REDUCTION OF NO_x IN DIESEL ENGINE USING DIESEL WATER EMULSION

A Thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology
in
Mechanical Engineering

by

DEBASIS DANI (108ME012)

Under the guidance of

Prof. S. Murugan

Department of Mechanical Engineering
National Institute of Technology
Rourkela 769008

REDUCTION OF NO_x IN DIESEL ENGINE USING DIESEL WATER EMULSION

A Thesis submitted in partial fulfillment
of the requirements for the degree of

Bachelor of Technology
in
Mechanical Engineering

by

DEBASIS DANI (108ME012)
Under the guidance of
Prof. S. Murugan

Department of Mechanical Engineering
National Institute of Technology
Rourkela 769008

CERTIFICATE

This is to certify that the thesis entitled, **Reduction of NOx in diesel engine using diesel water emulsion "** submitted by **Debasis Dani(108ME012)** in partial fulfillment of the requirements for the award of **Bachelor of Technology Degree** in **Mechanical Engineering** at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date:

Prof. S. Murugan

Dept. of Mechanical Engineering

National Institute of Technology

Rourkela-769008

ACKNOWLEDGEMENT

I am indebted to my guide **Prof. S.Murugan** for giving me an opportunity to work under his guidance .Like a true mentor, he motivated and inspired me through the entire duration of my Work. I express my gratitude towards our dept. HOD prof. K P Maity sir for his support throughout the project work.

I am also grateful to **Mr. Prakash, Mr. Barik and Mr. Bisoyi** of Mechanical department for assisting me and guiding me throughout the project. I also extend my thanks to the supportive staff of Mechanical department for providing me all the necessary facilities to accomplish this project.

Last but not the least, I express my profound gratitude to the Almighty and my parents for their blessings and support without which this task could have never been accomplished.

Debasis Dani

108ME012

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Diesel engines exhausting gaseous emission and particulate matter have long been regarded as one of the major air pollution sources, particularly in metropolitan areas, and have been a source of serious public concern for a long time. There has been numerous research in the field of reduction of these pollutants since diesel engines came to major use. Major emissions from a diesel engine are NO_x, SO_x, CO and particulate matter (PM).amongst these pollutants CO and Sox and some quantity of particulate matters are reduced by some after treatment methods, outside the engine, in the catalytic converter etc. unlike these NO_x can’t be oxidized to get some clean product. Nowadays NOx emissions are reduced by selective catalytic reduction.

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 of NO_x, SO_x, CO and particulate matter (PM) without compensating the engine’s performance. In this project a new kind of emulsion is prepared by mixed surfactant method, major concern being the long term stability of the same. Then performance and emission tests were carried out by using the fuel in a two cylinder water cooled diesel engine. The results were matched against that of diesel and comparison graphs were plotted to see what are the advantages and disadvantages of using the emulsion over diesel.

Chapter 1

INTRODUCTION

Internal combustion engines generate undesirable emissions during the combustion process. The pollutants that are exhausted from the internal combustion engines affect the atmosphere and cause problems such as global warming, smog, acid rain, respiratory hazards etc. These emissions are mostly due to nonstoichiometric combustion, dissociation of nitrogen and impurities in the fuel and air .Major emissions include Nitrogen Oxides (NOx), unburnt Hydrocarbons (HC), oxides of Carbon, oxides of Sulphur and other carbon particles or soot. There are various ways to treat these pollutants. Two major ways are –treatment inside the cylinder and after treatment or treatment outside the cylinder. In this project an emulsion is prepared which replaces the diesel fuel meant for the engine, and the emission and performance parameters are studied.

1.1 EMISSIONS FROM DIESEL ENGINES:

Diesel engines have been used in heavy duty applications for a very long time now; it is only recently that it has become very popular in light duty application due to their higher fuel efficiency. Higher fuel efficiency in the diesel engines is achieved due to the high compression ratios along with high oxygen concentration in the combustion chamber. However, these same factors results in high NOx emission in diesel engine. The main pollutants of diesel engines are NOx and particulate matter (PM). The mechanism of formation of Nitrogen oxides and particulate matter inside the combustion chamber of diesel engines are contradictory and the simultaneous reduction of both at the same time is very difficult [1]. Researchers have attempted to reduce the emissions and improve the fuel efficiency of diesel engines. Diesel engines have been used in heavy duty applications for a long time; it is only during the past decade that it has become very popular in light duty application due to their high fuel efficiency. Higher fuel efficiency in the diesel engine is achieved because of the high compression ratios along with relatively higher oxygen concentration in the combustion chamber. However, these same factors results in higher NOx emission in diesel engine. The stringent emission norms have been an important driving force to develop the internal combustion engines in a more environment friendly way. The main pollutants from diesel engines are NOx and particulate matter (PM). The mechanism of formation of NOx and particulate matter in the combustion chamber of diesel engines are contradictory and the simultaneous reduction of both is very difficult [1]. Researchers have attempted to reduce the emissions and improve the fuel conversion efficiency of diesel engines.

Main local air pollutants

1. Carbon Monoxide: CO A gas formed by the incomplete combustion of carbon-containing fuels. The more efficient the combustion processes the lower the emissions. The main outdoor source of CO is currently road transport.

2. Nitrogen Oxides: NOx All combustion products in air produce oxides of nitrogen: nitrogen dioxide (NO2) and nitric oxide (NO) – collectively known as NOx. Road transport accounts for about 50% of total emissions, more than the electricity supply industry and the industrial and commercial sectors put together. NOx is also a precursor of ozone and therefore an indirect greenhouse gas.

3. Particulates: PM10 Particulate matter smaller than 10 microns (10 millionths of a metre). They consist of primary particles arising from combustion sources (mainly road transport); secondary particles (mainly sulphate and nitrate formed by atmospheric chemical reactions); and coarse particles (suspended soils and dusts, sea salt, biological particles and particles from construction work).

4. Ultra-fine particles (smaller than 2.5 microns) are mainly primary and secondary.

5. Sulphur Dioxide: SO_2, the predominant source is the combustion of sulphur-containing fossil fuels, principally coal and heavy oils. Output from road vehicles is relatively small, but combustion of fuel (especially diesel) makes a significant contribution to emission levels in urban areas.

6. 1, 3 Butadiene: A gas at normal temperatures and pressures deriving mainly from the Combustion of diesel and petrol engines.

7. Volatile Organic Compounds: VOC In sunlight these react with NOx to form ozone. It can therefore be considered an indirect greenhouse gas. So high concentrations generally occur downwind of the source emissions, most frequently in summer, in the south, and in rural and suburban areas.

(***Source: HM Customs and Excise, Using the tax system to encourage cleaner fuels, November 2000)***

1.2 DIESEL WATER EMULSIONS:

Diesel water emulsions have come into recent field of study. When mixed directly, diesel being a lighter liquid than water comes to the top and water settles in the bottom. By using an appropriate surfactant the molecules of water and diesel can be bound together. The stability of the emulsion made is very important, because if it’s not stable for an appreciable period of time it won’t be practically useful. Using water mixing agent with diesel has many benefits on its own. It has been shown in many previous researches that it reduces the flame temperature thereby reducing the NOx emissions significantly. Addition of water also improves atomization and mixing which is attributed to droplet microemulsion. The improved mixing is due to the increased vaporized jet fuel momentum giving air more way to get into the fuel jet. this also assists in reduction in NOx from diffusive burning portion of combustion event as well as reducing the carbon formation. This effect along with the chemical effect of water results in increase in ignition delay. There is also a considerable proof that adding water to diesel can reduce the particulates and smoke emission.

There has been a growing interest in diesel fuel industry to produce and utilize the diesel water emulsion as usable fuels for diesel engines. Fuel additive manufacturers try to make diesel oil and water oil mix, or can be neighborly enough to form pollution cutting diesel fuel. There have been several trials done to produce a stable emulsion which will stay the same way for a long period of time. If the emulsion remains still for many days, larger droplets of chemically coated water may settle to the bottom of the tank, or it’s also been seen that coagulated particles settle down in the bottom of the tank. The fuel, however, will mx again if agitated slightly, and thus the tank is refueled to mix it again.

The influence of water on some of the performance parameters, exhaust emission of diesel engine has been studied by many works. However its effect on the heat flux crossing the combustion chamber components i.e. cylinder heads and cylinder liners, chamber metal temperature and thermal loading f such engines is still under study.

1.3 OBJECTIVE :

The objective of this project is to create a new fuel that can be used in a diesel engine as a fuel. The fuel is created by making an emulsion of diesel and water by using a suitable surfactant. The emulsion has to be stable for a longer period of time. This emulsion is then used in a laboratory installed diesel engine coupled with an eddy current dynamometer. The emission and performance characteristics of the engine are thus noted down and put in tabular form. Then the engine is run with regular diesel fuel and same observations are taken. A comparison is done between the two cases in terms of performance and emission properties of the fuel.

1.4 ORGANIZATION OF THESIS:

The entire thesis is divided into six chapters:

First chapter is all about the introduction about the project. It consists of the pre – ideas related to the project. It includes the objective and the work division of the thesis.

Second chapter consists of the literature survey done during the project work. It includes the briefs of the important references from journals and papers that were referred in course of the project.

Third chapter tells the reader about the fundamentals behind emulsions. The process of making emulsions, their types, their stability. The microscopic and macroscopic details of fuel water emulsions and their feasibility in using them in diesel engines.

Fourth chapter gives us information about use of diesel water emulsion in diesel engine, its effects on various parameters, such as combustion efficiency etc. it briefs about the real time water injection technology in disesel engines.

Fifth chapter gives the complete description of the setup of the experiments. It includes the apparatus and devices used during the experiment, the methodology involved and the various precautions taken during doing the experiment.

Sixth chapter is all about the observations, calculations and results obtained. Here the performances as well as the emission characteristics are studied. Proper observations were taken and deductive conclusions were drawn here.

Seventh chapter includes all the conclusions derived from the experiment, giving the optimal figures.

Eighth and the final chapter lists all the references used during the course of work.

Chapter 2

LITERATURE REVIEW

Anna Lif *et al*. [1] have worked on reduction of water and PM in diesel engines. The water content affects the combustion under on two accounts. The first is the reduced peak temperature in the cylinder, resulting in a lower levels of NOx formation. The second is the micro explosion phenomenon, which is due to the volatility difference between water and diesel. Water contents ranging from 5% to 45% have been studied. There is limited amount of information about the emulsifiers used in the emulsions and there are no reports dealing with the emulsion stability.

C. Alan Canfied[2] has worked on effects of diesel water emulsion on diesel engine and NOx emissions. Results also lead to conclude that NOx reduction from fuel injection timing delay and improved injector design, as demonstrated in, is also probably due to a reduced flame temperature. A trend to lower exhaust temperature and lower NOx emissions with increased timing delay, which corresponds to the trend for water added to the fuel. In general, it was concluded from the reported data that fuel—water mixtures are an effective option to reducing NOx emissions from diesel engines without requiring modifications to the engine, if a lower full load is acceptable. By installing larger fuel injectors, the diesel engine can attain the original load level.

Christopher J. Chadwell.[3]of Southwest Research Institute and Philip J. G. worked on Effect of Diesel and Water Co-injection with Real-Time Control on Diesel Engine Performance and Emissions.

R.Prakash *et al* [4]has worked on Performance and Emission Studies in a Diesel Engine Using Bio Oil-Diesel Blends. All the emissions such as CO, HC, NOx, PM Etc. were tested against diesel. The performance parameters were also analyzed.

Omar Badran *et al* [5]have worked on Impact of Emulsified Water/Diesel Mixture on Engine Performance and Environment. 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, operating between 1000-1600 rpm. 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 decrease as the percentage of water in the emulsion increased to 30%.

K. Kannan *et al[6]* have worked on NOx and HC emission control using single cylinder engine. This paper reports on the effects of water emulsified diesel fuel combustion on the brake thermal efficiency, brake specific fuel consumption and NOx and unburnt hydrocarbon emissions in a diesel engine. Experiments were conducted on a single cylinder four stroke cycle direct injection diesel engine running at a constant speed with a fuel injection pressure of 200 bars. Tests were done using commercial diesel fuel and emulsified diesel fuel with 10% and 20% water by volume.

Chapter 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. (Britannica) 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.

3.1 SURFACTANTS:

Surfactants are compounds that lower the surface tension of a liquid that is it decreases the interfacial tension between two liquids, or that between a liquid and a solid. Surfactants may act as detergents, wetting agents, emulsifiers, foaming agents and dispersants. In this experiment the role of surfactant is as an emulsifier. For emulsification process one of the biggest challenges is choosing the right surfactant for the two liquids to be emulsified. This depends on the HLB value of the surfactant. HLB i.e. the Hydrophilic Lipophilic Balance is the measure of degree to which it is hydrophilic or lipophilic.

Table 1[8][9]:HLB values for different types of emulsions.

HLB VALUE	TYPE OF EMULSION
<10	Lipid soluble (water insoluble)
>10	Water soluble
4 to 8	Antifoaming agent
7 to 11	Water in oil emulsifier
12 to 16	Oil in water emulsifier
11 to 14	Wetting agent
12 to 15	Detergents
16 to 20	Solubilize and hydro trope

Table 2 [8][9]: HLB values for some common surfactants

SURFACTANT	HLB VALUE
Sorbitan trioleate (Span 85)	1.8
Sorbitan monooleate, NF, (Span 80)	4.3
Sorbitan monostearate, NF, (Span 60)	4.7
Sorbitan monopalmitate, NF, (Span 40)	6.7
Sorbitan monolaurate, NF, (Span 20)	8.6
Polyoxyethylene sorbitan trioleate, (Tween 85)	11
Polysorbate 60, NF, (Tween 60)	14.9
Polysorbate 80, NF, (Tween 80)	15
Polysorbate 40, NF, (Tween 40)	15.6
Polysorbate 20, NF, (Tween 20)	16.7

3.2 TYPES OF EMULSIONS:

Depending upon the nature of the dispersed phase and dispersing medium, the emulsions are classified into two types:[10]

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. Milk is an example of oil in water emulsion. In milk fat globules are dispersed within water.

2. **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. They are also termed as oil emulsions. Butter, cold cream, cod liver oil etc. are examples of this emulsion.

Depending on the size of the droplets, the emulsions are classified into two types:

1. **Macro emulsions:**

   The size particles ranges from 0.2 to 50 mm. they are kinetically stable.

2. **Micro emulsions :**

   The size of the particles ranges from 0.01 to 0.02 mm. they are thermodynamically stable.

Properties of emulsions: [10]

(i) Emulsion shows all the characteristic properties of colloidal solution like the Brownian movement, Tyndall effect, electrophoresis etc.

(ii) These emulsions are coagulated by the addition of electrolytes containing polyvalent metal ions indicating the negative charge on the globules.

(iii) The size of the dispersed particles in emulsions ranges from 1000 Å to 10,000 Å that is larger than those in the sols.

(iv) Emulsions can be converted into two separate liquids by methods such as heating, centrifuging, freezing etc. This process is called demulsification.

3.3 WATER IN DIESEL EMULSION:

Water in diesel emulsion comes under the category of water in oil emulsion. The surfactant that has to be used should have an HLB value in the range of 7 to 11. One surfactant with this value can be used otherwise mixed surfactant can be used. In the latter case the two surfactants should be chosen carefully so that one is hydrophilic and other is lipophilic. In this experiment a mixed surfactant is made and has been used.

3.4 STABILITY

There are three types of instability in emulsions:

1. **Flocculation** is the process by which the dispersed phase comes out of suspension in the form of flakes.

2. **Coalescence** is another form of instability, when very small droplets bump into each other and combine to form progressively larger droplets.

3. **Creaming**: Emulsions can also undergo creaming, the migration of one of the substances to the top (or the bottom) of the emulsion under the influence of buoyancy, or under centripetal force when a centrifuge is used.

Chapter 4

USE OF DIESEL WATER EMULSION IN DIESEL ENGINES

There is a growing interest in the use of diesel emulsions and environmental aspects are the main driving force. The presence of water has a significant effect on several emission constituents: exhaust gases such as nitrogen oxides (both NO and NO_2, which are collectively referred to as NOx) and carbon monoxide (CO), as well as black smoke and particulate matter PM.

The interest in diesel water emulsions comes from the fact that the water in the form of micro sized droplets exerts some good effects on the combustion property of the fuel. Water in oil emulsions have been tried out with various fuels including some light hydrocarbons and triglycerides. The main reason for the major interest in water in diesel emulsion than in 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:[1]

1. Reduction of soot particles, particulate contents in the exhaust and nitrogen oxide NOx emissions.
2. Improved combustion efficiency of the engine.

The presence of water in diesel brings about an appreciable reduction in the quantity of NOx 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 NOx in the exhaust comes mainly from oxidation of nitrogen.

4.1 FORMATION OF NO_x IN CI ENGINE:

Exhaust gases of an engine can have up to 2000 ppm of oxides of nitrogen. Most of this exhaust contains nitrogen oxide (NO) with small amount of dioxide. These all come under NOx, x representing some suitable number. NOx is very undesirable as it has many adverse effects on the environment. Regulations to reduce NOx emissions are becoming stringent day by day.

NOx is created inside the engine due to air. Nitrogen constitutes some 78 % by mass in air. So it is the most abundant gas found in the air injected into the engine. During the combustion process at very high temperature and pressure nitrogen reacts with oxygen to form oxides and other gases. There are a number of possible reactions that form NO. Some reactions that occur inside the CI engine are:

$$O + N_2 \longrightarrow N + N$$

$$N + O_2 \longrightarrow NO + O$$

$$N + OH \longrightarrow NO + H$$

$$NO + H_2O \longrightarrow NO_2 + H_2$$

$$NO + O_2 \longrightarrow NO_2 + O$$

At low temperatures, atmospheric nitrogen exists as a stable di atomic molecule. Hence only very trace amounts of nitrogen oxides are found in the ground. However, at very high temperatures that occurs inside the combustion chamber of a CI engine, some diatomic N_2 breaks into monoatomic nitrogen (N) which is very reactive:

$$N_2 \longrightarrow 2N$$

It may be noted that the chemical equilibrium constant for this equation is highly dependent upon temperature. When the temperature range is around 2500 to 3000 K i.e inside the cylinder of the engine, significant amount of N is generated. This contributes to the formation of NOx at very high temperature. So higher the combustion temperature, more amount of diatomic nitrogen will dissociate to form monoatomic nitrogen N, and therefore more NOx will be formed.

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.

4.2 EFFECT ON COMBUSTION EFFICIENCY OF THE ENGINE[1]:

Addition of water in any form of an emulsion has a positive effect on the combustion efficiency of the engine. The output torque increases with water content over the entire rpm range. When the charge is fired inside the cylinder under very high temperature and pressure, water is turned into steam. Another reason for the improved combustion efficiency is that the presence of the oil-water interface with very low interfacial tension, leads to finer atomization of fuel during injection. [11] A finer dispersion of fuel droplets facilitates higher contact with air and thus increases the burning process, which is advantageous for the combustion. It has been postulated that water in fuel improves the combustion process owing to simultaneous rupture of drops, to elevate evaporation surface of drops and facilitates the better mixing of fuel burning in air. [12]

4.3 **REAL TIME INJECTION OF WATER IN DIESEL WATER EMULSION [3]:**

The RTWI system has an electronic unit pumps that delivers metered volumes of water to electronic unit injectors (EUI) modified to incorporate the water addition passages. The water and diesel mixed in the injector tip in such a way that the initial portion of the injection contains mostly diesel fuel, while the balance of the injection is a water and diesel mixture.

Water co-injected with diesel fuel using a RTWI system was shown to substantially decrease NOx, PM, and CO emissions during steady-state operation. Further, the reductions occurred with no increase in HC, and little increase in brake specific fuel consumption. At high loads, best performance of the RTWI system can be seen when the water injection is equal to 30% of the diesel injection. The RTWI system is not sufficiently sized to deliver a higher percentage of water at high loads, so it is unclear if further reductions would be possible.

Chapter 5

METHODOLOGY AND EXPERIMENT SET-UP:

5.1 PREPARATION OF EMULSION:

Components required for making emulsion are: Mechanical agitator, diesel, distilled water, burette, and pipette.

1. The pipette, burette and container were thoroughly washed and cleaned dry.
2. Diesel was measured in the burette in required volume and poured into container. Now calculated volume of each surfactant were measured in the pipette and poured into the container. Same done for water.
3. Now the container is placed under the mechanical agitator and the mixture is thoroughly mixed for about 10- 15 minutes.
4. The emulsion thus obtained is checked for stability.

Various trials were carried out before obtaining a stable emulsion:

Trial 1:

94 % diesel + 5% water + 1% tween 20 :

The emulsion was not stable after 1 hour. There was a visible distinct layer of water underneath diesel. Hence emulsion was not stable.

Figure 1: emulsion 1

Trial 2:

94 % diesel + 5% water + 1% span 20:

The emulsion was not stable after sometime. Some milky globs were formed which settled down the container. Hence this was also rejected.

Figure 2 : emulsion 2

Trial 3:

94 % diesel + 5% water + 0.5% tween 20 + 0.5% span 20:

Here a stable emulsion was obtained. The emulsion was milky white in colour and remained as it is for a very long period of time. This was used in the experiment as the new fuel. Same surfactants were used to make another emulsion by varying quantities of water and diesel.

Properties of the fuel:

Density: 831 kg/m3

Calorific value: 41380kJ/kg

Figure 3 : emulsion 3

5.2 ENGINE SPECIFICATIONS AND APPARATUS:

Comet diesel engine, twin cylinder, vertical water cooled, 7.5 KW @ 1500rpm. Compression ratio = 17.5, Eddy current dynamometer, Fuel measuring device, Stop watch scale and, Spring balance.

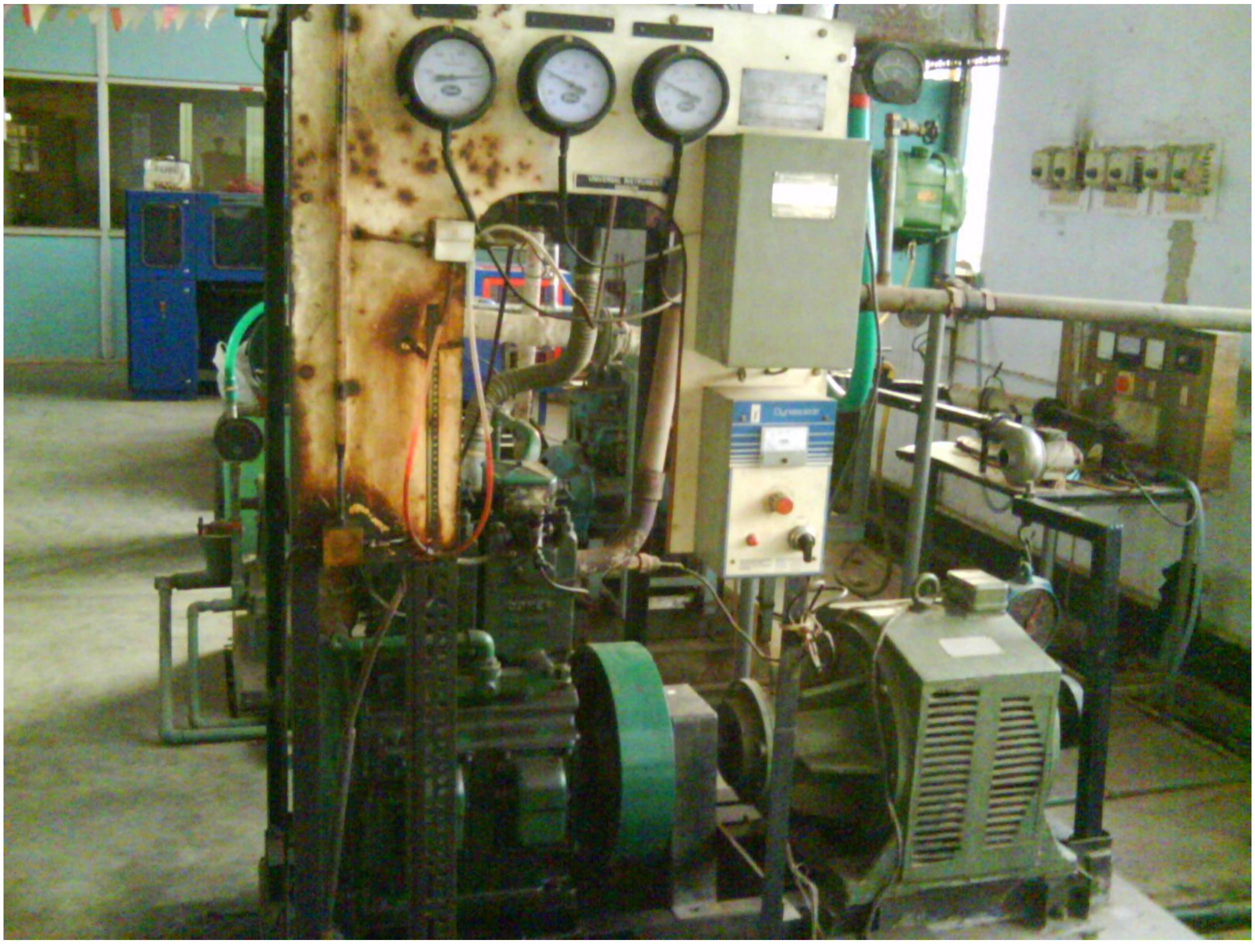

Figure 4: engine set up

5.3 AVL GAS ANALYZER AND SMOKE METERE:

Gas analyzer and smoke meter are used to measure the exhaust gases coming out from the engine. The AVL gas analyzer measure CO2, CO, HC, O2 and NOx coming out of the engine. It measures the standard values of these emissions.

5.4 MECHANICAL AGITATOR:

This is used to thoroughly mix the mixture and form the emulsion. It consists of a motor which is used to rotate the blades which is dipped in the mixture. There is speed control knob to optimize the speed of the motor.

Figure 5: mechanical agitator

5.4 PROCEDURE:

1. The filters of the engine were replaced and the injectors were cleaned and calibrated according to the desired pressure.

2. The AVL gas analyzer and smoke meter were installed. The input to the gas analyzer was taken from the exhaust port of the engine.

3. The fuel tank was then filled with diesel and the engine was run.

4. The engine was run at various loads of the dynamometer – 5,10,15,20,25 kgs and respective readings were taken for fuel consumption/ sec.

5. The readings of gas analyzer and smoke meter were noted in each case.

6. After all the readings were taken, the leftover diesel was drained out of the tank and emulsion was poured.

7. Same steps were taken and the readings were noted down for the emulsion.

8. Before using the next emulsion the engine was again run with diesel so that the results are not biased.

9. After taking all the observations graphs were plotted to compare the performance characteristics and emission characteristics of the engine in case of diesel and emulsion.

5.5

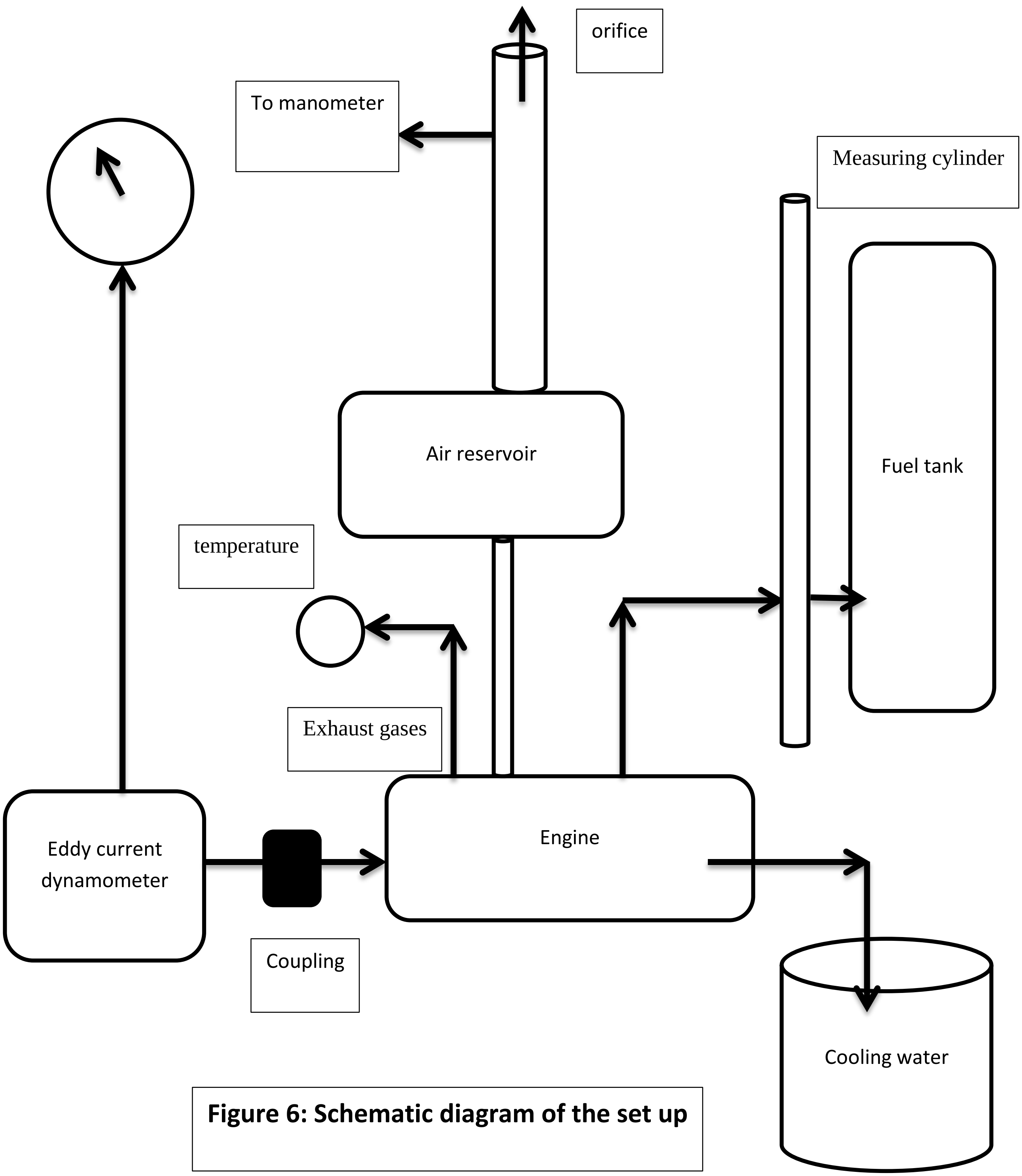

Figure 6: Schematic diagram of the set up

Chapter 6

RESULTS AND DISCUSSIONS

6.1 PERFORMANCE CHARACTERISTICS:

CALCULATION OF BRAKE POWER UNDER EACH LOAD CONDITION:

BRAKE POWER $= \frac{2 * \pi * N * T}{60 * 1000}$

Where, N = rpm of the engine

T = torque.

T = S*R,   S= spring weight

R = arm length.

Table -3: Brake power at different loads

LOAD (in kg)	BRAKE POWER(kW)
0	0
5	1.35
10	2.7
15	4.05
20	5.4

6.1.1 BRAKE SPECIFIC FUEL CONSUMPTION:

Brake specific fuel consumption of an engine is defined as the amount of fuel used in kgs per brake power per second. This is an important performance parameter as it determines the mileage of the vehicle. In practical purposes this very important aspect a consumer looks for, as it determines whether the product is value for money or not.

$$\text{Bsfc} = \frac{mass\ of\ fuel\ (kg)}{bp(kw)*time\ (\text{hr})}$$

It is seen from the graph that the bsfc of the engine increases when emulsion is used, but it also depends on the concentration water in the emulsion. It decreases up to a certain limit and then again increases. The bsfc is best obtained for the emulsion with 7.5% of water. Use of water increases the combustion efficiency of the engine by keeping the temperature in the working range. After a certain point when volume of water increases more, it inhibits the combustion.

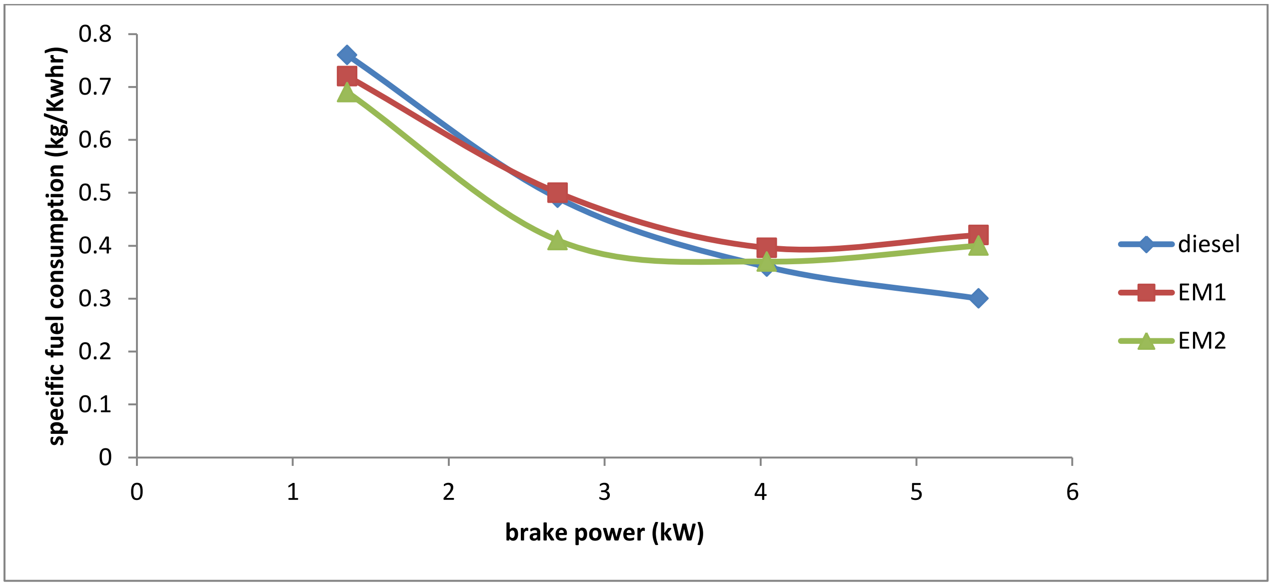

Figure 7: specific fuel consumption vs. brake power

6.1.2**BRAKE THERMAL EFFICIENCY:**

Brake thermal efficiency of a vehicle is a very important performance parameter. It is given by

BTE $=\frac{bp}{calorific\ value * fuel\ consumption\ per\ sec}$

It increases with increase in load. It can be seen that it increases linearly for diesel. Whereas for the emulsions it increases initially till a load and then decreases. But it can be observed that bte for emulsions are always higher than that of diesel except at very high loads. So emulsions prove out to be better fuels when bte is concerned.

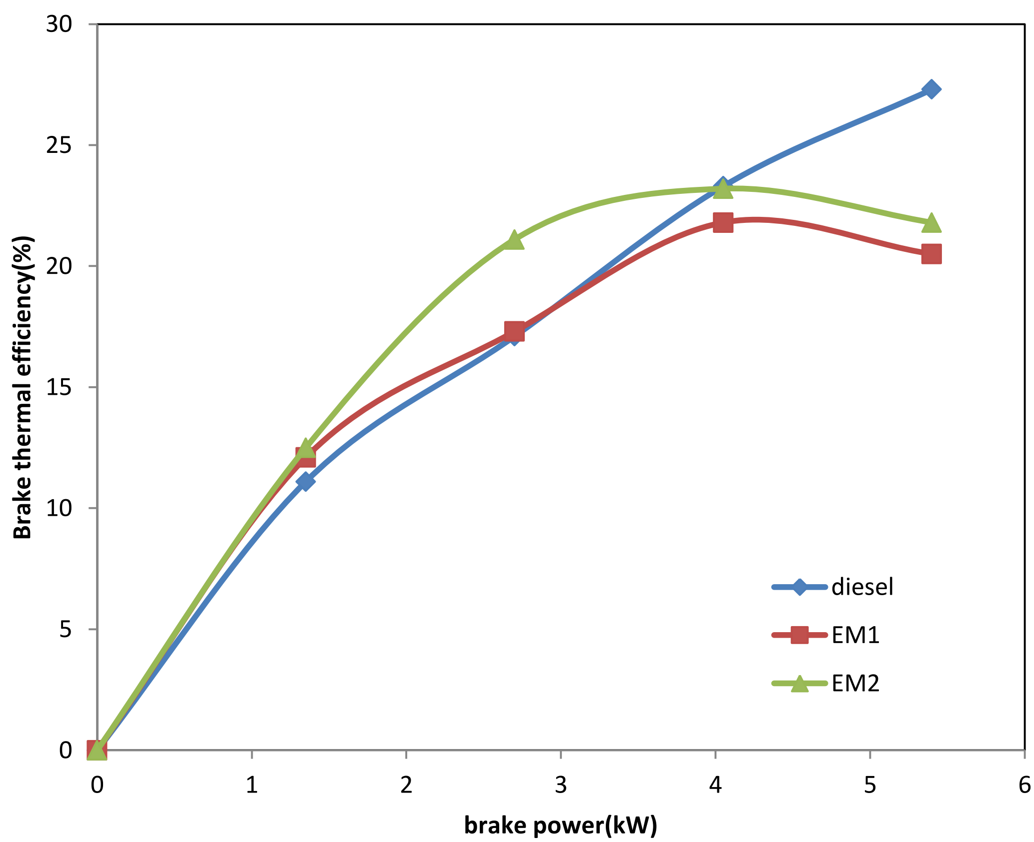

Figure 8: Brake thermal efficiency vs. brake power

6.2 EMISSION CHARACTERISTICS:

6.2.1 Carbon monoxide:

Carbon monoxide is emitted as a result of incomplete combustion of carbon and oxygen under high temperature inside the cylinder. With increase in load CO emission increases for all the fuels used. It has been observed that emission of CO increases with increase in volume of water in the emulsion. This happens because with increase in water the temperature inside the cylinder decreases slowing down the combustion of carbon, as a result of which incomplete combustion occurs.

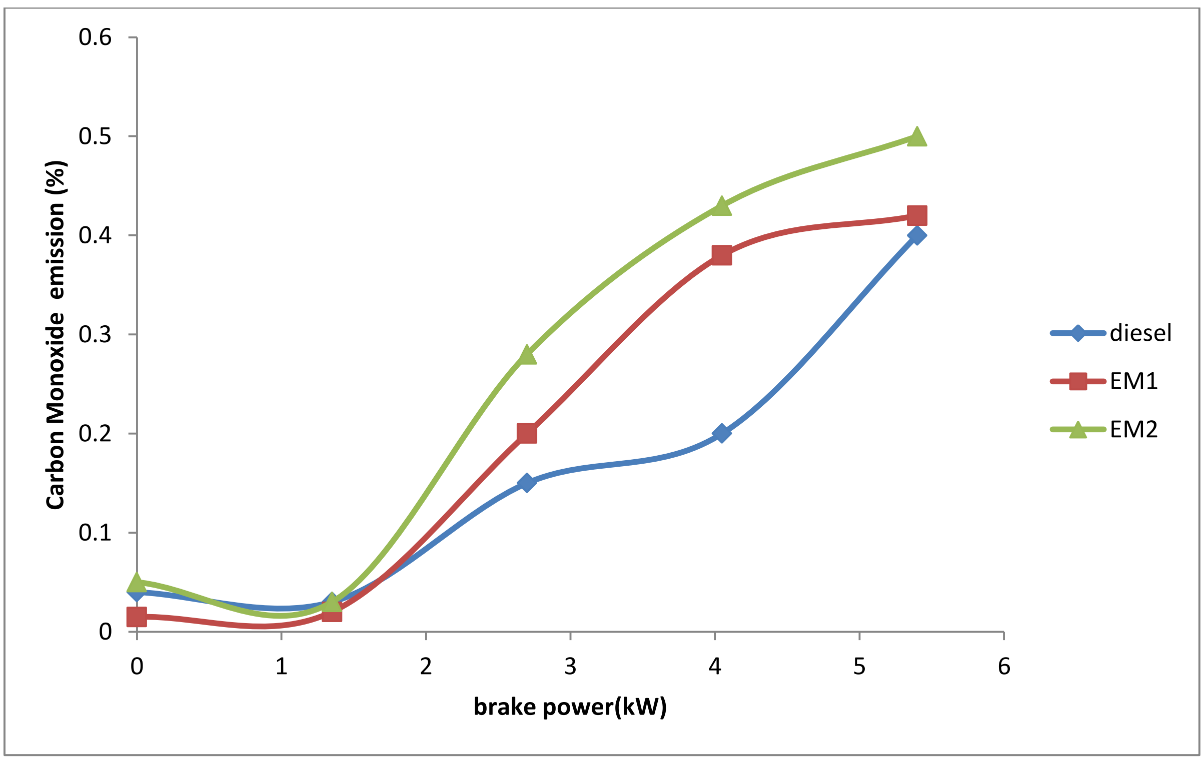

Figure 9: Carbon Monoxide emission vs. brake power

6.2.2 Hydrocarbon emission:

Exhaust gases leaving the combustion chamber of a CI engine contains up to 100 ppm of hydrocarbon. These consist of small non equilibrium which is formed when large fuel molecules break up during the combustion reaction. It is often convenient to treat these molecules as if they contained carbon atom. It is seen that HC emissions increases up to a certain load then decreases for diesel. For the emulsions it shows increasing trend as the load increases. Under lower load conditions emission in case of diesel is more than that of emulsions but at higher load conditions the emulsions give more HC emissions than diesel.

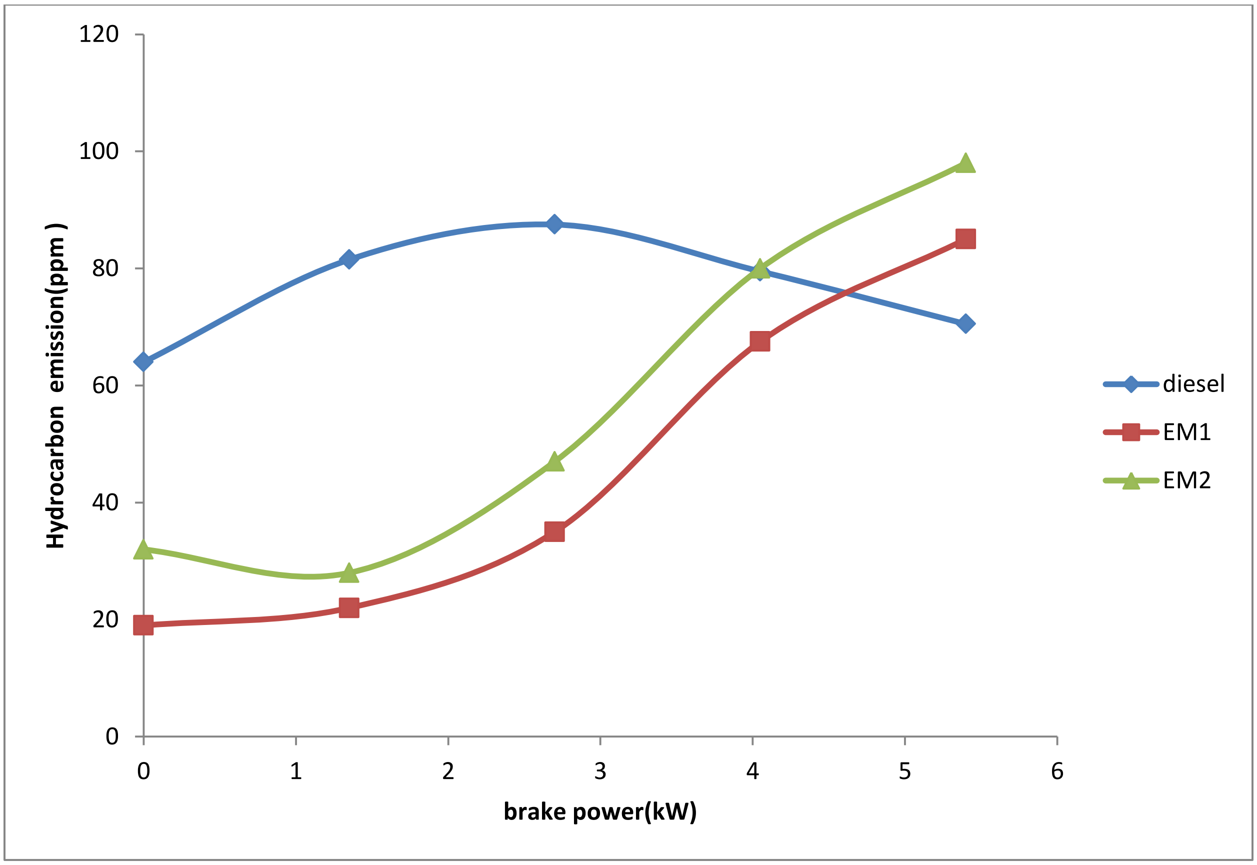

Figure 10: Hydrocarbon emission vs. brake power

6.2.3 **Carbon dioxide:**

Carbon dioxide comes as exhaust as a result of complete combustion of carbon particles in the fuel and the combustion of CO inside the cylinder. For diesel it increases linearly with increase in load. For the emulsions too it increases linearly with some variations at some loads. CO2 emission increases when we add water to diesel. With increase in the percentage of water in diesel CO2 emission increases.

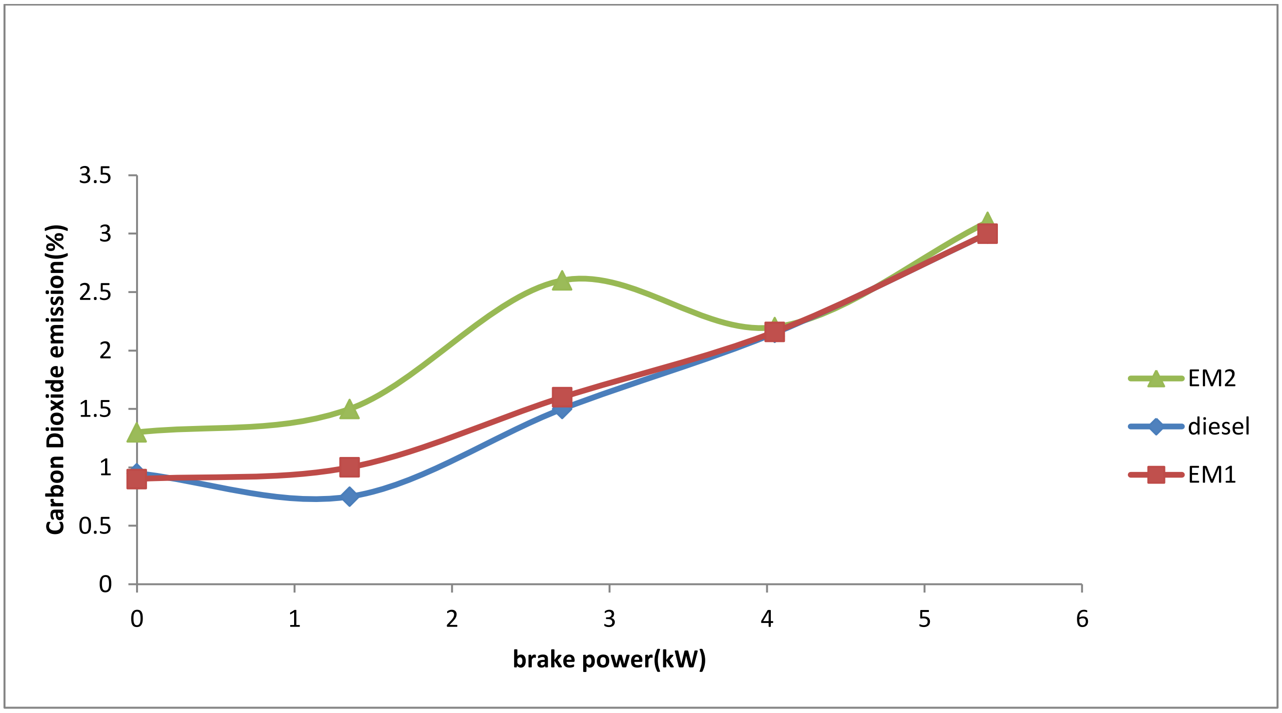

Figure 11: Carbon Dioxide emission vs. brake power

6.2.4 **Nitrogen dioxide (NOx):**

Exhaust gases of an engine can have up to 2000 ppm of oxides of nitrogen. Most of this exhaust contains nitrogen oxide (NO) with small amount of dioxide. These all come under NOx, x representing some suitable number. NOx is very undesirable as it has many adverse effect on the environment. With increase in load NOx emission increases for diesel as well as other fuels. It has been observed that using diesel water emulsion as fuel greately reduces the NOx emissions as compared to diesel. This happens because when water along with diesel enters the combustion cylinder, it is directly vaporized into steam due to presence of high temperature and pressure inside the cylinder. This takes some of the heat from the combustion chamber and brings down the cylinder temperature. As a result the conversion of diatomic hydrogen to more reactive monoatomic nitrogen decreases thereby reducing the chances of formation of NOx.

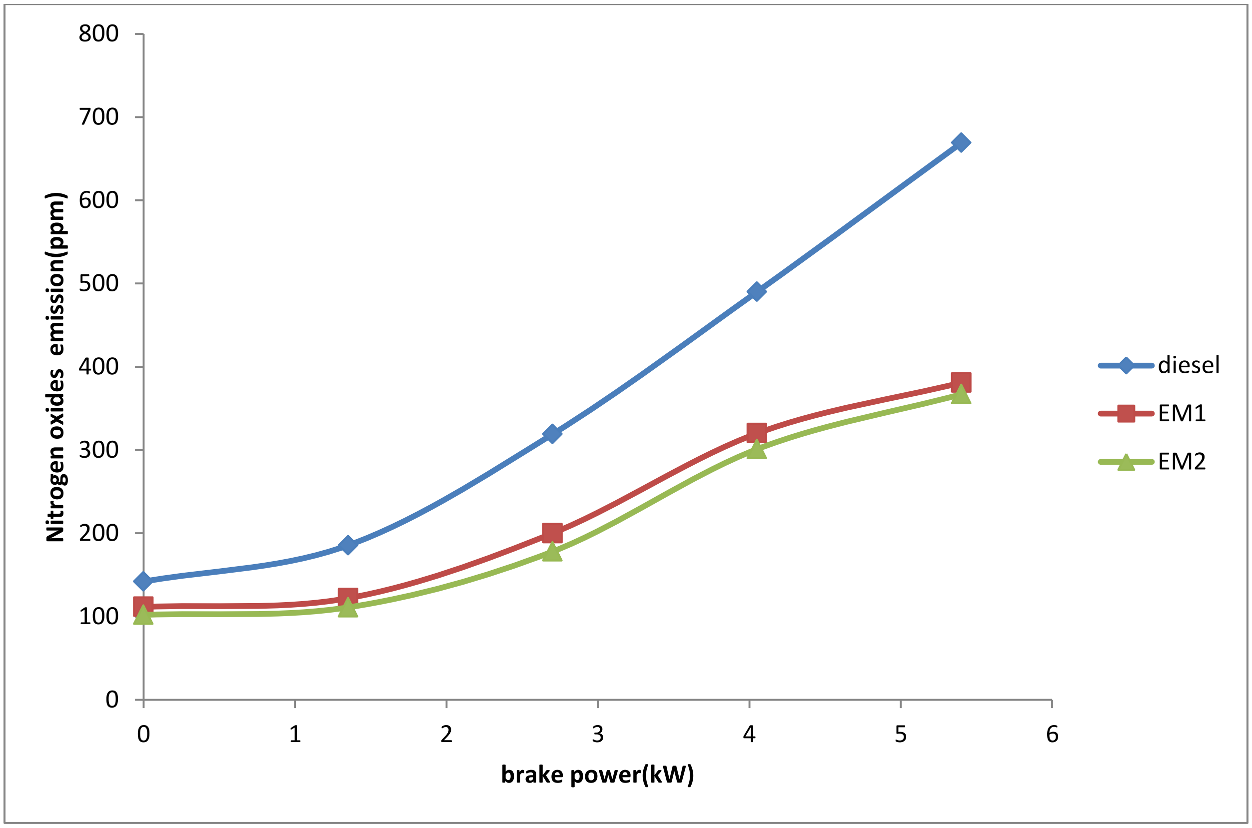

Figure 12: Nitrogen oxides emission vs. brake power

Chapter 7

CONCLUSIONS

- The specific fuel consumption was observed to decrease with increase in the percentage of water in diesel. Results show that specific fuel consumption is decreased by 2% to 3 %when concentration of water is increased from 5 % to 7.5 %, but further increase may increase the specific fuel consumption. However at higher loads the fuel consumption is more for emulsions than diesel.
- The brake thermal efficiency of the increases with increase in water content emulsion under low load condition. But it decreases at higher loads.
- The NOx emission is brought down by 30% - 50 % by use of diesel water emulsion. This trend goes on increasing with increase in amount of water in the emulsion.
- At lower loads the hydrocarbon emissions are lesser for emulsion as compared to diesel, however when the load increases HC emissions are higher for emulsions.
- Carbon monoxide and carbon dioxide emissions increase with increase in water percentage in the fuel. This is due to the fact that most of the hydrocarbons are burnt at lower loads.
- For optimal results use of diesel water emulsion with 7.5% water content will ive the best results in terms of performance and emissions.

References:

1. Anna Lif a, Krister Holmberg b:" Water-in-diesel emulsions and related systems" journal on advances in colloids and interface science ,27th june 2006.
2. C. ALAN CANFIELD " effects of diesel ater emulsions in diesel engine" thesis submitted in University of Florida, 1999.
3. Christopher J. Chadwell, phillip j tingle "Effect of Diesel and Water Co-injection with Real-Time Control on Diesel Engine Performance and Emissions" SAE technical papers ,2008
4. R.Prakash, R.K.Singh, S.Murugan Performance and Emission Studies in a Diesel Engine Using Bio Oil-Diesel Blends, International journal of chemical engineering and applications. ,2011.
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. K. Kannan and M. Udayakumar " NOx and HC emission control using single cylinder engine" VOL. 4, NO. 8, OCTOBER 2009 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences.
7. http://pharmcal.tripod.com/ch17.htm
8. Griffin WC: "Classification of Surface-Active Agents by 'HLB,'" Journal of the Society of Cosmetic Chemists 1 (1949): 311.

9. Griffin WC: "Calculation of HLB Values of Non-Ionic Surfactants," Journal of the Society of Cosmetic Chemists 5 (1954): 259

10. . http://www.transtutors.com/chemistry-homework-help/surface-chemistry/emulsion.aspx

11. . Walavalkar AY. Ph D Thesis, Pennsylvania State University, 2001

12. Dryer FL. Proc of the 16th Symp (Int) on Combust, MIT, Aug 15–20, 1976. Pittsburgh, Pa: The Combustion Institute; 1976. p. 279.

13. Matthews R, Hall M, Anthony J, Ullman T, Lewis D. SAE Spec Publ 2004; SP-1834:79.

14. Schlitt H-G, Exner P. Glueckauf-Forschungsh 1991;52:278.

15. Samec N, Kegl B, Dibble RW. Fuel 2002;81:2035.

16. Abu-Zaid M. Energy Convers Manag 2004;45:697.

17. Holmberg K, Jönsson B, Kronberg B, Lindman B. Surfactants and Polymers in Aqueous Solution. 2nd ed. Chichester: Wiley; 2003. p. 461.

18. V Ganesan ,Internal Combustion Engines (third edition) .