 1448[P:6]:1984. A fuel sample of 1ml was ignited in calorimeter's bomb in the existence of pure oxygen. The fuel sample was burned electrically. As the heat liberated, the increase in temperature was recorded. The water equivalent (active heat potential of the calorimeter) was also evaluated with aid of dry and pure benzoic acid as an analysis fuel. All samples were reworked three times. The equation used for calculating the gross heat of combustion of emulsion oil is given below:

$$H_f = (W_e * \Delta T)/ M_f \qquad 4.1$$

H_f = Heat of combustion of the sample fuel, Cal/g

W_e = Water equivalent of the calorimeter, Cal/^{O}C

ΔT = Rise in temperature, ^{O}C

M_f = Mass of fuel ignited

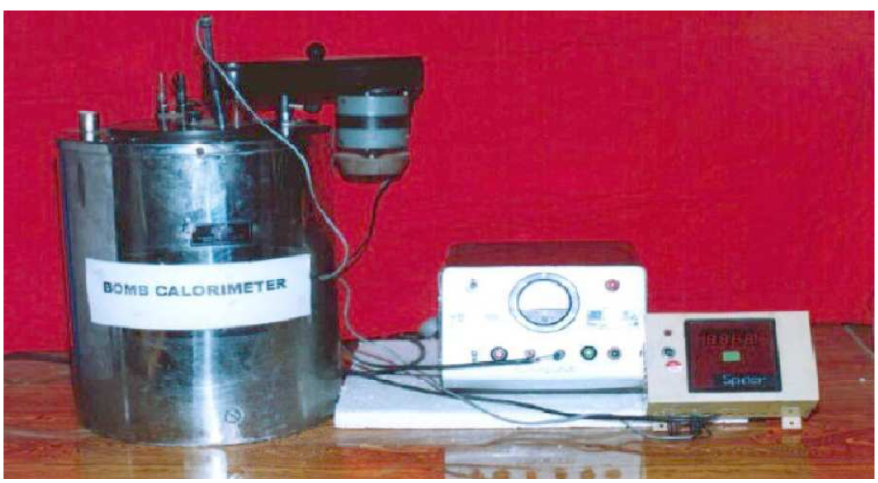


Figure 4.5 Bomb calorimeter apparatus used for measuring calorific value

4.4.2 The redwood viscometer: The redwood viscometer as show in fig 4.6 is frequently used for measurement of viscosities of lubrication oils. This equipment does not accord a direct magnitude of viscosity in absolute units but it permits the viscosities of oil to be correlated by gauging efflux of 50ml of oil over the standard orifice of the equipment under standard requirements as per IS: 1448 [P:25]:1976

The procedure to figure out viscosities of emulsion oil by using redwood viscometer is as below:

- Align the instrument with the support of the leveling screws on the tripod. Charge the water bath with water to the height equivalent to the tip of the indicator up to which the oil is filled in the cylindrical cup.
- Maintain the brass ball in place so as to shut the orifice. Keep the 50 ml flask in place underneath the jet. Keep the water and oil effectively stirred and record their temperatures.
- When the temperature of the water and oil are stable, rise the ball valve and suspend it from the thermometer bracket. At the same time start a stop watch. When the altitude of oil falling into the flask reaches the 50 ml mark, stop the watch and note the time in seconds.
- Return the ball valve in place to seal the cup to stop spilling of the oil. Refill the oil into the indicator tip of the oil cup and repeat the experiment two more time. Mean of these three readings is calculated as T_m in seconds.

The kinematic viscosity was then calculated using time units by using relationships given by Guthrie (1960) .Mean of these three readings is calculated as T_m in seconds.

If $T_m < 34$

$$V = 0.26 * T_m - 50/T_m \quad 4.2$$

If $T_m > 34$

$$V = 0.26 * T_m - 179/T_m \quad 4.3$$

Where:

T_m = Mean time in seconds

V = Kinematic viscosity in centistokes.

Figure 4.6(a) Top View of Viscometer

Figure 4.6(b) Viscometer used for measuring viscosity

4.4.3 Pensky Martin (closed) apparatus: The flash and fire point of the fuel samples were estimated as per IS: 1448. The test fuel was poured into the oil cup up to the mark. The apparatus used for determining the flash and pour point is shown in fig 4.7

Figure 4.7 Flash and fire point measurement using Pensky martin apparatus

The test fuel was stirred at a steady constant rate. The equipment is heated so that an increase in temperature of about 5 to 6 ^{O}C per minute occurs when the stirrer is rotating at approximately 60 R.P.M. The measurement of an increase in temperature is done with the help of a thermometer of -10 to 400 ^{O}C range. After every 1 ^{O}C increase, flame is launched for a moment with the help of a shutter. The flash point was taken as that minimum temperature at which, on introducing the test flame into the oil cup a distinct flash was observed. The fire point was recorded as the temperature at which fuel vapor pick up fire and stays for minimum of five seconds.

4.5 EQUIPMENT USED FOR PERFORMANCE CHARACHTERISTIC OF THE ENGINE

The engine and engine attachment were used for evaluating engine performance and emissions characteristics of different fuel blend are as follows.

Figure 4.8 Test rig of 4-cylinder,4-stroke diesel Engine

4.5.1 Engine

The diesel engine as shown in figure 4.9 is a 1400cc multi-cylinder, four stroke, liquid cooled, direct injection engine which was widely used in automotive sector

Figure 4.9 Tata make 1400cc, 4-cylinder, 4-stroke, DI Engine

Fuel was supplied to the fuel pump by gravity feed, through the fuel tank and paper element filter. Lubrication was done by forced feed to main and large end bearings and camshaft bush. Other working parts were splash lubricated. By-pass filter was used for cleaning the lubricating oil. The engine was started by electric starter motor which draws the power from 12V, 45 Amp batteries.

Table 4.1 Engine Specification

1	Engine	4-cylinder, 4-stroke, DI engine
2	Cooling	Water-cooled
3	Brand	TATA
4	Horse Power	60 H.P
5	Stroke Length	79.5 mm
	Bore Diameter	75 mm

Table 4.2 Value of Constants

1	Coefficient of discharge	0.64
2	Cross-sectional area of orifice	0.000551 m^2
3	Diameter of orifice	0.0265 m
4	Density of air at 0 ˚C	1.293kg / m^3
5	Dynamometer constant	2000
6	Density of water	1000 kg/m^3
7	Specific heat of water	4.18 kJ/ Kg ˚C
8	Acceleration due to gravity	9.8 m/s^2

4.5.2. Hydraulic Dynamometer

The photograph of hydraulic dynamometer is depicted in figure 4.10. It consists of an inner rotating member or impeller coupled to output shaft of the engine. This impeller rotates in a casing filled with fluid. This outer casing, due to centrifugal force tends to revolve with impeller, but was resisted by a torque arm supporting the balance weight. The frictional force between impeller and the water was measured by the spring balance fitted on the casing. The output can be controlled by regulating the sluice gates which can be moved in and out which forms an obstruction for the flow of water between the impeller and the casing.

Brake power measured by the hydraulic dynamometer is given by

$$B.P = (W \times N) \div C \qquad 4.4$$

Where W = weight measured on the dynamometer

Figure 4.10 Hydraulic dynamometer used to load the engine

N = R.P.M of the engine

C = Dynamometer constant (60×1000 / 2R) 4.5

The arm length (R) is selected in such a way that C is a whole number.

4.5.3 Control Panel

The photograph of control panel of diesel engine set up is depicted in figure 4.11. The control panel was equipped with inlet water temperature indicator from engine, outlet water temperature indicator from engine, inlet water temperature indicator from calorimeter, outlet water temperature indicator from calorimeter and load indicator.

Figure 4.11 Digital Control Panel

4.5.4 Fuel and Air consumption measuring arrangement

The fuel measuring arrangement consists of a fuel tank of suitable capacity mounted on a stand. Fuel goes to the engine through 50 ml burette. The burette facilitates the measurement of fuel consumption for a definite period with the help of stop watch. The method used for measuring the consumption of air is known as orifice chamber method as shown in figure 4.12. It consists of an air tight chamber fitted with orifice of known coefficient of discharge. The orifice was located away from suction connection to the engine. Due to the suction of engine, there was pressure depression in chamber which causes flow through orifice for obtaining the steady flow, the volume of chamber should be 500 to 600 times larger than the swept volume of the engine. A rubber diaphragm was provided to further reduce the pressure pulsations. It was assumed that the intermittent suction of engine will not affect the air pressure in air box due to large volume of air box. Water manometer was used to measure the pressure difference

Figure 4.12 Fuel and Air consumption measuring arrangement

4.5.5 Hand Tachometer

Hand tachometer was used to measure the R.P.M of the engine as shown in fig 4.13

Figure 4.13 Hand Tachometer

4.6 PROCEDURE OF EXPERIMENT

The experiment was performed firstly with diesel and then with four different blends of emulsion oil (E15, E15CeO_2 40, E15CeO_2 60, and E15CeO_2 80). The steps used are described as below:

- Ensure proper earthlings and electrical connections for the equipments.
- Check for water in the water supply tank.
- Ensure minimum 2 liters' of quantity for the selected fuel in the fuel supply tank.
- Fill the manometer with water up to half of the height of manometer.
- Diesel fuel was filled in burette with the help of opening the valve provided at the lower side of burette
- Supply the diesel fuel to the engine by accessing the valves provided on fuel supply line.
- Make sure of continuous supply of cold water to the engine jacket.
- Start electric power supply to the control panel
- Start electric supply of power to gas analyzer and smoke meter respectively for emission measurement
- With the help of an electric start motor, the engine was started. Then engine is let to run on no load condition for ten minute so that engine, flue gas analyzer and smoke meter is get warmed up and stabilized respectively.
- After that engine was made to run on desired load with the help of an hydraulic dynamometer. As the load on engine increased from no load to desired load, engine R.P.M decreases. For maintaining the desired constant R.P.M an increase in fuel supply was made.
- After that run the engine for three minutes so that it can stabilize.
- The R.P.M of engine and reading of load cell were noted with the help of hand tachometer.
- Then supply valve of diesel was closed and the valve of burette was opened. After that quantity of fuel consumed in 15 seconds was noted down. This would be termed as fuel consumption.
- Diesel supply valve was again opened to refills the burette.
- As the burette get filled with fuel close the burette valve and again supply of diesel was continued by opening valve of diesel supply.

- Manometer reading was noted down to calculate engine air intake.
- The inlet and outlet temperature was noted for water circulating around the engine jacket, As they get displayed on control panel
- Temperature of expelled exhaust gases from the engine is displayed on the digital control panel.
- Measurement of flow rate of water was done with the help of water meter and stop watch.
- Note down the reading unburned hydrocarbon, carbon monoxide, nitrogen oxides and smoke opacity with the help of flue gas analyzer and smoke meter respectively.
- Repeat the procedure for loads of 3.8, 6.6, 9.1, 11.7, 13.6, 15.9 kg, keeping the R.P.M constant by using screw arrangement ranges from 12 to 18.
- After making all the records engine was brought up no load condition and after that engine is fuelled with diesel for 15 min before testing another blend for flushing of fuel line.
- Repeat the experiment for the E15$CeO_2$40, E15$CeO_2$60, and E15$CeO_2$80 blends of emulsion oil.
- When all records were taken, bring engine to no load condition and turn off the engine.
- Stop the water supply to the engine.

4.7 PRECAUTIONS TAKEN DURING EXPERIMENT

- Before turning on the engine all the bolts and nuts are properly checked out.
- It is to be ensured that there is an adequate amount of oil present in the engine before turning it ON
- The engine was checked out continually so that at the time of power failure, the supply of cooling water to dynamometer and engine may not be stopped.
- It was ensured that the fuel line and fuel tank were properly cleaned.
- The water supply was turned on before starting the engine.

4.8 MEASUREMENT OF PERFORMANCE

Brake power is one of the most important parameter in the engine experiment. The hydraulic brake dynamometer was used for present investigation. The fuel consumption of an engine was measured by determining the time required for consumption of given volume of fuel using a glass burette. The mass of fuel was calculated by multiplying volumetric fuel consumption to its density. An air box with orifice meter and manometer was used for accurate volumetric measurement of air consumption and finally mass flow rate was determined. Digital type temperature sensor (thermocouples) was used for temperature measurement.

4.8.1 Brake power

The part of power developed in the engine cylinder is used to overcome the local friction. The net power output is available at the shaft is known as brake power and it is denoted by B.P. It depends on speed of engine (R.P.M) and the load. All the readings were taken at constant R.P.M by varying the load on the engine. Thus, all of the following graphs in this chapter will be plotted against Brake power.

4.8.2 Brake specific fuel consumption

It is defined as the fuel flow rate per unit power output. It is a measure of the efficiency of the engine in using the fuel supplied to produce work. It was desirable to have a lower value of BSFC which means that the engine uses less fuel to produce the same amount of work. This is one of the most important parameters to compare when testing various fuels.

4.8.3 Brake thermal efficiency

It is the ratio of the thermal power available in the fuel to the power the engine delivers to the crankshaft. It is the ratio of brake power developed by engine to the heat supplied to the engine. This greatly depends on the manner in which the energy is converted since the efficiency is normalized with fuel heating value.

4.9 EXHAUST EMISSION ESTIMATION:

The exhaust emission variables were analyzed with the help of smoke meter and flue gas analyzer. The exhaust emission variable with their respective test system are given below in Table 4.3

Table 4.3 Test Method used for Emission

S.No.	Parameters	Test Method
1	Smoke Opacity	Neptune
2	Hydrocarbon (ppm)	AVL flue gas analyzer
3	Carbon monoxide (ppm)	AVL flue gas analyzer
4	Nitrogen oxide (ppm)	AVL flue gas analyzer

4.9.1 Smoke Meter

The Hartridge type smoke meter was used to measure the smoke density. In this system the moderation in intensity of light beam when it passes through the smoke was used to obtain the value of smoke opacity. Neptune OPAX2000*II*/ DX200P -smoke meter manufactured and marketed by M/S Neptune India Pvt. Ltd, Gurgaon, was used for measuring the smoke opacity in the present work as shown in figure 4.14. It measures the opacity of the polluted air especially for diesel exhaust gases in a measurement chamber of well defined measurement length. Opacity is an inactive light between the light source and receiver. The smoke opacity is defined as the ratio of electric output from photocell when sample is passed through the column to the electric output when clean air is passed through it. The smoke opacity is the extinction of light between light source and receiver. A light beam was launched across a free-flowing out flux of exhaust gases, a certain portion of light is absorbed or scattered by the suspended soot particle in the exhaust.

Figure 4.14 Smoke Meter to measure smoke opacity

The remaining portion of the light falls on a photocell which results in generating a photoelectric current, which was a measure of smoke opacity in Hartridge unit.

4.9.2 AVL flue gas Analyzer

The measurement of unburned hydrocarbon, carbon monoxide and nitrogen oxides were done with help of exhaust gas analyzer. The AVL flue gas analyzer is shown in fig 4.15(a) and 4.15(b)

Figure 4.15(a) Control panel view of AVL flue gas analyzer

Figure 4.15(b) Exhaust inlet of AVL flue gas analyzer.

A series of steps to be followed for the exhaust evaluation are mention below:

- At particular load condition, the exhaust outlet was attached to respective analyzer and the exhaust gases were passed through analyzer.
- After few minute a stabilized three output reading were displayed on the screen of analyzer were noted
- Mean of these three reading was taken for the calculation purpose.
- Analyzer were removed from the exhaust outlet of the engine and brought up to initial zero reading
- Above mention steps were repeated for different loads and different fuel blend respectively.

CHAPTER 5

RESULTS AND DISCUSSIONS

The fuel consumption and rating test of a 45 kW, four cylinders, and four stroke water cooled CI engine was also conducted to evaluate the performance of the engine on diesel and on different blends emulsion oil and nanoparticle blended emulsion. The results of parameters measured and analytical interpretation with discussion are presented in this chapter.

Phase I: The fuel properties of prepared emulsion blend were compared with pure diesel.

Phase II: The brake thermal efficiency, fuel consumption and brake specific fuel consumption were measured.

Phase III: Engine emission characteristics of different fuel blends.

5.1 Fuel Properties Analysis:

5.1.1 Viscosity:

The effect of cerium oxide dose level on the viscosity of emulsion oil is shown in fig 5.1.

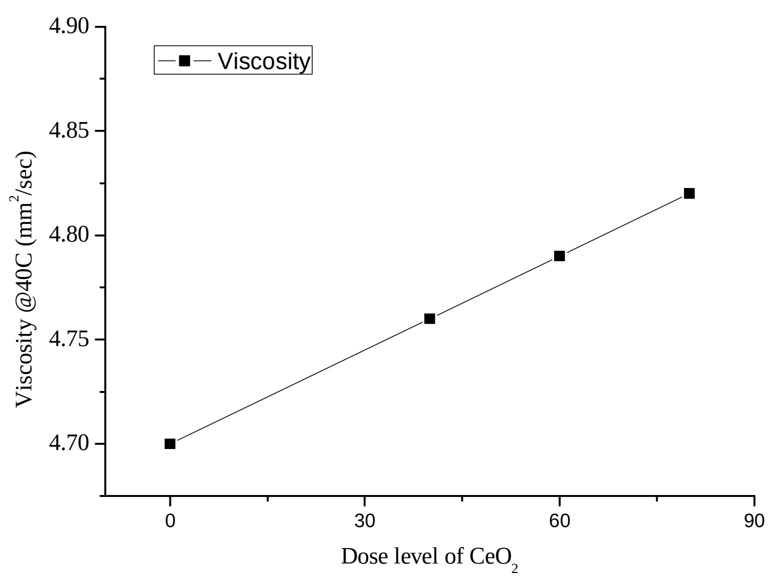


Figure 5.1 Variation of viscosity with respect to cerium oxide dose level

It was observed that viscosity of emulsion fuel increases as the fraction of nanoparticle increases. Nanoparticles were prone to form agglomerates in nanofluid, which results in higher viscosity. Further increase in the viscosity of nanoparticle blended emulsion was due to non-Newtonian behavior of nanofluid which is obvious for increase in volume fraction, resulting in higher agglomeration [1]. Higher the fuel viscosity higher the power requirement of pumping and would result in poor atomization and low viscosity fluid may not perform sufficient lubrication of plunger pump and this would result in leakage or increased wear. So based on the above effect of fuel properties on engine performance an optimum dosing level should be chosen.

5.1.2 Flash Point

The influence of cerium oxide dose level on flash point of emulsion oil is depicted in figure 5.2. It was observed that flash point of emulsion fuel was observed to increase with respect to dose level. Flash point is an indication of the volatility of fuel. For safe handling of liquid fuel it should always have high value.

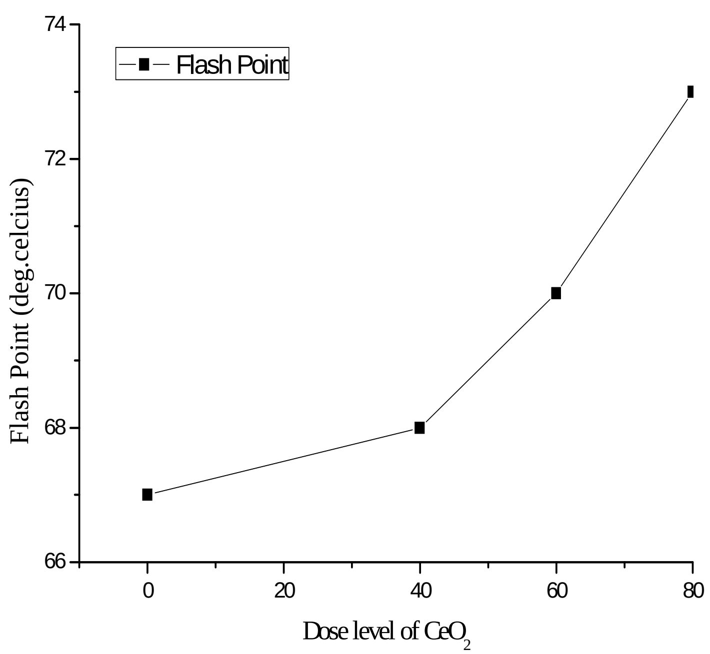


Figure 5.2 Flash point variations with respect to cerium oxide dose level

The increasing trends in flash point were observed due to the presence of nanoparticle, which allows the change in temperature to store within the nucleus of nanoparticle. Ajin et al. also reported increase in flash point of the fuel with respect to increase in volume fraction level [2].

5.2 Engine Performance Analysis

5.2.1 Brake Power

The power developed in the engine cylinder is known as indicated power and the part of the power developed in the engine cylinder is used to overcome the internal friction. The net power available at the shaft is known as brake power. The test was conducted for pure diesel fuel which was base line fuel and then for different blends of emulsion oil E15, $E15CeO_2$ 40, $E15CeO_2$ 60, and $E15CeO_2$ 80 samples and the load on engine was varied from 2.1 to 15.9 Kg. It was observed that brake power increases when the load was increased for all operations of diesel and emulsion oil. Generally, the brake power was approximately similar at any load for diesel and blends of emulsion oil and diesel.

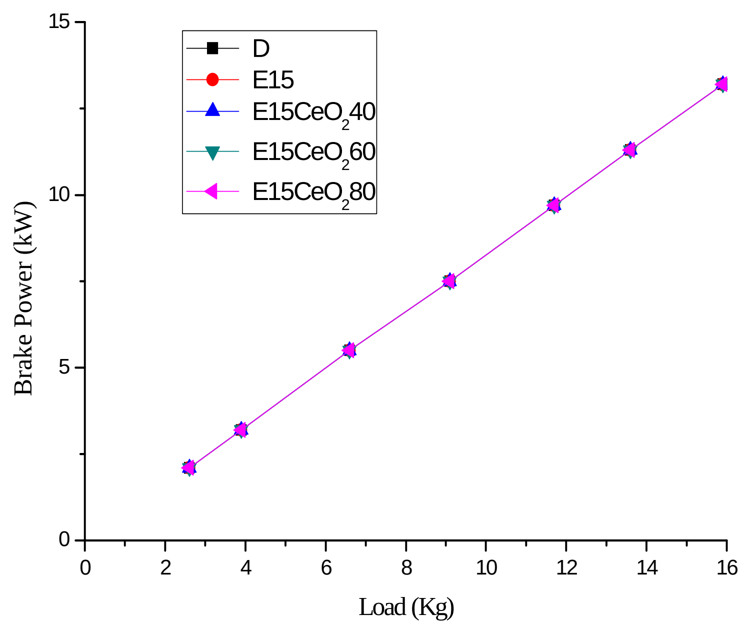


Figure 5.3 Variation of brake power with respect to load.

5.2.2 Fuel Consumption

The test were performed for pure diesel fuel and then for different blends of emulsion E15, $E15CeO_240$, $E15CeO_260$, $E15CeO_280$ sample and the load on engine was varied from 2.1KW to 13.2KW. Experimentally, it was observed that the fuel consumption increases when the load was increased for all operations of diesel and emulsion blends as shown in figure 5.4

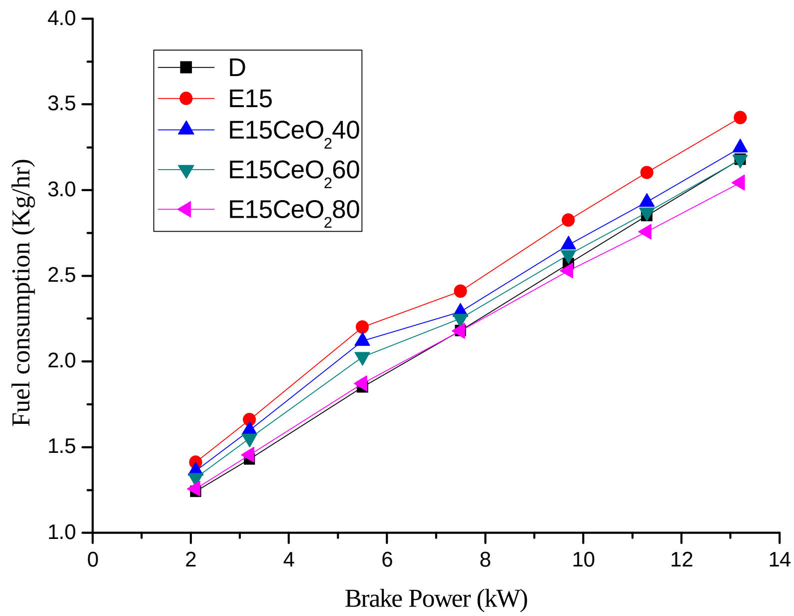


Figure 5.4 Variation of fuel consumption with respect to brake power.

It was also observed that fuel consumption decreases when nanoparticle volume fraction in the emulsion blend was increased for any given load. Also for E15 blend, the increase in fuel consumption was more than that of other blends and diesel operations at higher load conditions. This was due to the higher viscosity and lower calorific value of B15 as compared to other blends and conventional Diesel fuel [1]. At full load operation maximum power of the engine was produced that needs higher amount of fuel energy and due to lower energy content of E15 as compared to conventional diesel and other blends, fuel consumption increases for E5 as compared to diesel and the other blends at higher loads. Nanoparticle blended emulsion were found to be improve with the increase in their calorific value due to presence of cerium oxide nanoparticle which acts as oxygen buffer, thereby making the engine to consume less fuel compared to E15 to overcome identical load

5.2.3 Brake Thermal Efficiency:

The Brake thermal efficiency is defined as the ratio of work output at the engine shaft to the energy supplied by fuel. It is a measure of the engine's ability to make efficient use of fuel. The brake thermal efficiency for different blends of fuel and that of conventional diesel at different load is reported in figure 5.5.

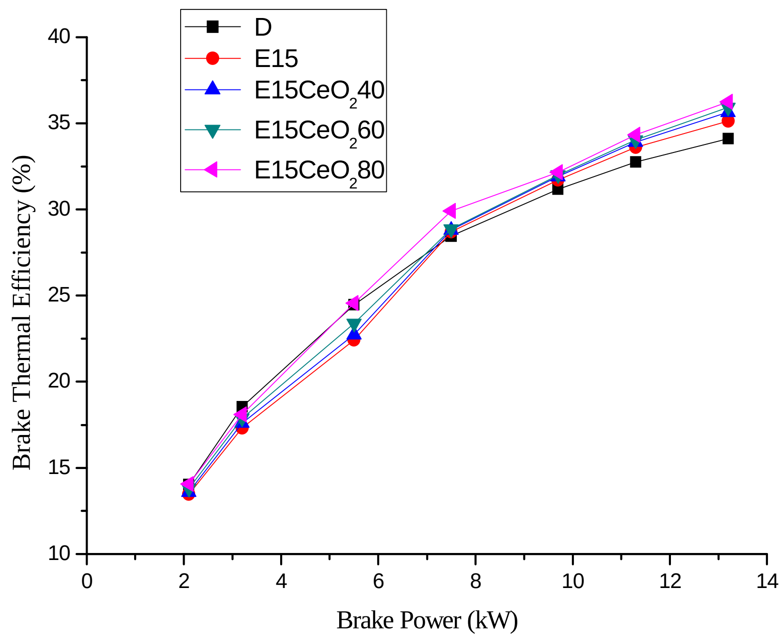


Figure 5.5 Variation of brake thermal efficiency with respect to brake power.

The test was conducted for pure diesel fuel which is base line fuel and then for different blends of emulsion oil E15, E15CeO_2 40, E15CeO_2 60, and E15CeO_2 80 samples and the load on engine was varied from 2.1KW to 13.2KW. It was observed that brake thermal efficiency increases when the load was increased for all operations of diesel and emulsion oil blend. On comparing all fuel blends, it was observed that the brake thermal efficiency of cerium oxide nanoparticle blended water in diesel emulsion fuel is higher among different fuel blends as the load increases. This is due to the cerium oxide nanoparticle encapsulation in water molecule which offers the secondary atomization immediate after the primary micro explosion phenomenon of emulsion fuel as shown in fig.5.6

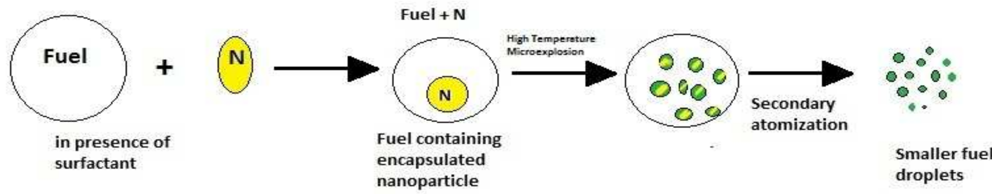


Figure 5.6 Atomization phenomenon of nanoparticle blended fuel [3]

As the atomization takes place nanoparticle offer high surface area to volume ratio which leads to catalytic combustion resulting in an increased thermal efficiency. However, at low load heat is transferred to cylinder wall resulting in lower thermal efficiency in case of water-diesel emulsion but it increase as the concentration of nanoparticle increases in the water-diesel emulsion over the entire load range. At full load, variation of brake thermal efficiency of all fuel blends is classified in table 5.1

Table 5.1

Brake thermal efficiency (%) at full load condition	
D	34.11
E15	35.13
$E15CeO_2$ 40	35.65
$E15CeO_2$ 60	35.82
$E15CeO_2$ 80	36.24

5.2.4 Brake Specific Fuel Consumption.

The brake specific fuel consumption is defined as the fuel consumed by engine in kg for per kW per hour. The brake specific fuel consumption for different blends of emulsion fuel and that of conventional diesel at different load is reported in figure 5.7. The test was conducted for pure diesel fuel which was base line fuel and then for different blends of emulsion oil E15, $E15CeO_2$ 40, $E15CeO_2$ 60, and $E15CeO_2$ 80 samples and the load on engine was varied from 2.1 kW to 13.2 kW. It was observed experimentally that the brake specific fuel consumption decreases when the load was increased for all operations of diesel and emulsion oil. The higher brake specific fuel consumption was observed for E15 among all the fuel blends.

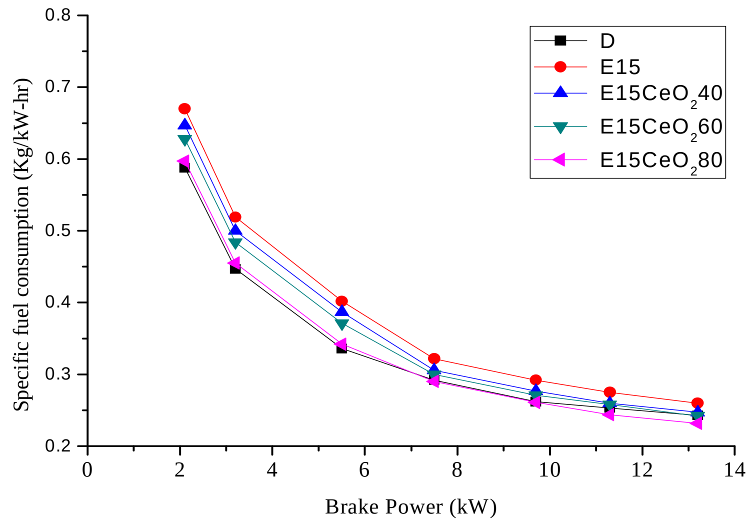


Figure 5.7 Variation of brake specific fuel consumption with respect to brake power.

This is due to the presence of water which results in lower calorific value of E15 [4]. But the improvement was observed with nanoparticle blended emulsion in their respective concentration. As the concentration was increased brake specific fuel consumption decrease. This is due to the shortening of ignition delay characteristics of nanoparticle by virtue of enhanced surface area to volume ratio. The lower specific fuel consumption was observed for $E15CeO_2$ 80. Result of all fuel blends at high load was figured in table 5.2

Table 5.2

Brake specific fuel consumption (Kg/kW-hr) at full load condition	
D	0.243
E15	0.260
$E15CeO_2$ 40	0.247
$E15CeO_2$ 60	0.242
$E15CeO_2$ 80	0.232

5.3 Exhaust emission analysis

5.3.1 Unburned Hydrocarbon (HC)

The variation of unburned hydrocarbon emission with respect to brake power for pure diesel fuel, which is base line fuel and then for different blends of emulsion oil E15, $E15CeO_2$ 40, $E15CeO_2$ 60, and $E15CeO_2$ 80 samples is shown in figure 5.8. It was observed that E15 emulsion fuel produces large magnitude of unburned hydrocarbon due to incomplete combustion. It was due to the presence of water and longer ignition delay of the fuel. Though, it was observed to be reduced in magnitude in case of cerium oxide nanoparticle blended water-diesel emulsion. It was due to presence of cerium oxide nanoparticle which acts as oxygen buffer and promotes the complete combustion. Moreover, cerium oxide gets converted to cerous oxide (Ce_2O_3) by supplying enough oxygen for reduction of hydrocarbon as well as for soot.

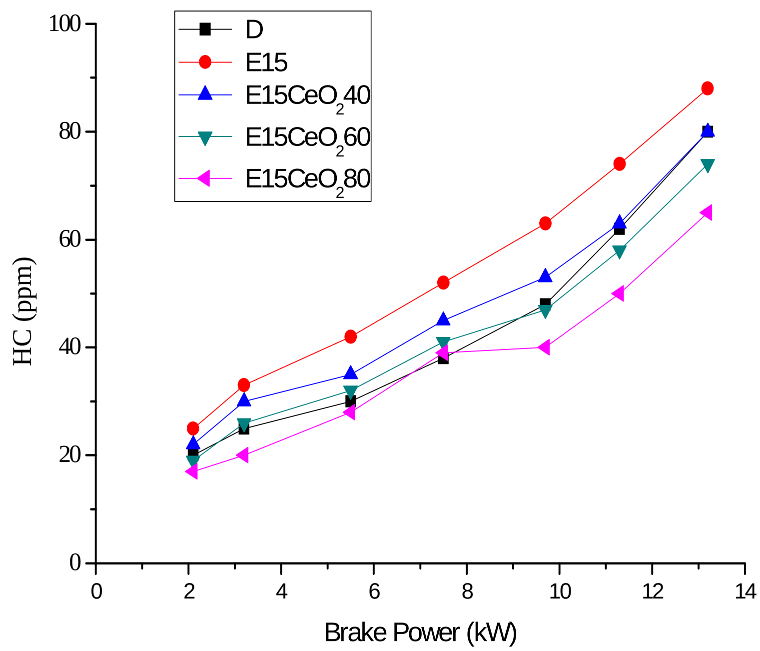


Figure 5.8 Variation of unburned hydrocarbon with respect to brake power

The magnitude of hydrocarbon at full load for different fuel blends is listed in table 5.3

Table 5.3

Hydrocarbon (ppm) at full load condition	
D	80
E15	88
$E15CeO_2$ 40	79
$E15CeO_2$ 60	74
$E15CeO_2$ 80	65

5.3.2 Carbon Monoxide (CO)

Carbon monoxide highly relies upon the air-to-fuel proportions comparative to stoichiometric ratio. In most cases CI engine function with lean mixture and thus results in lower CO emission. The variation of CO emission with respect to brake power is shown in fig 5.9. It was observed that CO emission in case of cerium oxide nanoparticle blended emulsion oil was marginally improved due to the secondary atomization produced by emulsion fuel, reduces the air requirement for emulsion blend due to presence of nanoparticle causes rapid evaporation which results in rapid mixing of water molecule inside diesel droplets thus reducing the air requirement which in turn results in less conversion of unburned carbon molecule to carbon monoxide. However, the magnitude of CO emission was high for E15 due to longer ignition delay and lower calorific value. The CO emission was observed to decrease at all loads respective of dose level of cerium oxide nanoparticle, but at high load catalytic activity was not that prominent.

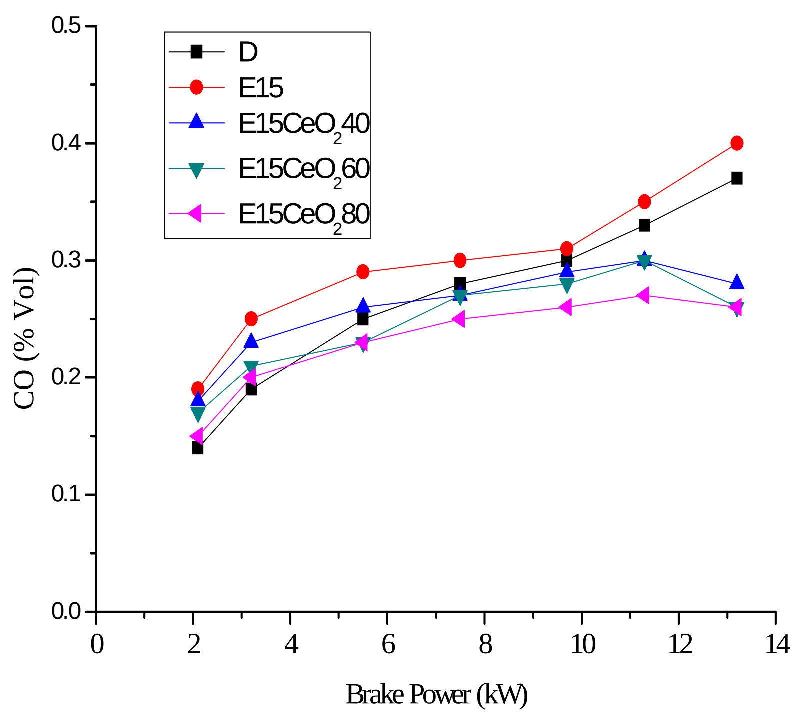


Figure 5.9 Variation of carbon monoxide with respect to brake power

The variation of CO with respect to brake power at full load was tabulated in table 5.4

Table 5.4

Carbon monoxide (% vol.) at full load condition	
D	0.37
E15	0.40
$E15CeO_2$ 40	0.28
$E15CeO_2$ 60	0.26
$E15CeO_2$ 80	0.26

5.3.3 Nitrogen Oxide (NO_x)

The response of NOx emission with respect to brake load for various fuel blends is depicted in fig. 5.10. It was observed that there is fair reduction in NO_x emission magnitude of E15 emulsion oil. This was due to water present in emulsion oil takes heat which is present inside cylinder to evaporate which in turn results in lowering of flame temperature. There was further reduction in NO_x emission magnitude was found to occur in case nanoparticle blended emulsion fuel.

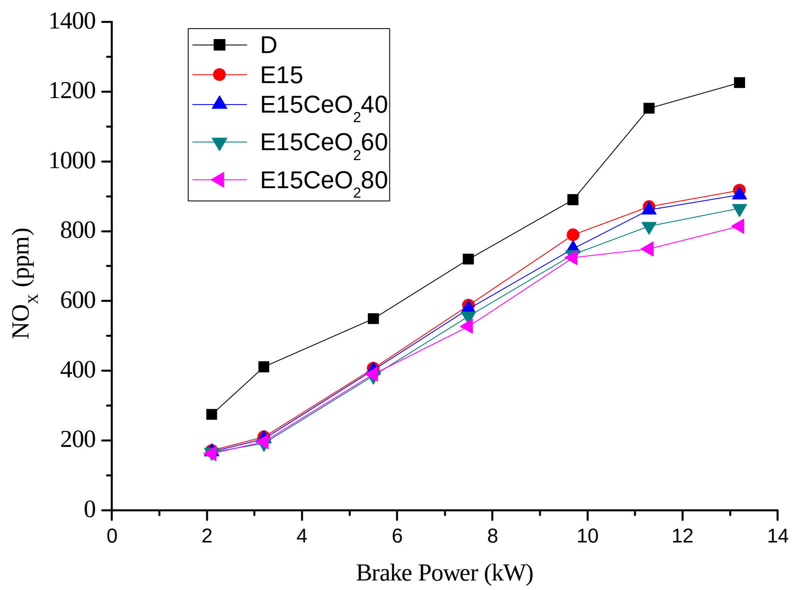


Figure 5.10 Variation of nitrogen oxide with respect to brake power

This was due to shortening of ignition delay and heat transport characteristic of nanoparticle by offering high surface area to volume ratio, which results in rapid heat transport from flame to water and bring the temperature inside the cylinder down. The observed magnitude at full load for different fuel blends is tabulated in table 5.5

Table 5.5

Nitrogen oxide as NO_x (ppm) at full load condition	
D	1226
E15	917
E15CeO_2 40	904
E15CeO_2 60	865
E15CeO_2 80	814

5.3.4 Smoke opacity

The Smoke opacity for different blends of fuel and that of conventional diesel at different load is reported in figure 5.11. The test was conducted for pure diesel fuel which was base line fuel and then for different blends of E15, E15CeO_2 40, E15CeO_2 60, and E15CeO_2 80 samples and the load on engine was varied from 2.1KW to 13.2KW. It was observed that smoke opacity increases for all blends as the load increased. Diesel fuel show the higher magnitude of smoke opacity over the entire load range. But the smoke opacity in case of E15 was found to reduce due to micro-explosion of emulsion fuel improving the evaporation of fuel which results in an improvement in mixing with air.

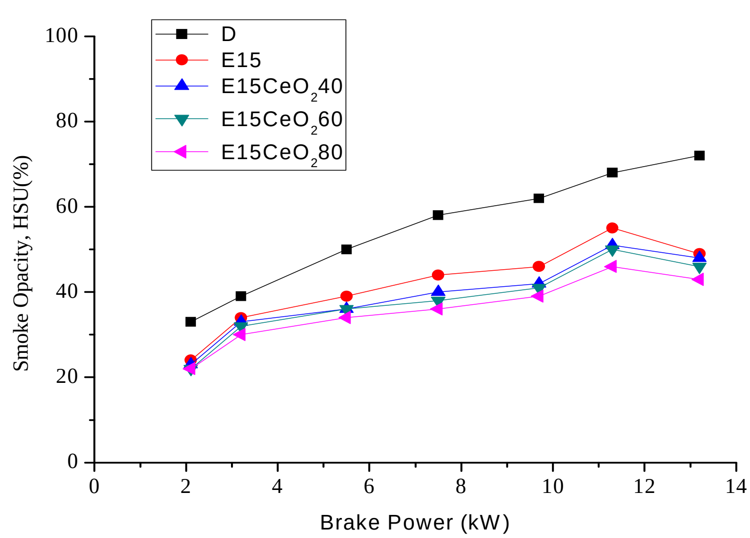


Figure 5.11 Variation of smoke opacity with respect to brake load.

The cerium oxide nanoparticle blended emulsion fuel shows the same trends with a further reduction in smoke opacity. This due to fact that nanoparticle encapsulation improves the evaporation rate which in turn results in much better mixing. At full load, the smoke opacity for various blends is shown in table 5.6

Table 5.6

Smoke Opacity , HSU (%) at full load condition	
D	72
E15	49
E15 CeO_2 40	48
E15 CeO_2 60	46
E15 CeO_2 80	43

References

[1] Fei Duan, Dingtian Kwek, Alexandru Crivoi, “Viscosity affected by nanoparticle aggregation in Al2O3-water nanofluids” Nanoscale research letter, 2011

[2] V. Sajith, C. B. Sobhan, G. P. Peterson, “Experimental Investigations on the Effects of Cerium Oxide Nanoparticle Fuel Additives on Biodiesel”, Advances in Mechanical Engineering, 2010

[3] D.Ganesh, G.Gowrishankar, “Effect of Nano-fuel additive on emission reduction in a Biodiesel fuelled CI engine”, Electrical and control engineering conference, 2011

[4] M. Ebna Alam Fahd, Yang Wenming, P.S. Lee, S.K. Chou, Christopher R. Yap, “Experimental investigation of the performance and emission characteristics of direct injection diesel engine by water emulsion diesel under varying engine load condition”, Applied Energy, 2013

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

Present study focus on the influence of cerium oxide dose level on water-diesel emulsion fuels performance and emission characteristics when charged in compression ignition engine.

Based on the results of present work, following conclusion can be drawn:

6.1.1 Fuel Properties:

- The viscosity and flash point holds direct relation to dose level. It was found that both viscosity and flash point increase with the increase in concentration level of cerium oxide nanoparticle

6.1.2 Engine Performance: All conclusions were summarized at full load condition from experiments.

- Nearly 1% improvement was observed in brake thermal efficiency for E15 and it was further found to improve up to 2% by varying dose level in range of 40 to 80 ppm as compared to base line fuel diesel.
- The minimum specific fuel consumption was observed for E15CeO_2 80 which is 0.232 Kg/kW-hr where it is for diesel, E15 were 0.242 Kg/kW-hr and 0.260 Kg/kW-hr respectively.

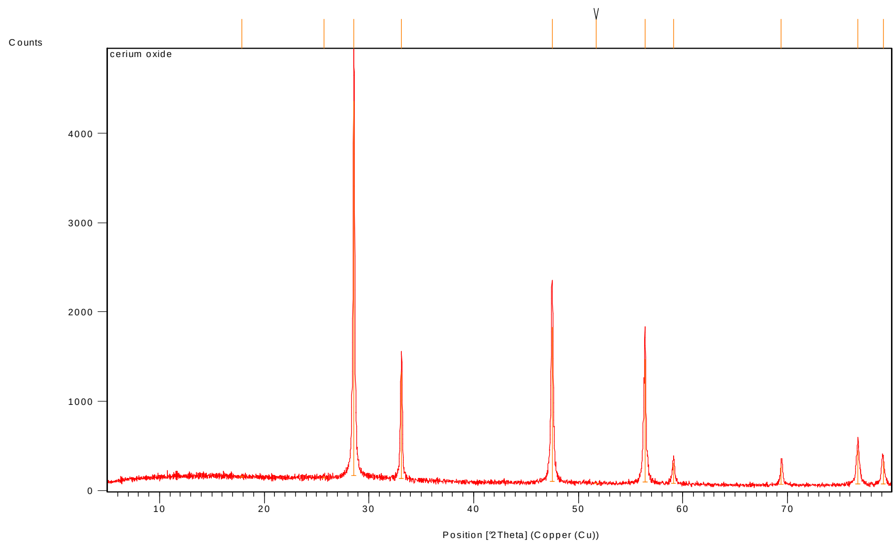
6.1.3 Emission Parameters: All conclusions were summarized at full load condition from experiments

- The magnitude of NOx emission for diesel, E15, E15CeO_2 40, E15CeO_2 60, and E15CeO_2 80 observed were 1126 ppm, 917 ppm, 904 ppm, 865 ppm and 814 respectively. The magnitude of NOx emission was very low in case of cerium oxide nanoparticle blended emulsion as compared to diesel and E15
- The unburned hydrocarbon and smoke opacity was found to lower in case of cerium oxide nanoparticle blended emulsion as compared to diesel and E15.

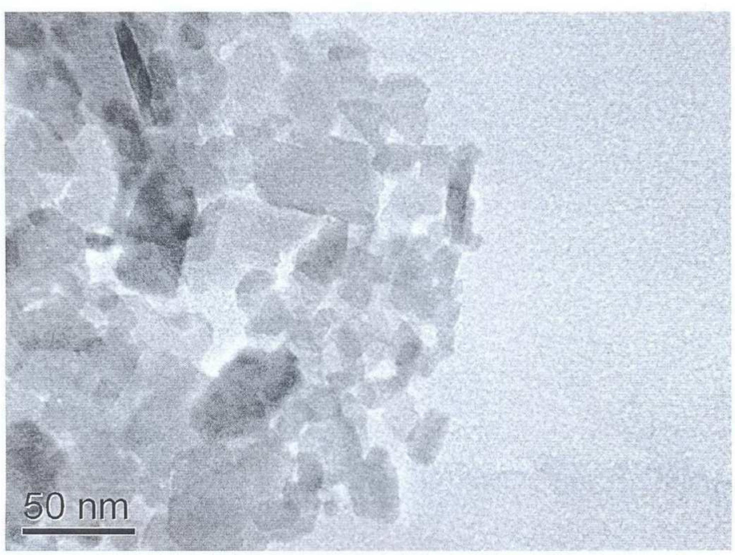
- There was marginal improvement in reduction of carbon monoxide emission for cerium oxide nanoparticle blended emulsion as compared to neat diesel and E15

6.2 FUTURE SCOPE

- The long term stability of blends was not studied and there is scope for study of long term stability of blends.
- The performance and durability and performance of engine was tested for small time period so there is scope to evaluate the durability of the engine with prolonged operation on these blends.
- There is scope for research on compatibility of nanomaterial how these fuel blends to overcome the emission regulation.
- Further investigation can be carried out to study the effect of the parameters such as water content, surfactant concentration, agitation speed etc. Nanoparticle recovery and its impact on fuel properties
- Performance and emission tests can be carried out on multi-cylinder turbocharged generator engines and surface transportation engines like tractor, car, jeep, bus, trucks etc.
- Environmental studies can be made to reveal a total picture on impact of using nanoparticle blended fuels.
- A detailed long-term endurance test can be carried out to study physical condition of various surfaces reflecting extent of wear and carbon depositions due to difference in performance of the different fuels and to conduct through tribological investigations



E.1 XRD Image of Cerium Oxide Nanoparticle



E.2 SEM Image of Cerium Oxide Nanoparticle

A. Nanoparticle

Table A.1 Cerium oxide nanoparticle specification

Purity	99.97%
Average particle size	10-30 nm
Specific surface area	30-50 m^2/g
Bulk density	0.8 – 1.1 g/cm^3
True Density	7.132 g/cm^3
Color	Light yellow

B. Fuel Properties

Table B.1 Fuel properties of different emulsion's oil compared to diesel

S. No	Properties	D	E15	E15C40	E15C60	E15C80
1	**Density, g/cc**	0.8402	0.8610	0.8614	0.8617	0.8621
2	**Viscosity @ 40˚C, mm^2/sec**	2.4	4.7	4.76	4.79	4.82
3	**Flash Point, ˚C**	55	67	68	70	73
4	**Calorific value, KJ/Kg**	43470	38919.12	40827.10	41520.20	42842.92

C. Experimental Data of Engine Performance Test

Table C.1 Performance test observations on diesel fuel 'D'

S. No.	1	2	3	4	5	6	7
Load, kg	2.55	3.87	6.63	9.1	11.7	13.6	15.9
RPM	1650	1650	1650	1650	1650	1650	1650
Fuel Consumption, ml	6.1	7.1	9.1	10.8	12.7	14.1	15.7
Time, sec	15	15	15	15	15	15	15

Table C.2 Test results of engine performance on diesel fuel 'D'

S.No	1	2	3	4	5	6	7
Brake Power, (BP) KW	2.1	3.2	5.5	7.5	9.7	11.3	13.2
Fuel Consumption, Kg/hr	1.24	1.43	1.85	2.18	2.57	2.85	3.18
Brake Specific Fuel Consumption, (BSFC) Kg/ KW-hr	0.588	0.447	0.336	0.292	0.266	0.253	0.243
Brake Thermal Efficiency, %	14.02	18.53	24.47	28.45	31.18	32.76	34.11

Table C.3 Performance test observations on 'E15'

S. No	1	2	3	4	5	6	7
Load, kg	2.55	3.87	6.63	9.1	11.7	13.6	15.9
RPM	1650	1650	1650	1650	1650	1650	1650
Fuel Consumption, ml	6.8	8.1	10.6	11.6	13.6	15.0	16.5
Time, sec	15	15	15	15	15	15	15

Table C.4 Results of engine performance test on 'E15' blend

S. No	1	2	3	4	5	6	7
Brake Power, (BP) KW	2.1	3.2	5.5	7.5	9.7	11.3	13.2
Fuel Consumption, Kg/hr	1.410	1.660	2.200	2.410	2.824	3.102	3.422
Brake Specific Fuel Consumption, (BSFC) Kg/ KW-hr	0.670	0.519	0.402	0.322	0.292	0.275	0.260
Brake Thermal Efficiency, %	13.47	17.32	22.44	28.70	31.71	33.61	35.13

Table C.5 Performance test observations on ‘E15CeO$_2$40’ blend.

S. No	1	2	3	4	5	6	7
Load, kg	2.55	3.87	6.63	9.1	11.7	13.6	15.9
RPM	1650	1650	1650	1650	1650	1650	1650
Fuel Consumption, ml	6.6	7.7	10.2	11.1	13.0	14.2	15.7
Time, sec	15	15	15	15	15	15	15

Table C.6 Results of engine performance test on ‘E15CeO$_2$40’ blend.

S. No	1	2	3	4	5	6	7
Brake Power, (BP) KW	2.1	3.2	5.5	7.5	9.7	11.3	13.2
Fuel Consumption, Kg/hr	1.362	1.598	2.120	2.290	2.680	2.930	3.247
Brake Specific Fuel Consumption, (BSFC) Kg/ KW-hr	0.647	0.500	0.387	0.306	0.277	0.260	0.247
Brake Thermal Efficiency, %	13.60	17.60	22.74	28.81	31.90	33.91	35.65

Table C.7 Performance test observations on ‘E15CeO$_2$60’ blend.

S. No	1	2	3	4	5	6	7
Load, kg	2.55	3.87	6.63	9.1	11.7	13.6	15.9
RPM	1650	1650	1650	1650	1650	1650	1650
Fuel Consumption, ml	6.3	7.5	9.8	10.8	12.7	13.8	15.4
Time, sec	15	15	15	15	15	15	15

Table C.8 Results of engine performance test on ‘E15CeO$_2$60’ blend.

S. No	1	2	3	4	5	6	7
Brake Power, (BP) KW	2.1	3.2	5.5	7.5	9.7	11.3	13.2
Fuel Consumption, Kg/hr	1.320	1.550	2.028	2.251	2.623	2.870	3.178
Brake Specific Fuel Consumption, (BSFC) Kg/ KW-hr	0.628	0.484	0.371	0.300	0.271	0.258	0.242
Brake Thermal Efficiency, %	13.81	17.88	23.38	28.86	32.0	34.04	35.82

Table C.9 Performance test observations on ‘E15CeO$_2$80’ blend.

S.No	1	2	3	4	5	6	7
Load, kg	2.55	3.87	6.63	9.1	11.7	13.6	15.9
RPM	1650	1650	1650	1650	1650	1650	1650
Fuel Consumption, ml	6.07	7.03	9.04	10.5	12.2	13.2	14.7
Time, sec	15	15	15	15	15	15	15

Table C.10 Results of engine performance test on ‘E15CeO$_2$80’ blend.

S. No	1	2	3	4	5	6	7
Brake Power, (BP) KW	2.1	3.2	5.5	7.5	9.7	11.3	13.2
Fuel Consumption, Kg/hr	1.257	1.456	1.872	2.177	2.530	2.757	3.044
Brake Specific Fuel Consumption, (BSFC) Kg/ KW-hr	0.597	0.455	0.342	0.290	0.261	0.244	0.232
Brake Thermal Efficiency, %	14.06	18.09	24.55	28.91	32.16	34.34	36.24

D. Emission analysis

Table D.1 Result of Unburned hydrocarbon (PPM) emission

Brake Power (kW)	D	E15	E15CeO$_2$40	E15CeO$_2$60	E15CeO$_2$80
2.1	20	25	22	19	17
3.2	25	33	30	26	20
5.5	30	42	35	32	28
7.5	38	52	45	41	39
9.7	48	63	53	47	40
11.3	62	74	63	58	50
13.2	80	88	80	74	65

Table D.2 Result of carbon monoxide (vol. %) emission

Brake Power (kW)	D	E15	$E15CeO_240$	$E15CeO_260$	$E15CeO_280$
2.10	0.14	0.19	0.18	0.17	0.15
3.20	0.19	0.25	0.23	0.21	0.2
5.47	0.25	0.29	0.26	0.23	0.23
7.49	0.28	0.3	0.27	0.27	0.25
9.68	0.3	0.31	0.29	0.28	0.26
11.27	0.33	0.35	0.3	0.3	0.27
13.2	0.37	0.4	0.28	0.26	0.26

Table D.3 Result of Nitrogen oxides (PPM) emission

Brake Power (kW)	D	E15	$E15CeO_240$	$E15CeO_260$	$E15CeO_280$
2.10	274	171	168	166	162
3.20	411	210	205	192	196
5.47	549	407	402	385	390
7.49	720	588	578	556	527
9.68	890	789	750	733	724
11.27	1152	870	861	814	749
13.2	1226	917	904	865	814

Table D.4 Result of smoke opacity (HSU %) emission

Brake Power (kW)	D	E15	$E15CeO_240$	$E15CeO_260$	$E15CeO_280$
2.10	33	24	23	22	22
3.20	39	34	33	32	30
5.47	50	39	36	36	34
7.49	58	44	40	38	36
9.68	62	46	42	41	39
11.27	68	55	51	50	46
13.2	72	49	48	46	43