We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



1

Role of Emulsified Fuel in the Present IC Engines – Need of Alodine EC Ethanol Corrosion Resistant Coating for Fuel Injection System

M. P. Ashok
Department of Mechanical Engineering, FEAT, Annamalai University, Annamalai Nagar, Tamil Nadu, India

1. Introduction

The present environment gets polluted day by day, due to the increase in industries, automobiles, etc., Eventhough, government has given strict rules and regulations against the environment pollution, practically there are lot of problems to implement the same by the users and production units, which leads to the result of global warming, acid rain, damaging of ozone layer affecting the green house effect and human health, etc. The pathetic information is that, the harmful pollutant does not allow the children also from their birth itself.

Due to the depletion of fossil fuel and its dangerous harmful emissions, the entire universe has given much attention for identifying an alternate fuel for the current existing engine. Also the fuel to be identified must have the property of fuel to the current existing engine and much free from the harmful pollution, emitted by IC (Internal Combustion) engine. Based on that, many research works have been carried out.

Present days emulsified fuel is much familiar for the IC Engines. Particularly ethanol based emulsion process fuels are much familiar, due to the depletion of fossil fuels. Entire universe has given much attention & many research works are going on based on the alternate fuel to the IC engines.

Based on that, emulsification technique is one of the possible approaches to identify an alternate fuel. Particularly /presently, the bio fuel from ethanol addition to the fossil fuels, play a vital role to run the current existing IC Engine, with best performance and fewer harmful emissions.

Presently the maximum blending of 50% Ethanol to 50% Diesel (50E: 50D), research work has been carried out by M.P.Ashok, academician, researcher and scientist {(in the field of Water-in-Oil) W/O–Emulsion} at Annamalai University, India, during the year 2007.

Based on the test result of Phase-I, it is possible to run the engine at 50% blending of ethanol, in the normal fuel injection system for a single cylinder, DI (Direct Injection) oriented engine.

Another point to be noted in this case is that, the engine gives better performance but emits more harmful emissions, at the higher rate for the emulsified fuel than the diesel fuel.

Further investigation has been carried out by the same author and identified the solution for reducing harmful emission by adding oxygen enriched additive Hydrogen Peroxide (H_2O_2) to the same emulsified fuel for increasing the cetane number of the fuel, with the selected emulsified fuel ratio of 50D: 50E.

Based on the test result of Phase-II, it is possible to run the engine at 50% blending of ethanol, in the normal fuel injection system for a single cylinder, DI (Direct Injection) oriented engine. Also, point to be noted in this case is that, the engine gives better performance and poor harmful emissions for the oxygen enriched additive added emulsified fuel than diesel and surfactant only added emulsified fuel.

Further investigation has been carried out by the same author, for selecting the best oxygen enriched additive among the three additives, namely Hydrogen Peroxide (H_2O_2), Di-Ethyl Ether (DEE) and Di-Methyl Ether (DME).

Based on the test result of Phase-III, it is possible to run the engine at 50% blending of ethanol, in the normal fuel injection system. Points to be noted in this case is that, the engine gives better performance and poor harmful emissions, for the oxygen enriched additive added emulsified fuel than the diesel and surfactant only added emulsified fuel.

Next research work has been carried out by the same author, introducing water as a fuel to the selected ratio of the emulsified fuel. Engine test report shows that, better performance and fewer emissions have been obtained.

Continuation of Phase-IV results, it is understood that, the engine could be run with the selected best ratio of the emulsified fuel along with water addition (small volume of water directly added to the emulsified fuel). The outcome of the test result have been given that, best in performance, lower emission obtained by the water, surfactant, oxygen enriched additive added emulsified fuel. Normally ethanol addition based fossil fuel cost is less than the normal fossil fuel cost. Further addition of water to the emulsified fuel, reduces the cost of the fuel much more. So, considering the cost economics, water added emulsified fuel is good for present engine operation.

The above mentioned outcome results, has given the details of best performance, poor harmful emissions and water addition using the best selected emulsified fuel ratio, based on ethanol addition. Also, it has been proved that the emulsified fuel is suitable for current existing engine.

But considering the part of corrosion, fossil fuel is already having the property of corrosion. Moreover, as ethanol is basically corrosive in nature, addition of ethanol fuel makes the engine components further more corroded. Also, some of the research works have already proved that ethanol fuel makes the engine parts to get more damaged.

Based on this, the present research work has been dealt for making Alodine corrosion coating for all the inner parts of the fuel injection system (normal fuel injection system used in the current (Internal Combustion) IC engine). The Alodine EC (Electro Ceramic) Coating the only and easy solution, which gives remedy for the corrosion caused by the emulsified fuel. This micro level Alodine coating based fuel injection system is much cheaper in cost

and will increase the life span of the current fuel injection system (single and common system) available in the exiting engines, which is running under emulsified fuel category.

2. Role of emulsified fuel

2.1 Need of alcohol to the IC engine

Eugene Ecklund E., et.al, (1984), have given a detailed report on the concept of using alcohol fuels as alternative fuels to diesel fuel in diesel engine. They have also explained the different techniques for adding alcohol to the fossil fuels. In this case, blending of alcohol in the emulsion method has been clearly given and the merits and demerits of using alcohol as an alternate fuel are also explained. Their research has opened a whole new range of possibilities for using alcohols in transportation vehicles and has stated that the importance of this work will increase as the proportion of diesel-powered highway vehicles increases and as diesel fuel supply becomes more limited or degrades in quality.

2.2 Use of ethanol in CI engine

Ajav E. A. and Akingbehin O.A. (2002), have made a study on some of the fuel properties of ethanol blended with diesel fuel (six blends: 5, 10.15 . . .). Some properties have been experimentally determined to establish their suitability for use in CI engines. The results showed that both the relative density and viscosity of the blends decreased as the ethanol content in the blends has increased. Based on the findings of their report, blends with 5 &10% ethanol content are found to have acceptable fuel properties for use as supplementary fuels in diesel engines.

Alan.C.Hansen, et.al, (2004), have given a detailed review on ethanol-diesel fuel blends. They have stated that ethanol is an attractive alternative fuel because it is a renewable bio-based resource and it is oxygenated, thereby providing the potential to reduce the emissions in CI engines. Also, the properties and specifications of ethanol blended with diesel fuel have been discussed. Special emphasis has been placed on the factor of commercial use of the blends. The effect of the fuel on engine performance, durability and emissions has also been considered.

2.3 Use of surfactant to prepare the emulsified fuel

Santhanalakshmi.J and Maya.S.I, (1997), state about Span-80 and Tween-80 as the two non ionic surfactants, which could be used for preparing the emulsified fuel. Micellisation of surfactants in solvents of low dielectric constant differs from those in aqueous media due to the differences in the solute-solute, solute-solvent and solvent-solvent interactions. They have also explained about the solvent effects of the non ionic surfactants. They have stated that surfactants in non aqueous and non polar solution form reverse in order the micelles with hydrophilic core.

2.4 Selection of best emulsified fuel ratio

M.P.Ashok., et al., (2007) have conducted a research to identify the best ratio from the emulsified fuel ratios and compare with diesel fuel, based on its performance and emission characteristics. Water–in–Oil type emulsion method has been implemented to produce the

emulsified fuel. Emulsified fuels have been prepared with different ratios of 50D: 50E (50 Diesel: 50 Ethanol - 100% Proof), 60D: 40E, 70D: 30E, 80D: 20E and 90D: 10E. From the investigation, it is observed that the emulsified fuel ratios have given the best result than diesel fuel. Also, 50D: 50E has given the best performance result than the other emulsified fuel ratios and diesel fuel. It has been observed that there is reduction in Smoke Density (SD), Particulate Matter (PM) and Exhaust Gas Temperature (EGT) with an increase of Oxides of Nitrogen (NOx) and Brake Thermal Efficiency.

2.5 Role of selected oxygen enriched additive in the emulsified fuel

Cherng – Yuan Lin and Kuo-Hua Wang, (2004) have given their report on the effects of an oxygenated additive in the emulsion field. Emulsified fuel characteristics have also been discussed, after adding the additives. They have shown the oxygenated additive to the diesel fuel which improves the combustion characteristics of the diesel engines. For the purposes of comparison, the emulsification characteristics of the two phases of emulsified fuels with additive have been analyzed. The chemical structures, HLB values and specific gravity of the surfactants Span-80 and Tween-80, have been given in detail. Also, they have stated that the efficiency and combustion properties of the CI engine have been improved by adding oxygenated additives in the emulsified fuel.

Mark.P.B.Musculus and Jef Dietz, (2005) have stated the effects of additives in the emulsion field on in-cylinder soot formation in a heavy duty DI diesel engine. Report states that the additives could potentially reduce in–cylinder soot formation by altering combustion chemistry. Chemical and physical mechanisms of the additives may affect soot formation in diesel engines. From the investigation, they have concluded that the effect of ignition delay on the soot formation and ethanol containing fuels display a potential for reduction of in – cylinder soot emission.

2.6 Role of best selected additive in the emulsified fuel (performance and emission)

M.P.Ashok., et., al., (2007) have studied about identifying an alternate fuel, for the current existing engines without any modification, with better performance and less emission. Emulsion technique is the best method to solve the above mentioned problems. Emulsified fuel with a surfactant is familiar nowadays. Addition of oxygen enriched additives in the emulsified fuels gives good results than the previous one. Usually NOx emission is high for the emulsified fuels, when compared with diesel fuel. But additive added emulsified fuels emit less NOx than diesel. Based on this, the present work has been carried out using oxygen enriched additives: Diethyl Ether (DEE), Hydrogen Peroxide (H_2O_2) and Dimethyl Ether (DME). The W/O type emulsion method is used to prepare the emulsified fuel. The test results have shown that DME has given the best performance and less emission, with the selected emulsified fuel ratio of 50D: 50E, comparing with the other two additives.

2.7 Role of emulsified fuel in the CI engine (performance and emission)

M.P.Ashok., et. al., (2007) have stated in their research work that various emulsified fuel ratios of 50D: 50E (50% Diesel No: 2: 50% Ethanol 100% proof), 60D: 40E and 70D: 30E have been prepared. Performance and emission tests are carried out for the emulsified fuel ratios and they have been compared with diesel fuel. The test results show that 50D: 50E has given

the best result based on the performance and less emission than the other fuel ratios. By keeping the selected fuel 50D: 50E, the same performance and emission tests are conducted by varying their injection angles at 18º, 20º, 23º and 24º. The outcome shows better performance and less emission by the fuel 50D: 50E at 24º Injection Angle (IA). Further, ignition delay, maximum heat release and peak combustion pressure tests have been conducted. These results show that increase in IA decreases the delay period thus increasing the pressure obtained at the maximum output. Also, P-θ diagram is drawn between crank angle and cylinder pressure. The maximum value is attained by the fuel 50D: 50E at 24º IA. All the tests have been conducted by maintaining the engine speed at 1500 rev/min. The result shows that 50D: 50E ratio fuel has been identified as a good emulsified fuel and its better operation is obtained at 24º IA based on its best performance and less emissions.

2.8 Role of emulsified fuel in the CI engine (performance and emission)

M.P.Ashok., et. al., (2007) have studied about the best performance and less emission of 50% diesel and 50% ethanol [(50D/50E); 100% proof] emulsified fuel. Oxygen-enriched additive Dimethyl ether has been added to the selected best ratio of 50D: 50E emulsified fuel. Then, the performance and emission tests for diesel, 50D: 50E emulsified fuel ratio and oxygen-enriched additive-added emulsified fuel have been conducted. Finally, it has been found that the oxygen-enriched additive-added emulsified fuel has given the best performance and less emission when compared to the other two fuels. In comparison to diesel and the selected best ratio of the emulsified fuels, the oxygen-enriched additive-added emulsified fuel shows an increase in brake thermal efficiency and a decrease in SFC, PM, SD, and NOx.

Jae W.Park, et.al, [11] (2000) have done an experimental study on the combustion characteristics of emulsified fuel in a Rapid Compression and Expansion Machine (RCEM). Water–in–Oil emulsion type has been implemented and shows the best performance with respect to the better thermal efficiency. In the emission part, it is observed that NOx and Soot have been decreased. Also, the emulsified fuel has been characterized by a longer ignition delay and a lower rate of pressure rise in a premixed combustion.

2.9 Role of water added emulsified fuel in the CI engine (performance and emission)

Svend Henningsen, (1994), has investigated that NOx emission has been reduced by adding water to the emulsified fuel. The result shows that NOx is reduced with the addition of water, without deterioration in the SFC and the NOx behaviour is correlated, with the injection intensity as well as the water amount in the fuel. The report explains the result of the parameters such as injection valve opening, closing, duration, combustion starts and ignition delay. The concluding result is that the NOx emission and Specific Fuel Consumption (SFC) have been reduced considerably, because of water added to the emulsified fuel.

Wagner U., et.al, (2008), have described the possibilities of simultaneous in-cylinder reduction of NOx and soot emissions, for the DI diesel engines. They have stated that diesel engines with direct fuel injection give the highest thermal efficiency. Optimization of the injection process and the addition of water to the emulsified fuel are the two different possibilities for the reduction of NOx and soot emission, which have been discussed. Result of water addition gives increase in the value of thermal efficiency and reduction of NOx and

soot emissions, when using the emulsified fuel. As the concept of water addition to the emulsified fuel leads to the reduction of peak combustion temperature, the NOx emission gets decreased. It concludes that the potential of water added emulsified fuel in the diesel combustion process has improved in thermal efficiency and reduction of especially NOx and soot emissions.

2.10 Role of corrosion water added emulsified fuel in the CI engine (performance and emission)

Teng Zhang and Dian Tang., (2009), have discussed about the recent patents on corrosion resistant coatings. The materials of corrosion resistant components, e.g., metals and alloys, ceramics, polymers as well as composite materials, developed for environmental, economic and other concerns were discussed. In addition, the novel methods for forming the coatings, including the powder floating by vibration and the precursor gas, as well as some widely employed methods in the industrial applications were also included.

3. Procedure for the preparation of the emulsified fuel

3.1 With the help of surfactant

Normally Ethanol–in–Diesel emulsion fuel preparation method, diesel and ethanol are the dispersion and dispersed medium respectively. Hence, the dispersed medium is added slowly to the dispersion medium. The surfactant is used to reduce the interfacial tension between the diesel fuel and ethanol fuel. Here Tween–80 has been selected as surfactant, whose HLB (Hydrophile Lipophile Balance) value is 15. Based on the above, the selected surfactant reduced the interfacial tension between two fuels and producing the emulsified fuel. By varying different quantities of ethanol and diesel fuels at different ratios say 90D: 10E, 80D: 20E, 70D: 30E, 60D: 40E, 50D: 50E, with the variation of surfactant level, the emulsified fuel formed. But in and every cases the properties of the emulsified fuel have been changed.

In the Phase–I, for an example the best succeeded ratio of 50D: 50E has been prepared by adding 49.5% diesel fuel with ethanol fuel and the addition of surfactant Tween–80 of 1% by volume basis. Based on the above combination best emulsified fuel has been formed. All the addition of fuels, surfactants and other chemicals have been added by volumetric basis only.

3.2 With the help of surfactant and selected oxygen enriched additive addition

In phase–II, for the preparation of the emulsified fuel, initially the ethanol fuel 44% has been added with the diesel fuel 44% with the addition selected additive of Hydrogen Peroxide 11% has been added by volume basis. The above mentioned surfactant Tween–80 (1%) has been added to prepare the emulsified fuel.

3.3 With the help of surfactant and best selected oxygen enriched additive addition

Before preparing the emulsified fuel, the following oxygen enriched additives have been taken into account and finalized which additive is having higher rate of oxygen enriched properties for preparing the best emulsified fuel. For that, the following oxygen enriched additives of Hydrogen Peroxide (H_2O_2), Di-methyl Ether (DME) and Di-ethyl Ether (DEE) has been involved in the test. In phase–III, the outcome result shows that, the best selected oxygen

enriched additive is DME, which is having higher rate of its oxygen enriched properties, when it is mixed with ethanol, diesel fuels and surfactant. Also the additive DME is having higher rate of oxygen enriched molecular condition, giving good stability of the emulsified fuel.

Based on that, ethanol, diesel, additive and surfactant have been added 45%, 45%, 9%and 1% respectively, added to prepare the emulsified fuel. Also the addition of oxygen enriched additive added emulsified fuel leads to give the best stability and increased life span of the of the emulsified fuel under the condition of Phase–I. Another main point to be considered is that, DME has the properties of highly volatile and easy evaporation based one. But considering the small addition by volume basis, it hasn't given any harmful one (For an Example: 1000ml (millilitre) total of emulsified fuel, the role of DME is 90 ml only, while preparing time. Considering the vaporization property of DME and liberation of oxygen atoms condition it doesn't give any harm).

3.4 With the help of selected surfactant, additive with water as fuel addition to the emulsified fuel

Already it is much familiar that, emulsified fuel cost is cheaper, when comparing with normal fossil fuel, because of the major addition of ethanol to the fossil fuel (Example: Diesel Fuel). So, in Phase–IV it has been considered that small quantity of water to be added to the emulsified fuel under the condition of Phase–III, for further reducing the cost of the emulsified fuel. Based on that 5% and 10% of water has been added to the emulsified fuel under the condition of Phase–III.

At one part the addition of water leads to reduce the performance of the engine and spoiling the emulsified fuel properties and considering the another part, water is also consists of oxygen atoms and having the evaporation property. So the water addition to the emulsified fuel doesn't majorly affect the property of the emulsified fuel (For an Example: out of 1000 ml, the water to be added only 5ml or 10ml). Base on that, the outcome result give the result of Phase–IV, with the condition if Phase–III.

3.5 Emulsified fuel producing machine operation with surfactant, additive and water fuel

Initially the required quantities of ethanol and diesel fuel are to be added as per the Water–in–Oil type emulsion type, along with the selected Surfactant. After adding all the above, the mixture is placed in a special type of mechanical stirrer, which has the specifications of 3-Phase, A.C. supply, 0-10000 rev/min variable speed, vertical motor having twin blades, helical shape attached with the vertical shaft of the motor, four numbers of zig- zag shaped blades which are fixed in the emulsified fuel containing drum vessel to get swirl motion for better mixing. After the required time interval, a good emulsion is formed due to the sharing effects produced by the helical blades of the shaft and fixed blades in the emulsified fuel vessel. Then selected best additive to be added along with the mixture of the emulsion, further the above mentioned action of the motor was started to get further best emulsified fuel. After getting the emulsified fuel, the required quantity of water fuel to be added to the emulsified fuel. The same Rapid Combustion and Expansion Machine (RCEM) action has been repeated, for the required time interval. At last the required emulsified fuel will be obtained. The stability period has been obtained 3 and 1/2 days for the prepared emulsified fuel. In all addition of the test, the required all chemicals have been added under volumetric basis condition.

3.6 Role of alodine EC ethanol corrosion resistant coating in the IC engine

Eventhough emulsified fuel is much cheaper in cost, by considering the cost economics further cheaper based on the water addition: ethanol, surfactant, additive, water are having basically corrosive in nature.

In normal day by day experience, any technical knowledge person could understand / come across that, the direct corrosion for the petro products used engine. In addition to the pert products, above mentioned emulsified fuel and its based chemicals are having the properties to damage the engine and engine parts easily. Based on the above statement, it is prove that, the life span of the engine gets reduced in faster rate.

So, emulsified fuel is having the advantage of being solution for the depletion of fossil fuels, could be used directly to the current existing engine, easily available, bio products based, it having its own disadvantages of corroding the engine parts very easily. Particularly the minute parts like fuel injector, fuel injection system, filter, piston, cylinder etc., gets corrode rapidly with faster rate / easily and the every where the problem will be raised in future, if the engine runs with emulsified fuel.

Based on this, in this present work, making the above mentioned engine parts to be saved from the chemical corrosion from petro products based emulsified fuel by giving a Alodine EC ethanol corrosion resistant coating, with minimum level thickness to the emulsified fuel holding / carrying engine parts and the parts which is kept in contact with emulsified fuel.

4. Experimental setup

The schematic diagram and the details of the test engine are given in the Figure 1 and Table 1 in details. Fuel flow rate is obtained by using the burette method and the airflow rate is obtained on the volumetric basis. NOx emission is obtained using an analyzer working on chemiluminescence principle.

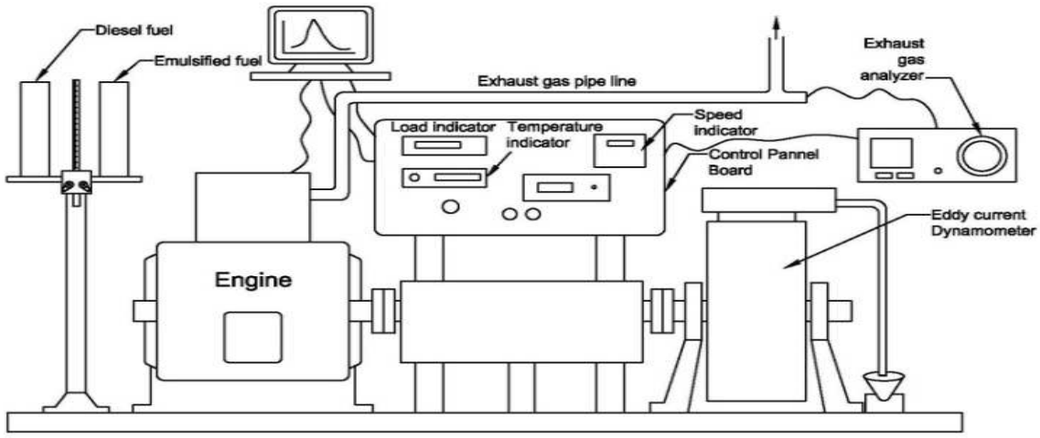


Fig. 1. Experimental Setup

The particulate matter from the exhaust is measured with the help of the micro high volume sampler. AVL smoke meter is used to measure the smoke capacity. AVL DIGAS 444 {DITEST} five-gas analyzer is used to measure the rest of the pollutants. A burette is used to

measure the fuel consumption for a specified time interval. During this interval of time, how much fuel the engine consumes is measured, with the help of the stopwatch. Regarding the fuel injection system, MICO plunger pump type fuel injection system is used in this experiment. All the measurements are collected and recorded by a data acquisition system.

The specifications of the engine are given below:

Make	:	Kirlosker TV – I
Type	:	Vertical cylinder, DI diesel engine
Number of cylinder	:	1
Bore × Stroke (mm)	:	87.5 x110
Compression ratio	:	17.5:1
Cooling system & Fuel used	:	Water Cooling & Diesel
Speed (rpm)	:	1500
Rated brake power (kW)	:	5.4 @1500rpm
Fuel Injection pump	:	MICO inline, with mechanical governor, flange mounted
Injection Pressure (kgf/cm^2)	:	220
Ignition timing	:	23° before TDC (rated)
Ignition system	:	Compression Ignition

Table 1. Specifications of the Diesel engine

The properties of Ethanol and Diesel No: 2 are given in table 2.

#	Ethanol (100% Proof)	Diesel No: 2
Chemical formula	CH_3CH_2OH	$C_{12}H_{26}$
Boiling point (^oC)	78	180 to 330
Cetane number	8	50
Self ignition temperature (^oC)	420	200 to 420
Stoichiometric air/fuel ratio (wt/wt)	9	14.6
Lower Heating value (kJ/kg)	27000	42800
Viscosity in centipoises at (20^oC)	1.2	3.9
Specific gravity	0.783	0.894
Density (kg/m^3)	794	830

Table 2. Properties of Ethanol and Diesel No: 2

5. Results and discussion

5.1 Phase – I selection of best emulsified fuel ratio (performance, emission and combustion)

Figure 2 shows the variation of brake thermal efficiency. All the emulsified fuel ratios have given the best efficiency than the diesel fuel. The difference in the value of the brake thermal efficiency at 5 kW between the emulsified fuel ratio of 50D: 50E and diesel fuel is 6.6%. This is due to more quantity of oxygen enriched air present in ethanol fuel than in diesel fuel. (Presence of volume of air in ethanol and diesel fuel is 4.3–19 and 1.5–8.2 respectively). The possible reason for this increase in efficiency is that, ethanol contains oxygen atoms, which are freely available for combustion, (Naveen Kumar., et.al., 2004). The oxygen present in ethanol

generally improves the brake thermal efficiency, when it is mixed with neat diesel. Due to this reason, the brake thermal efficiency increases as concentration of ethanol is increased.

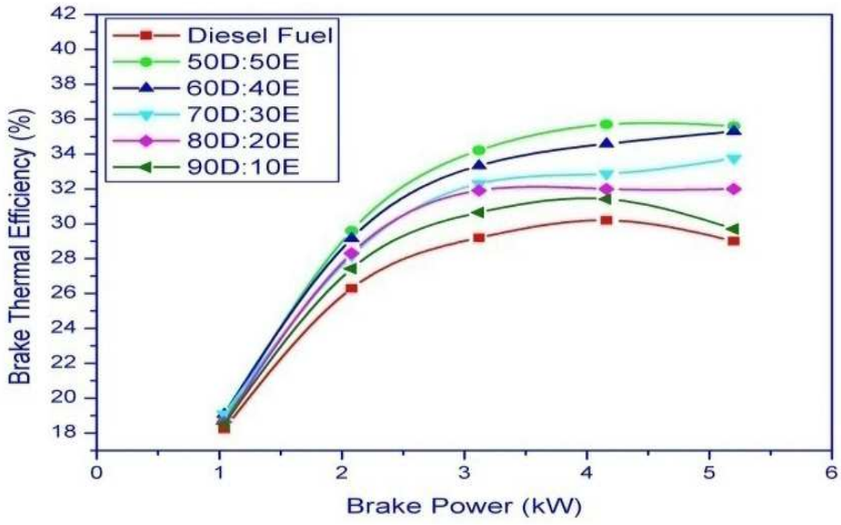


Fig. 2. Variation of Brake Thermal Efficiency

Figure 3. shows the variation of brake power verse SFC. SFC takes lower values for the emulsified fuels than the diesel fuel. This is because of the reduction of the energy content due to addition of ethanol, (Tsukahara, M and Yoshimoto, Y., 1992). Since, the energy content is low for ethanol, when it is mixed with diesel, it makes the emulsified fuel mixture to get poor in energy content. Also, the heating value of ethanol is lower, when compared to diesel. Due to this reason, the SFC is lower for the emulsified fuel ratio 50D: 50E.

As the brake thermal efficiency and SFC are inverse, the two basic parameters are most essential for a good performance of an engine. This could be achieved by the emulsified fuel ratio 50D: 50E. Therefore, the performance of the engine will be good, if it is run with emulsified fuel.

All the emulsified fuel ratios have taken less values of SD than the diesel fuel. The least value is taken by the emulsified fuel ratio 50D: 50E as shown in the figure 4. The reason is, addition of ethanol causes decrease in smoke level because of the better mixing of the air and fuel and increase in OH radical concentration, (K.A.Subramanian., A.Ramesh, 2001). Also, smoke emission of the ethanol–in-diesel fuel emulsion is lower than those obtained with neat diesel fuel because of the soot free combustion of ethanol under normal diesel engine operating conditions. Hence, as the ethanol concentration increases, the smoke density decreases.

All the emulsified fuels emit higher range of NOx than diesel fuel. Masahiro et al., (1997) have stated that generally alcohol/diesel fuel emulsion causes higher NOx emission because of the cetane–depressing properties of alcohol. Ethanol–diesel fuel emulsion causes high NOx emission because of low cetane number of ethanol. Low cetane number leads the fuel to increase the ignition delay and greater rates of pressure rise, resulting in higher peak cylinder pressures and high peak combustion temperatures. This high peak temperature increases NOx emission, (Masahiro Ishida,et.al., 1997). From the experiment, it is observed that as ethanol content increases, emission of NOx also increases.

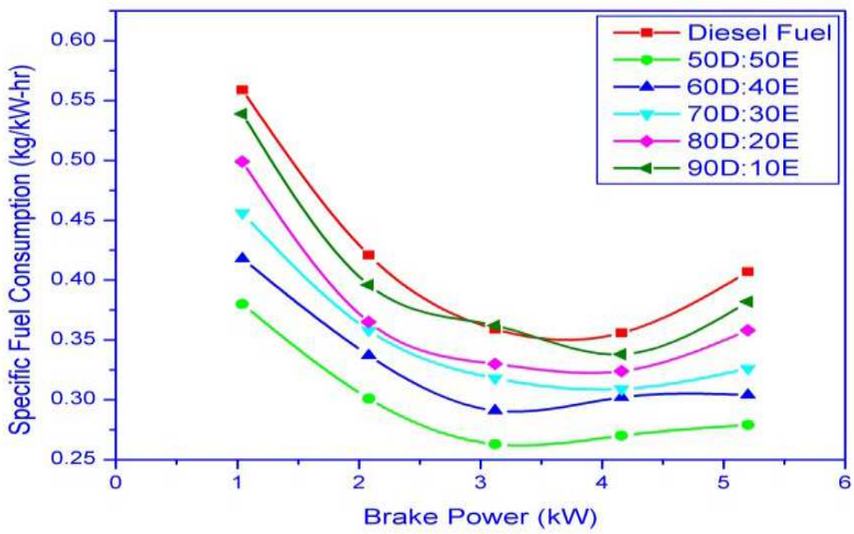


Fig. 3. Variation of Specific Fuel Consumption

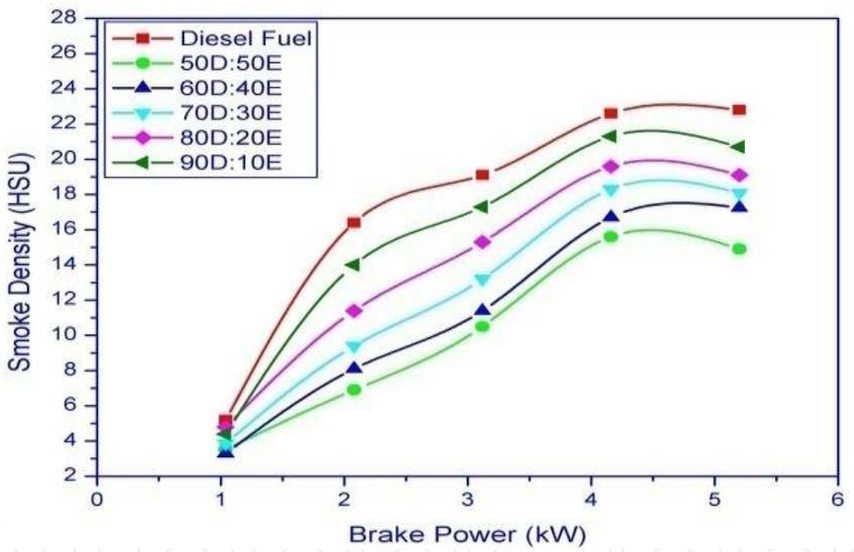


Fig. 4. Variation of Smoke Density

Also if ethanol mixes with any ratio with the diesel fuel, it emits more heat release. Considering the point of heating value, the difference between ethanol and diesel fuel is very small. This is adjusted by the higher latent heat of evaporation of ethanol. Even though the heating value of the ethanol fuel is less with the diesel fuel, the combustion takes place properly by the increased value of the latent heat of ethanol fuel. From this, it is understood that ethanol concentration is directly proportional to the heat release. At the rated output, heat release rate is the highest with ethanol–diesel operation due to enhancement of the premixed combustion phase. Normally, the rate of heat release depends largely on the turbulence intensity and also on the reaction rate, which is dependent on the mixture composition. Hence, 50D: 50E, 60D: 40E, 70D: 30E, 80D: 20E, 90D: 10E and finally the diesel fuel have taken the heat release rate based on the ethanol concentration.

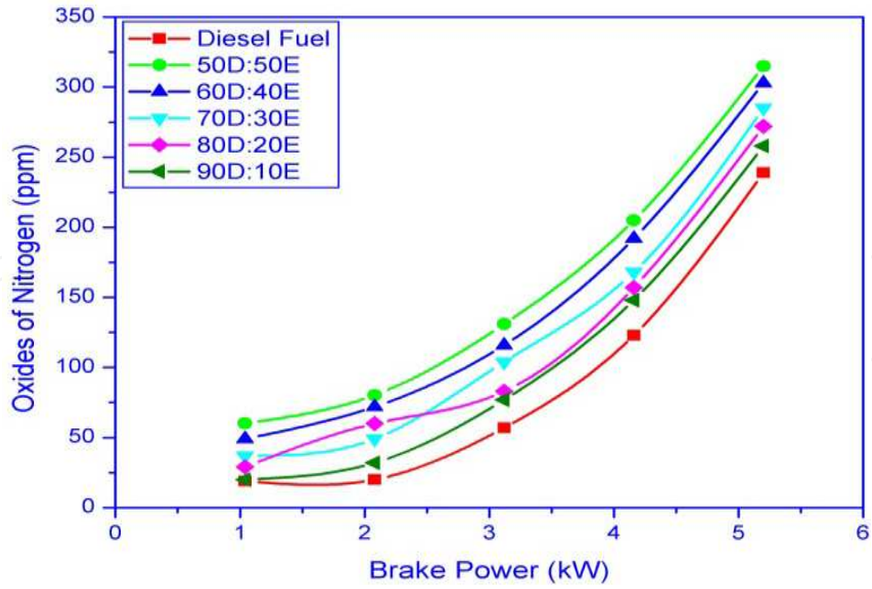


Fig. 5. Variation of Oxides of Nitrogen (NOx)

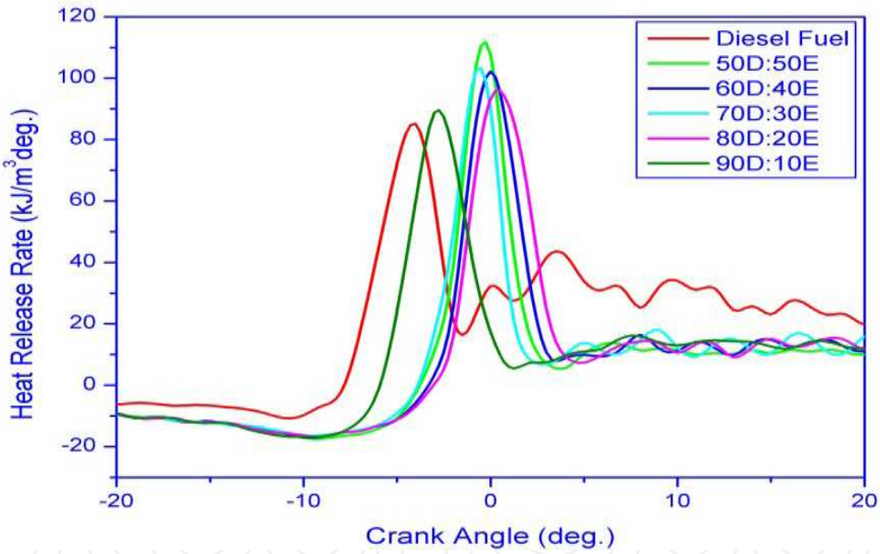


Fig. 6. Comparison of Heat Release Rate at 50% load

Figures 9 and 10 show the comparison of cylinder pressure at 50% and 100% load conditions. In general, there is no such significant change between the emulsified fuel and pure diesel. But there is a small rise in pressure caused by the emulsified fuel in both the cases. Basically, the pressure rise depends on the duration of the delay period. As the cetane number increases, the delay period decreases. Since ethanol has low cetane number, the ignition delay period is longer for emulsified fuel ratios (Cetane Number: for ethanol is 8 & diesel fuel is 50). This longer ignition delay helps to reach a high peak pressure to produce more work output during the expansion stroke. Due to this reason, the emulsified fuel ratios show higher pressure rise than diesel fuel. Also, the pressure rise is due to the amount of

fuel involved in pre mixed combustion, which increases with longer ignition delay, (Tsukahara, M., et.al., 1982). Hence, the order is in the form of 50D: 50E, 60D: 40E, 70D: 30E, 80D: 30E, 90D: 20E and diesel fuel.

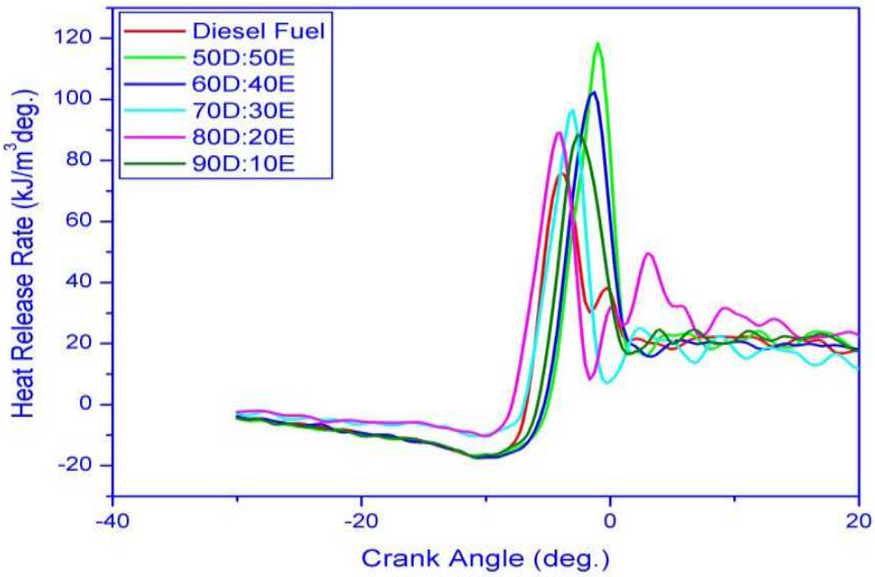


Fig. 7. Comparison of Heat Release Rate at 100% load

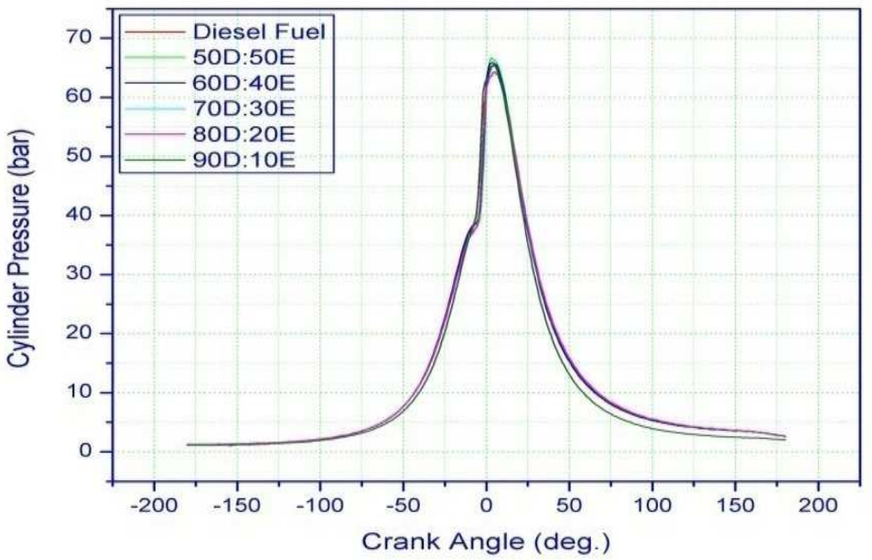


Fig. 8. P-θ for various fuels at 50 % Load condition

Figure 10 shows the comparison of brake thermal efficiency for all oxygen enriched additives added emulsified fuels DME, DEE and H_2O_2. Normally the oxygen enriched additives added emulsified fuels give greater brake thermal efficiency, because of their in higher cetane number. Higher cetane reduces the self-ignition temperature, which in turn reduces the delay period and results in smoother engine operation. Result of the longer

ignition delay leads to a rapid increase in premixed heat release rate that affects brake thermal efficiency favorably. Also, the oxygen present in ethanol generally improves the brake thermal efficiency, when it is mixed with neat diesel (Dr.V.Ganesan). Based on this, the following oxygen enriched additives added emulsified fuels, take the role in the descending order of DME, DEE and H_2O_2. The maximum efficiency given by DME is 37.87%, at the maximum load condition. But considerable attention has to be given for the materials' compatibility and corrosiveness.

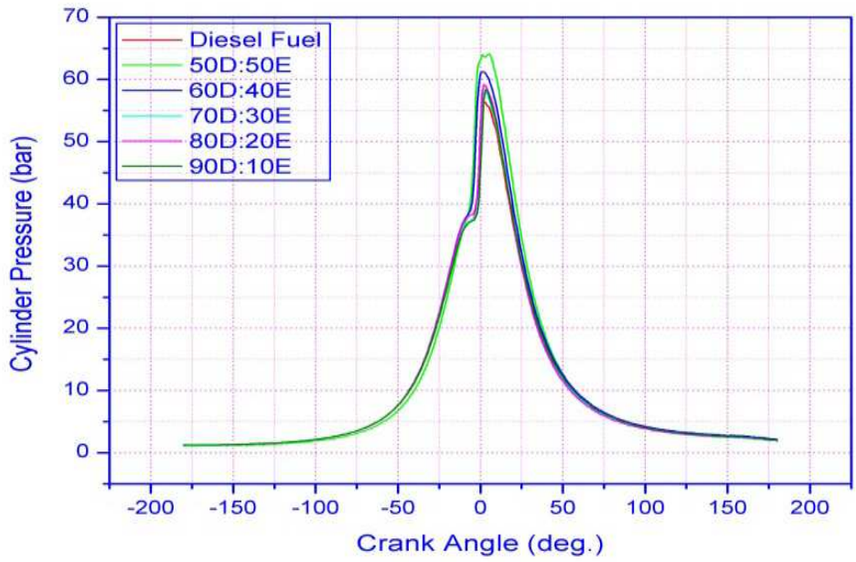


Fig. 9. P-θ for various fuels at 100 % Load condition

5.2 Phase – II & III best selected oxygen enriched additive and surfactant addition (performance and emission)

From figure 11, the SFC values are lower for all the fuels. Even though there is not much variation in the values, the order taken from minimum to maximum is the oxygen enriched emulsified fuels DME, DEE and H_2O_2 respectively. This is based on the energy content of the fuel. Normally, ethanol has less energy content than the diesel fuel. Based on this, the oxygen enriched emulsified fuel shows less value of SFC. Also, DME has the property of less energy content value than ethanol, (Cherng-Yuan Lin., et.al., 2004). Hence less SFC for the DME added emulsified fuel is found than in the other fuels. The least value obtained by DME, at the maximum load condition is 0.249 kg/kW-hr.

Figure 12 shows the comparison of SD, for all oxygen enriched additive added emulsified fuel. The order taken in the form of minimum to maximum is DME, DEE and H_2O_2 respectively. This is due to the better mixing of the air. Addition of ethanol causes decrease in smoke level and fuel and increase in OH radical concentration. The effect of fuel droplets vaporization plays a vital role with particular attention given for the oxygen content in the fuel as related to smoke density, (K.A.Subramanian. and A.Ramesh 2001). Because, oxygen enriched additives have more oxygen in nature, which lead to increase OH radical concentration and oxygen content in the additive improves the fuel droplet size to get more vaporization. The least value obtained by DME is 46 HSU at maximum load condition.

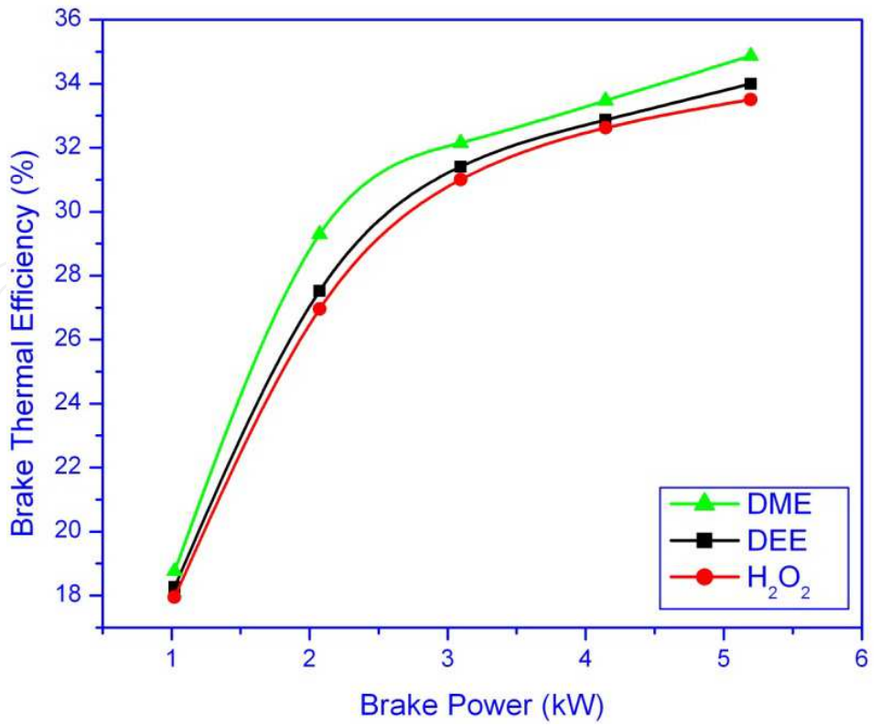


Fig. 10. Comparison of Brake Thermal Efficiency

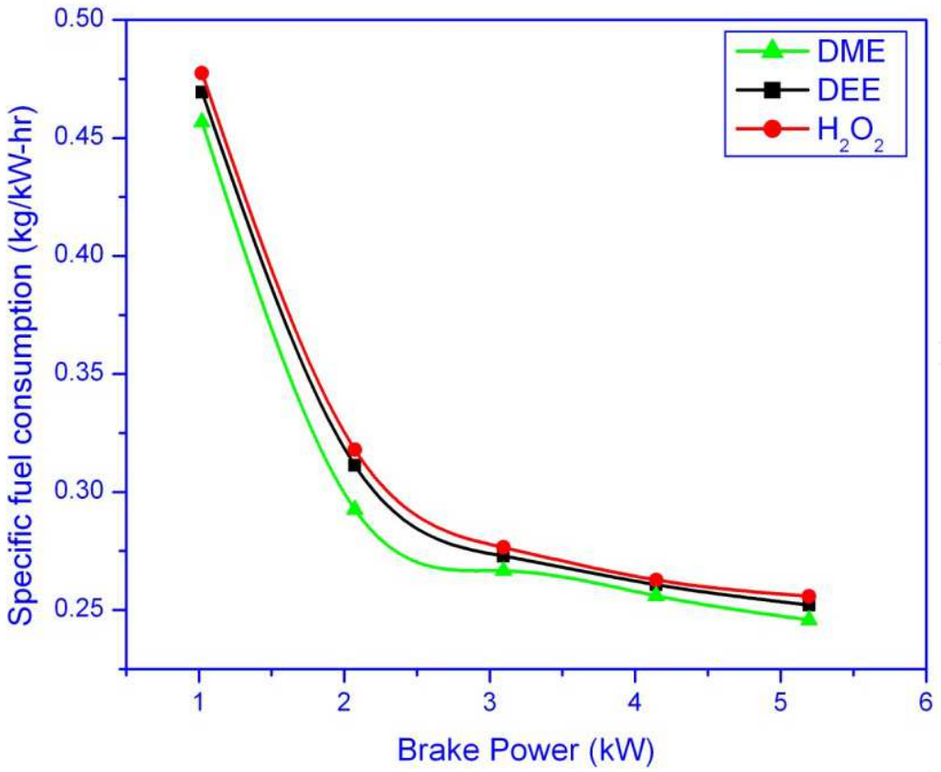


Fig. 11. Comparison of Specific Fuel Consumption

Figure 13 shows the comparison of the NOx emission, for various oxygen enriched additives added emulsified fuels, with the selected ratio of 50D: 50E. All the emulsified fuels emit higher range of NOx than diesel fuel. Masahiro et al., (1997) have stated that generally alcohol/diesel fuel emulsion causes higher NOx emission because of the cetane-depressing properties of alcohol. Normally, surfactant added emulsified fuels emit higher NOx than diesel fuel, because of its low cetane number, (M.P.Ashok 2007). Low cetane number leads the fuel to increase ignition delay and greater rates of pressure rise, resulting in higher peak cylinder pressures and high peak combustion temperatures. This high peak temperature increases NOx emission, (Masahiro Ishida 1997). But in the case of all oxygen enriched additives added emulsified fuels with the selected ratio of 50D: 50E less NOx is emitted. It is because all the oxygen enriched additives have higher value of cetane number. Based on the higher cetane number the order takes place from minimum to maximum of DME, DEE and H_2O_2.

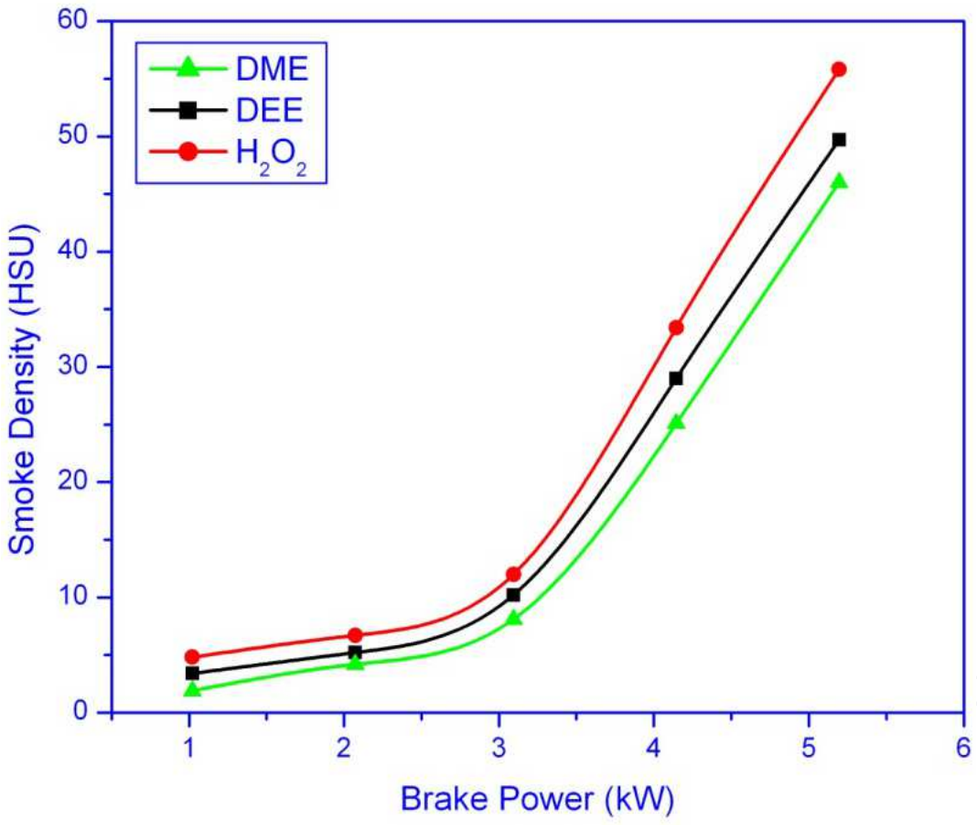


Fig. 12. Comparison of Smoke Density

Figure. 14 shows the comparison of maximum cylinder pressure, for different oxygen enriched additives DME, DEE and H_2O_2, with selected emulsified fuel ratio of 50D: 50E. Basically, the pressure rise depends on the duration of the delay period. As the cetane number increases, the delay period decreases. Since ethanol blending with oxygenated additives (quantity of additive added getting changed–by volume basis) has high cetane number, ignition delay period is shorter for additive added emulsified fuels, (Tsukahara, M. 1982). Based on this reason, the order taken from minimum to maximum is DME, DEE and H_2O_2.

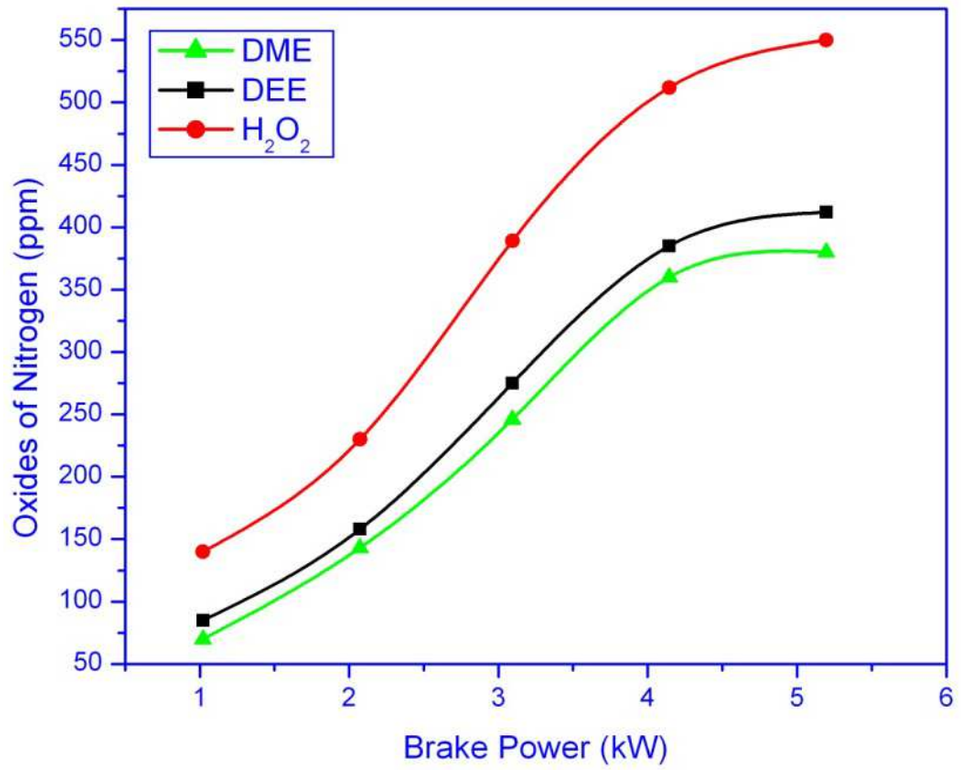


Fig. 13. Comparison of Oxides of Nitrogen

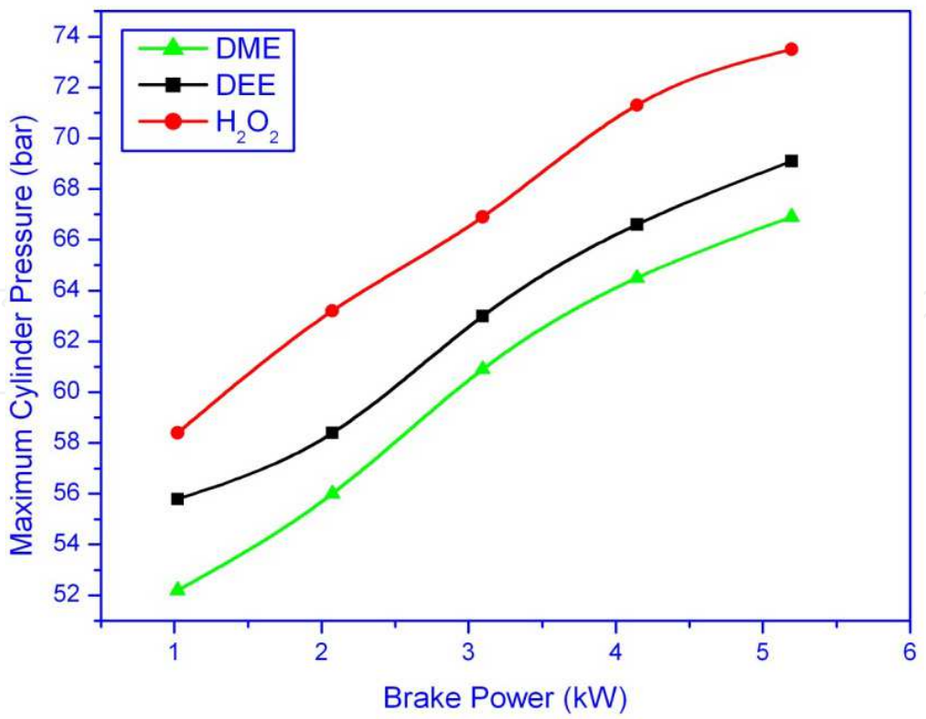


Fig. 14. Comparison of Maximum Cylinder Pressure

Comparison of heat release for the different oxygen enriched additives, with selected emulsified fuel ratio of 50D: 50E is shown in figure. 15. This is due to the higher and lower values of latent heat of evaporation of ethanol and diesel fuel respectively (Latent heat of evaporation: Ethanol–840 kJ/kg; Diesel–300 kJ/kg). At the rated output, heat release rate is the highest with ethanol-diesel operation due to enhancement of the premixed combustion phase, (Ajav. E.A, 1998). But the oxygen enriched additives DME, DEE and H_2O_2 added emulsified fuels have released minimum heat for the selected emulsified fuel ratio of 50D: 50E. In the case of oxygen enriched additives based emulsified fuels have more cetane number. Blending of additive and diesel leads to higher cetane number. Higher cetane number reduces the self-ignition temperature and hence emits less heat. Hence the oxygen enriched additive added emulsified fuels release less heat. Normally, the rate of heat release depends largely on the turbulence intensity and also on the reaction rate, which is dependent on the mixture composition. Based on these reasons, the order taken from maximum to minimum is H_2O_2, DEE and DME.

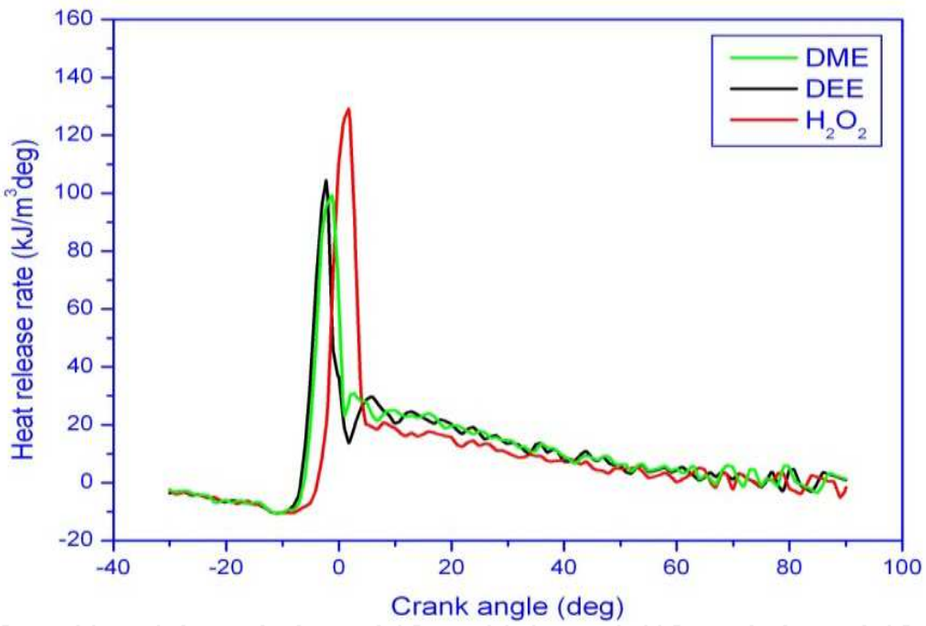


Fig. 15. Comparison of Heat Release Rate

5.3 Phase – IV addition of water fuel to the selected oxygen enriched additive and surfactant (performance and emission)

Figure 16 shows the variation of Brake Thermal Efficiency. There is no such output variation in the lower load condition. But at the middle and higher output level, there is a small variation. This is due to more quantity of oxygen enriched air present in ethanol fuel than in diesel fuel and the presence of oxygen content in water, (M.Abu-Zaid., 2004). Also, higher cetane number of diesel fuel leads to decrease in the delay period and causes reduced self-ignition temperature. Based on this, the variation is taken in the middle and the higher load conditions. The difference between the diesel fuel and the 10% water added emulsified fuel is 1.03% at 5.2 kW load condition.

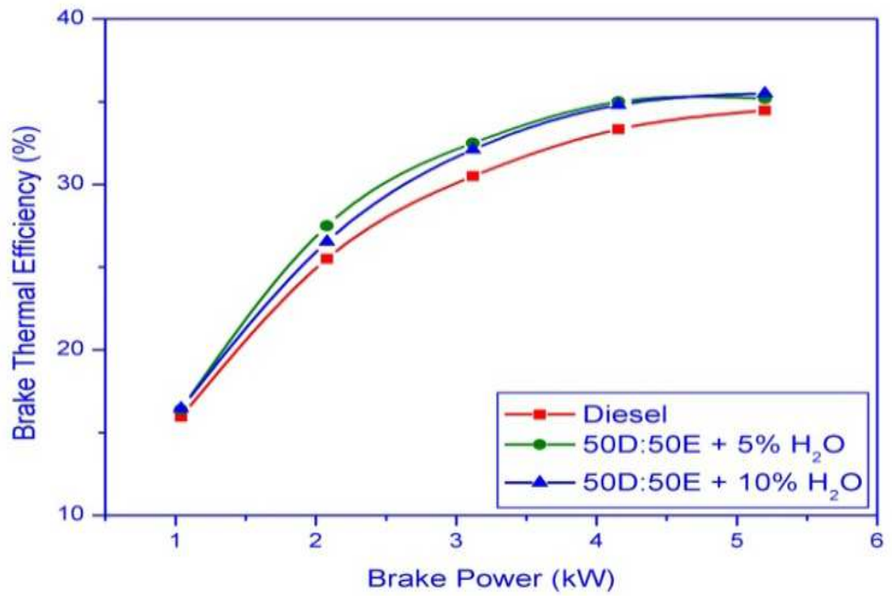


Fig. 16. Variation of Brake Thermal Efficiency

The variation of SFC is shown in figure 17. In this diesel fuel takes the maximum value than the remaining two fuels. This is because of the reduction of the energy content due to addition of water and ethanol, (Moses.C.A.,et.al., 1980). Already the ethanol fuel has less energy content and in addition to that if water is mixed with the emulsified fuel, it leads to very poor energy content of the fuel. Hence diesel fuel has attained the maximum value but the rest of places are attained by the emulsified fuels, according to the percentage of water addition. Also, the latent heat of vaporization of ethanol is high, when compared with diesel fuel. The addition of water reduces the latent heat of vaporization of the emulsified fuel.

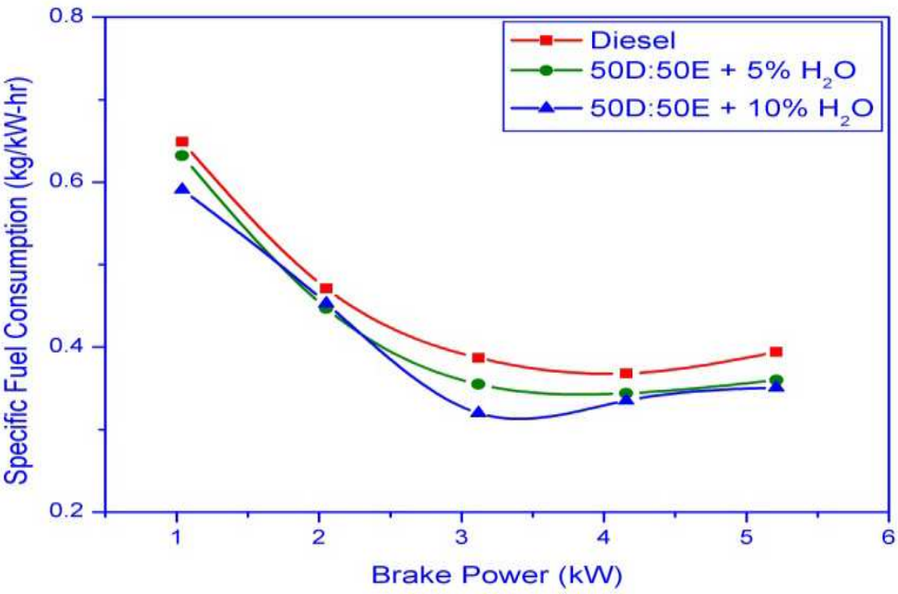


Fig. 17. Variation of Specific Fuel Consumption

Figure 18 shows the variation of SD. SD level increases for the emulsified fuel than diesel fuel due to poor mixing of air and fuel and increase in OH radical concentration, (Minoru Tsukahara., et.al., 1989). The same is higher for the emulsified fuel ratio 50D: 50E. The rest of the fuels are placed according to the order based on their OH radical concentration. The difference between the diesel fuel and the emulsified fuel (10% H_2O addition) emulsified fuel ratio is 14.4 HSU.

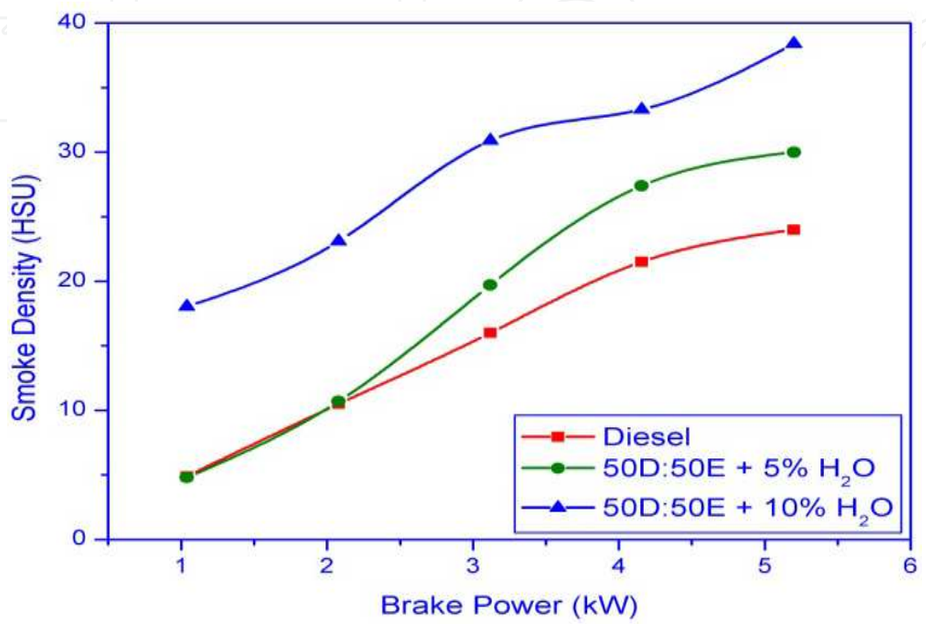


Fig. 18. Variation of Smoke Density

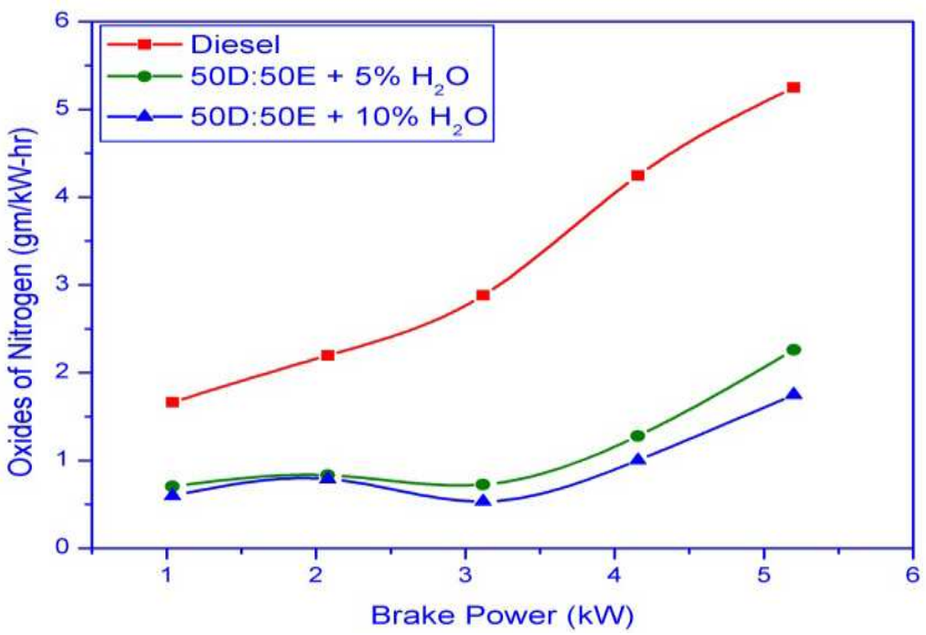


Fig. 19. Variation of Oxides of Nitrogen

The variation of NOx is shown in figure 19. The low cetane depressing properties cause an increase in ignition delay and greater rates of pressure rise, resulting in high peak cylinder pressure and high peak combustion temperatures. The peak temperature always increases the NOx formation, (Masahiro Ishida and Zhi-Li Chen., 1994). Based on the above statement, the emulsified fuel emits more NOx. But in this experiment water is added to the emulsified fuel. Normally water addition reduces temperature. Hence NOx value gets decreased based on the peak combustion temperature reduction. From the above, the order is diesel fuel, emulsified fuel (5% H_2O addition) and finally emulsified fuel (10% H_2O addition). The difference between diesel fuel and the emulsified fuel (10% H_2O addition) at the maximum load condition is around 164 ppm. From the above, it is understood that NOx reduction is possible by using the water added emulsified fuel.

5.4 Phase–V Alodine EC ethanol corrosion resistant coating for fuel injection system and its parts dealing with emulsified fuel

The Alodine Electro Ceramic (EC) Corrosion Resistance Coating is the best solution for protecting the engine parts against corrosion. Presently the prepared emulsified fuel is more corrosive in nature and for that alodine EC corrosion resistant is the best solution. Application of alodine EC coating is cheaper and will be the best solution for corrosion. Particularly, the alodine EC coating could be applied to the minute parts of the engine. Manufacturers rely on EC to provide engine protection under a wide variety of extreme conditions, ranging from low temperature short trip service to extended high speed, high temperature operations.

Alodine EC also provides not only chemical protection but also wear resistance coating protection for intake manifolds, fuel injection system, fuel injection system pipe line, top of the piston, entire cylinder walls. It also reduces the friction in certain percentage; the performance of the engine gets increased.

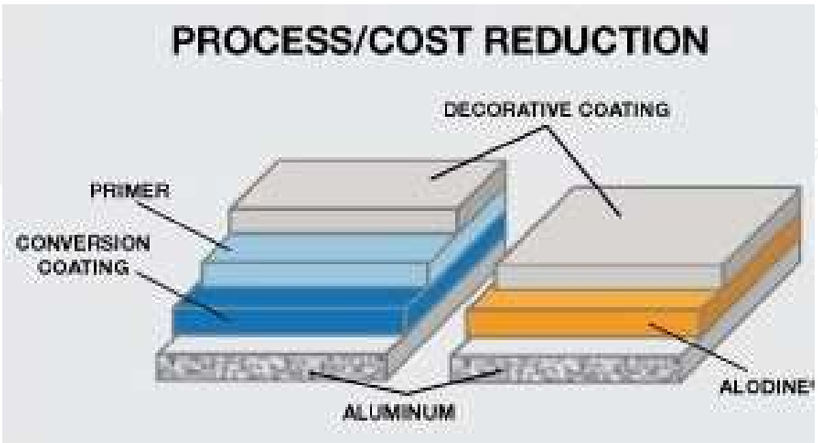


Fig. 20. Different layers of deposition based on Alodine EC coating



Fig. 21. Engine parts with alodine EC coating



Fig. 22. Engine parts after the Alodine EC coating

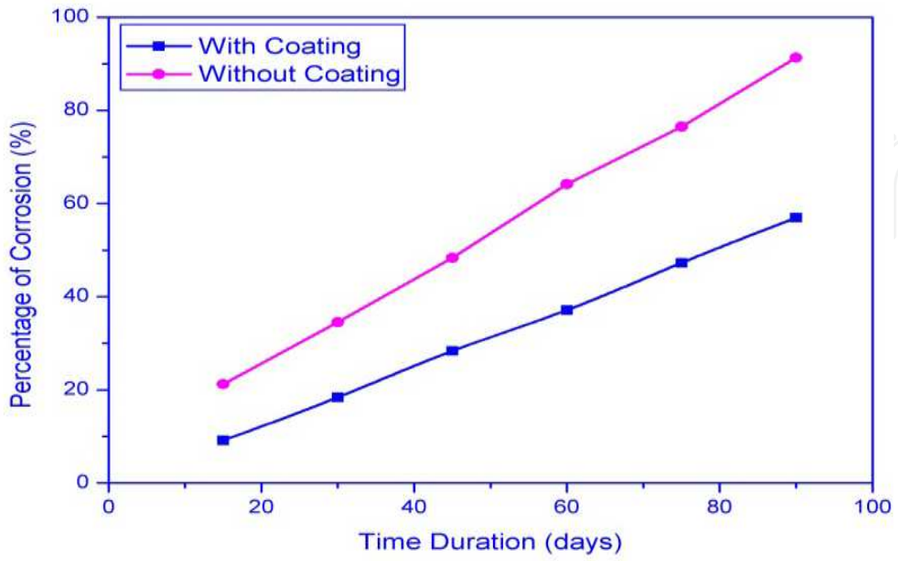


Fig. 23. Variation of duration with respect to life of the material

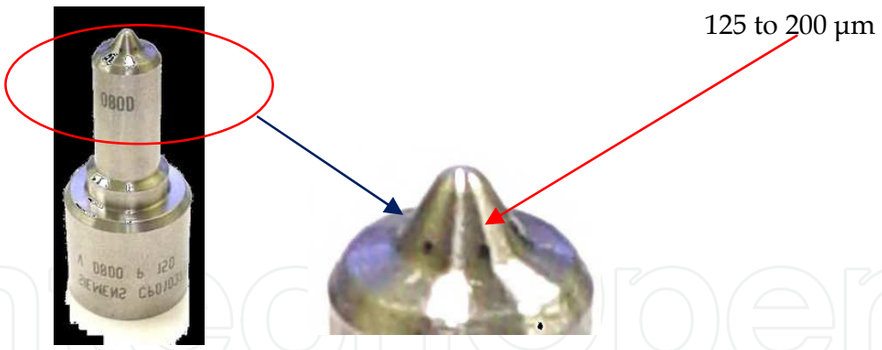


Fig. 24. Alodine coated Fuel Injector and its Nozzle Part



Fig. 25. Alodine coated Fuel Injection Fuel Lines

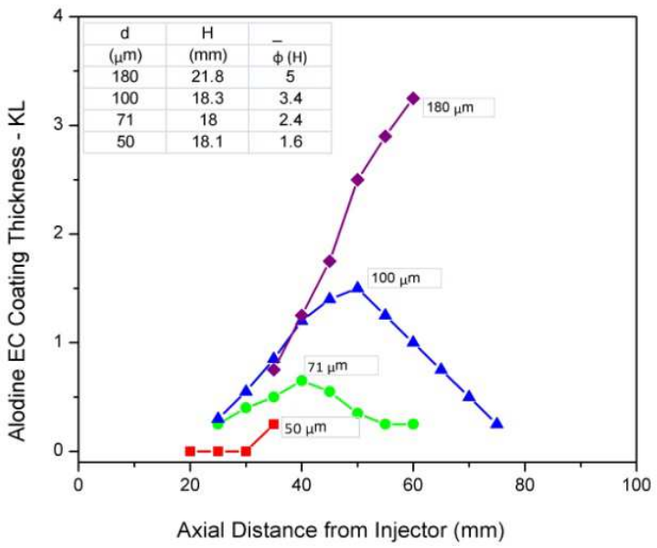


Fig. 26. Axial Distance from Injector verses Alodine Coated thickness

From the above it is understood that Alodine EC Coating is much useful against corrosion. The thickness is around minimum and maximum of 25 and 250µm respectively. This would compromise the corrosion and increase the life span of the parts of the engine particularly fuel injection system.

Fig. 23 shows the variation of corrosion with standing capacity of the material verses duration days. In this case, alodine EC coated material and normal material have been kept in bath contact with Phase–IV condition of the emulsified fuel. Keeping the room temperature and moisture content, the above mentioned test has been carried out. After 90 days duration, both the materials have been undergone for the corrosion resistance test. Based on the test result, the alodine EC material gives maximum life then the ordinary material.

Also figure 24 & 25 show diagrams of Alodine EC coated fuel injector, edge of the nozzle part fuel injection hose lines. Figure 26 represents axial distance from the fuel injector, edge of the nozzle part verses Alodine EC Coating thickness given to the fuel Injector. It would indicate the different in thickness, diameter and height provided by the Alodine EC coated matrial. Also it shows that, the minute hole of the fuel injector gets Alodine coating with minimum thickness. Based on that entire fuel injection system gets safe against ethanol based emulsified fuel corrosion.

6. Future scope of the work

Further research work will be taken the study based on the performance, emission and combustion test along with alodine EC coated material of the engine parts, including fuel injection system.

7. Conclusions

- From Phase–I, it is well understood that Emulsified fuel 50E: 50D is the best emulsified fuel ratio for the CI Engine operation with increase in performance and NOx emission
- From Phase–II, it is understood that H_2O_2 additive added emulsified fuel under the ratio of 50D: 50E gives the best performance and less emissions of NOx.
- From Phase–III, it has been proved that DME is the best additive, when compared with the other two additives, which gives best performance and much poor emission.
- Phase–IV illustrates that water is also a fuel to the CI engine operation along with emulsified fuel.
- Finally Phase–V shows that Alodine EC coating is the best solution against corrosion, which has been caused by the emulsified fuel.

8. References

Abu-Zaid.M. (2004). *Performance of Single Cylinder, Direct Injection Diesel Engine using Water Fuel Emulsions*, Elsevier: Energy Conversion and Management 45 (2004) 697 – 705.

Ajav.E.A. & Akingbehin. O.A. (2002). *A Study of Some Fuel Properties of Local Ethanol Blended with Diesel Fuel* - CIGR Journal of Scientific Research and Development. EE 01 003. Vol. IV. March, 2002.

Ajav. E.A.; Singh. B. & Bhattacharya. T.K. (1998). *Performance of a Stationary Diesel Engine using vapourized Ethanol as Supplementary Fuel,* Bio Mass Bio energy 1998; 15(6): 493 – 502.

Alan.C. Hansen.; Qin Zhang. & Petter.W.L. Lyne. (2005). *Ethanol–Diesel Fuel Blends–A Review,* Elsevier – Journal of Bio Resource Technology – No: 96 (2005) Page No: 277 –285.

Ashok.M.P. & Saravanan.C.G. (2007). *Selection of the Best Emulsified Fuel Ratio Compared to Diesel Fuel*, SAE Technical Paper No. 2007 – 01 – 2138.

Ashok.M.P. (2010). *Identification of Best Additive Using the Selected Ratio of Ethanol–Diesel Based Emulsified Fuel*, International Journal of Sustainable Energy, Taylor & Francis Publication, Paper No. gSOL-2010-0139.

Ashok.M.P. (2011). *Effect of Dimethyl Ether in a Selected Ethanol-Diesel Emulsified Fuel Ratio and Comparing the Performance and Emission of the same with Diesel Fuel*, Journal of Energy and Fuels, ACS Publications, Paper Number: ef-2011-007547.

Ashok.M.P. & Saravanan.C.G. (2007). *Combustion Characteristics of Compression Engine Driven by Emulsified Fuel under various Fuel Injection Angles*, Journal of Energy Resources and Technology, ASME Publication, Paper Number : JERT-06–1055.

Cherng-Yuan Lin. & Kuo–Hua Wang. (2004). *Effects of an Oxygenated Additive on the Emulsification Characteristics of two and three Phase Diesel Emulsions* – Elsevier – Journal of Fuel – Fuel 83 (2004) 507-515.

Eugene. E. Ecklund.; Richard Bechtold L.; Thomas J.; Timbario. & Petter W. McCallum. (1984). *State of the Art Report on the use of Alcohols in Diesel Engines,* SAE Technical Paper No: 840118.

Ganesan.V. (1998). *Internal Combustion Engines,* Publisher - Tata McGraw–Hill Book Company.

Jae W.Park.; Kang Y.Huh. & Kweon H.Park. (2000). *Experimental Study on the Combustion Characteristics of Emulsified Diesel in a RCEM*–Seoul 2000 FISITA World Automotive Congress – Paper No: F2000A073.

Mark.P.B.Musculus. & Jef Dietz. (2005). *Effects of Diesel Fuel Combustion – Modifier Additives on In–Cylinder Soot formation in a Heavy Duty DI Diesel Engine,* Sandia National Laboratories, Sandia Report, SAND – 2005 – 0189.

Masahiro Ishida.; Hironoku.Ueki. & Daisaku Sakauguo. (1997). *Prediction of NOx reduction rate due to port water Injection in a DI Diesel Engine,* SAE Paper No: 972961.

Masahiro Ishida. & Zhi-Li Chen. (1994). *An Analysis of the added water effect on NOx Formation in DI Diesel Engines*, SAE Technical Paper No: 941691.

Minoru Tsukahara.; Yasufumi Yoshimoo. & Tadashi Murayama. (1989). *W/O Emulsion Realizes Low Smoke and Efficient Operation of DI Engines without High Pressure Injection,* SAE Technical Paper No: 890449.

Moses . C.A.; Ryan.T.W. & Likos. W.E. (1980). *Experiments with Alcohol/ Diesel Fuel Blends in Compression Ignition Engines*. In: VI International Symposium on Alcohol Fuels Technology, Guaruja, Brazil.

Naveen Kumar.; P.B.Sharma.; L.M.Das. & S.K.Garg . (2004). *Ethanol – Diesel Emulsion as Diesel Fuel Extender*. SAE Technical Paper No: 2004 – 28 – 032.

Santhanalakshmi. J. & Maya.S.I. (1997). *Solvent Effects on Reverse Micellisation of Tween-80 and Span-80 in Pure and Mixed Organic Solvents* – Proceedings of the Indian Acad. Sci (Chem.Sci), Vol: 109, No: 1997: Page No: 27 -38.

Svend Henningsen. (1994). *Influence of the Fuel Injection Equipments on NOx Emission and Particulates on a Heavy – Duty Two – Stroke Diesel Engine Operating on Water–in–Fuel Emulsion*, SAE Technical Paper No: 941783.

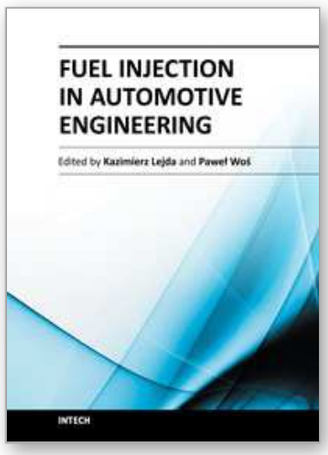
Subramanian.K.A. & Ramesh.A. (2001). *Experimental Investigation on the Use of Water Diesel Emulsion with Oxygen- Enriched Air in a Di Diesel Engine*. SAE Technical Paper 2001-01-0205.

Teng Zhang. & Dian Tang. (2009). *Current Research Status of Corrosion Resistant Coatings*, 2009, Recent Patents on Corrosion Science, 2009, *1*, 1-5.

Tsukahara.M. & Yoshimoto, Y. (1992). *Reduction of NOx, Smoke, BSFC, and Maximum Combustion Pressure by Low compression ratios in a Diesel Engine Fueled by Emulsified fuel*. SAE Technical Paper No: 92046.

Tsukahara.M.; Murayama.T. & Yoshimoto. Y. (1982). *Influence of Fuel Properties on the Combustion in Diesel Engine Driven by the Emulsified Fuel,* Journal of the JSME, 1982, Vol. 25, No: 202, pp. 612 – 619.

Wagner U.; Eckert P. & Spicher U. (2008). *Possibilities of Simultaneous In–cylinder Reduction of Soot and NOx Emissions for Diesel Engines with Direct Injection*. International Journal of Rotating Machinery – Vol No: 2008: Article ID: 175956.



Fuel Injection in Automotive Engineering

Edited by Prof Kazimierz Lejda

ISBN 978-953-51-0528-2
Hard cover, 144 pages
Publisher InTech
Published online 20, April, 2012
Published in print edition April, 2012

The main topic of "Fuel injection in automotive engineering" book is fundamental process that determines the development of internal combustion engines and performances of automotive vehicles. The book collects original works focused on up-to-date issues relevant to improving injection phenomena per se and injection systems as the engine key components.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

M. P. Ashok (2012). Role of Emulsified Fuel in the Present IC Engines - Need of Alodine EC Ethanol Corrosion Resistant Coating for Fuel Injection System, Fuel Injection in Automotive Engineering, Prof Kazimierz Lejda (Ed.), ISBN: 978-953-51-0528-2, InTech, Available from: http://www.intechopen.com/books/fuel-injection-in-automotive-engineering/role-of-emulsified-fuel-in-the-present-ic-engines-need-of-alodine-ec-ethanol-corrosion-resistant-coa

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the Creative Commons Attribution 3.0 License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen