Emission Control in CI Engine using Ethanol Emulsion

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***Abstract*–**In a laboratory experiment was conducted on the utilization of Ethanol-Diesel emulsion in a single cylinder direct injection diesel engine, a single cylinder, water cooled, four stroke diesel engine was used. The principal goals of the present work are to obtain emission data and combustion characteristics for this type of Diesel Engine, and to identify the ratio of Emulsion which is effective in reducing emissions. Experiments were conducted with emulsions viz (90%diesel + 10%ethanol), (80% diesel + 20% ethanol), (70% diesel + 30%ethanol) as fuel. While AVL smoke meter was employed to measure the smoke density in HSU, the exhaust gas analyzer was used to measure the NO_x emission. High volume sampler was employed to measure the particulate matter emitted at the exhaust. The combustion characteristics were studied using AVL combustion analyser. From the experimental investigation it was found that the smoke, particulate matter and Oxides of Nitrogen emissions were reduced marginally. From the pressure curve and cumulative heat release curve, it was observed that the combustion started earlier and the rate of pressure rise increased marginally.

Keywords—Emission, NOx, Particulate matter, Emulsion and Smoke Density.

I. INTRODUCTION

As a result of research conducted in the 1980's on the use of ethanol blend with diesel, it was shown that ethanol-diesel blends were technically acceptable for existing diesel engines. It has already been accepted that Diesel engines have better fuel efficiency, high power output and greater thermal efficiency but generate undesirable emissions during the combustion process. There has been a constant search for alternate fuels, which will meet the present emission norms, in view of the unsatisfactory emission characteristics.

The major pollutants from a diesel engine are Oxides of Nitrogen (NOx), Smoke, Particulate Matter, Carbon monoxide, Unburnt Hydrocarbons and Carbon dioxide Of these Smoke, Particulate Matter and Oxides of Nitrogen (NO_x) are the three main pollutants from Diesel engine.

There are many techniques being adopted to control the above emissions and to improve the performance of the Diesel engines. The following techniques may be employed to reduce the pollutants and to improve the performance of Diesel engines.

- ❖ Methods to modify engine operation
- ❖ Modification of fuel
- ❖ Change of Design

A number of adjustments like retardation of fuel injection, the EGR effect, a high pressure injection system and providing after injection are tried to reduce the emission levels in Diesel engines.

Fuel modification technique like fuel additives, modified fuel, hybrid fuel etc. reduces Engine emissions. Diesel Emulsion with Alcohols also reduces emission and increases engine performance. Engine Design changes like intake system modification for better mixing of air and fuel, pre-chamber injection aims to reduce the emission and increases the engine performance.

Amongst many methods available to reduce emissions, emulsion is the simplest method. This leads to the use of ethanol as an alternate fuel for diesel engines. In this research, to reduce the emission and to improve the performance of Diesel engine, the fuel modification technique was employed. Ethanol-Diesel emulsion was used in this project work. Various proportions of Ethanol and Diesel fuel were injected into the engine and the performance and emission characteristics were investigated.

II. DIESEL ENGINE POLLUTANTS AND ITS CONTROLLING METHODS

The major pollutants from diesel fuel vehicles are Particulate Matter (PM), smoke, NO_x, Sulphur di-oxide, CO and HC. Most of this pollutant's are emitted from the exhaust. Because diesel engines operate at high air-fuel ratios, they tend to have low HC and CO emissions. They have considerably higher PM emissions than gasoline-fueled vehicles; however, for heavy-duty vehicles CO, HC and NO_x emissions in the exhaust also vary with driving modes, engine speed and load.

A. Pollutant from Diesel Engine

The following pollutants are coming under regulated emissions. They are Smoke, Oxides of Nitrogen, Particulate matter, Oxides of Sulphur, Hydro carbon and Carbon monoxide.The following pollutants are coming under unregulated emissions. They are polycyclic aromatic hydrocarbon (PAH), Ketone, Aldehydes and 3-Nitrobenzanthrone

The Following Factors Causes the Pollutants

The factors causing the pollutants are incomplete combustion, Injection of fuel, Air-fuel ratio, Time of injection, High excess air, Availability of oxygen and Fuel atomization

Diesel Engine Pollution Control Methods

Control Methods

The diesel vehicles emit carbon monoxide, hydrocarbons, oxides of nitrogen, and oxides of Sulphur, particulate and smoke. In addition to these pollutants, secondary pollutants are formed through chemical reactions between the vehicle emissions and the constituents of normal atmosphere. These emissions are highly harmful to human beings and plants as well.

The exhaust emissions can be controlled by any one of the following methods

- Design parameters
- Operating parameters
- In – cylinder combustion control
- Exhaust gas treatment

The after treatment control methods do not solve all the problems and improve the performance of diesel engines. It becomes necessary to adopt the technique of in-cylinder treatment to control the emission from C.I engine and improve the performance.In this research, in-cylinder treatment method is followed and three different techniques are adopted. They are

- Catalyst coatings in the combustion chamber
- Fuel modification
- Exhaust gas recirculation

Catalyst coating in the combustion chamber

The catalyst coated on the combustion chamber induces faster chemical reaction and completes combustion resulting in reduction of emission from the engine. There are many techniques generally used to coat the combustion chamber and other engine components. They are anodic coating, cathodic coating, hot dipping, emission plating, metallized coating, diffusion coating and electroplating.

Fuel Modification

Another method of emission control on diesel engine is by fuel modification. The principal requirement of fuels for high speed diesel engine is good ignition quality. Poor ignition quality fuel can load to extended ignition delay and the result in diesel knock. To modify the fuel quality, additive can be added in small quantity either to enhance engine performance or reduce the emission. There are different types of fuel additives. They are detergents, cetane improvers combustion catalysis, deposit modifiers, flow improvers, smoke suppressants and oxygenated fuel additives.

Exhaust gas re-circulation

A portion of the exhaust gas is re-circulated to the cylinder intake change, which reduces the peak combustion temperature since the inert gas serves as a heat sink. This in turn reduces the cylinder temperature resulting in the reduction of NOx. But simultaneously unavailability of oxygen causes increase in particulate emission due to incomplete combustion.

Exhaust Gas treatment

An exhaust treatment technology that substantially reduces diesel engine particulate emissions is the trap oxidizer. A temperature – tolerant filter or trap removes the particulate material from the exhaust gas; the filter is then "cleaned off" by oxidizing the accumulated particulates.

III. TECHNIQUES OF USING ETHANOL IN DIESEL ENGINES

Alcohol cannot be used as a neat fuel in C.I. engines due to its poor self ignition character, low calorific value, and high latent heat of vapourisation .To overcome this, engine modification is adopted. Alcohol would require high compression ratio due to high self-ignition temperature, long ignition delay and high latent heat of evaporation. Even with high latent heat of evaporation the problem of starting in cold conditions and low load running conditions are present. Hence without alcohol as the total fuel and without affecting engine modifications it can be used easily as a part of the substitute for diesel oil in the dual fuel operation of the engine.

A. Properties of Ethanol

Ethanol is the simplest alcohol, containing two carbon atoms. It is colorless, tasteless liquid with a very faint odour Ethanol is one of the number of fuels that could substitute for gasoline or diesel fuel in passenger cars, light trucks, heavy-duty trucks and buses. Ethanol's physical and chemical characteristics result in several inherent advantages as an automotive fuel.

Ethanol requires less air per kilogram of fuel as compared to hydrocarbon fuels as the stoichiometric air fuel ratio is 9: 1. To generate the same amount of power of about 55 percent, more weight of ethanol will be required than that of diesel oil as the heat of combustion of ethanol is 27,000 kJ/kg against 42,800 kJ/kg for diesel. Alcohol fuel has a very high latent heat of vapourisation which reduces the charge temperature and improves the volumetric efficiency. Due to their low molecular weight its vapour occupies more volume. The cetane value of ethanol is low. Low cetane value of ethanol shows large ignition delay in diesel engine and poor ignition quality. Hence it is not a suitable fuel for diesel engines.

Thus alcohol can be used as partial substitution of diesel fuel without major modification to the engines. Alcohol can be supplied by fumigation on the induction manifold by spray and diesel fuels as pilot spray in a dual fuel configuration requires a slight modification in the inlet manifold.

Property	Ethanol	Diesel
Octane number	106-108	39
Cetane number	8	50
Carbon percent (by weight)	52	--
Hydrogen percent (by weight)	13	--
Oxygen percent (by weight)	35	--
Boiling point (°C)	78	180-330
Flash point (°C)	21	75
Self ignition temperature (°C)	420	200-420
Viscosity at 20°C	1.2	3.9
Stoichiometric A/F ratio	9	14.6
Percent by volume in air	4.3-19	1.5-8.2
Lower heating value (kJ/kg)	27,000	42,800
Latent heat of evaporation (kJ/kg)	840	300
Liquid density (kg/m^3)	794	830
Molecular weight	46	--

Table 1 Properties of Ethanol and Diesel

B. Methods of Utilizing Alcohol in Diesel Engines

There are many techniques by which ethanol can be used as a fuel in compression ignition engines. The techniques are Solution, Fumigation, Dual Injection, Spark Ignition, Ignition Improvers and Surface Ignition.

The easiest method by which ethanol can be used is in the form of solutions. But ethanol has limited solubility in diesel; hence ethanol/diesel solutions are restricted to small percentages (typically 20%). This problem of limited solubility has been overcome by emulsions that have the capability of accommodating larger displacement of diesel up to 40% by volume. But the major drawbacks of emulsions are the cost of emulsifiers and poor low temperature physical properties.

Fumigation is a method by which ethanol is introduced into the engine by carbureting or vapourising the ethanol into the intake air stream and about 50% of the fuel energy can be derived from ethanol under road load conditions. This method requires addition of a carburetor or a vapouriser along with a separate fuel tank, lines and controls. Also the distribution of ethanol will be uneven as the diesel intake manifolds are not designed to handle two-phase flows.

Dual injection is a method by which nearly 90% displacement of diesel by ethanol is possible. The drawbacks of this method include the complexity and expense of a second injection system and a second fuel tank and system. Fuel injection pumps and injectors to handle neat ethanol have not yet been developed. Also converting to dual injection requires, space in the combustion chamber be available for a second injector at a location where the injector can be effective.

Spark ignition of neat ethanol in diesel engine provides a way of displacing 100% of diesel. A spark plug and the associated ignition system components must be added to the engine

Another method of using neat ethanol is to increase their cetane numbers sufficiently with ignition improving additives to ensure that compression ignition will occur. This method saves the expense and complexity of engine component changes, but adds in fuel cost.

Surface ignition is another method of using 100% ethanol in diesel engines. Surface ignition occurs when the temperature of the air-fuel mixture adjacent to a hot surface exceeds its self-ignition limit.

IV. EMULSIONS - THEORY AND PREPARATION

Emulsion theory is partly an outgrowth of classical colloid chemistry. The colloid state is a heterogeneous dispersion of two immiscible phases. If both, the dispersed phase and the dispersion phase are liquids it is called Emulsion.An emulsion is a two-phase liquid system consisting of fairly coarse dispersions of one liquid in another in the form of droplets, whose diameter, in general, exceeds 0.1 microns.Of the two phases, dispersed phase is present in the form of finely divided droplets (greater than 0.1 microns) and the dispersion phase or continuous phase is one which forms the matrix in which these droplets are suspended.

A. Types of Emulsion

Generally there exist two distinct emulsion types.

(i) Oil-in-Water type.

(ii)Water-in-Oil type

B. *Application of Emulsions*

Emulsions find wide application in the areas like Pharmaceutical preparation, Halibut-liver oil, cleaning action of soap, Paint industries, Ice cream production, etc.

Of the two types of emulsions, Water-in-Oil type is suited better type of fuel for Internal Combustion Engines, rather than Oil-in-Water type. While using emulsion as fuel the care must be taken so that there may be no side effects and we should also succeed economically in producing them. The reason behind .the use of *W/O* emulsion as engine fuel is mainly due to the micro-explosion phenomenon of droplet of water which causes large fragmentation of the oil and less change in viscosity with water content.

C. *Emulsifying Agents*

Emulsifying agents are chemicals which are added during the process of emulsion preparation. The main aim of adding emulsifying agents is to reduce the interfacial tension between the two liquid phases to form a homogenised stable solution.

D. *Types of Emulsifier*

a. Anionic
b. Cationic
c. Nonionic

Only Nonionic emulsifying agents are suggested for preparing emulsified fuel for engine applications owing to its non reactive and non corrosive nature without any source for secondary pollutant formation in engines.

E. *Emulsion Instability*

It is well said that an emulsion is stable only when the large droplets are broken down into fair dispersible droplets. The fact is that even the most stable emulsion bears within itself the seeds of its own destruction. Emulsions can show instability in three ways. They are Breaking, Creaming and Flocculance.

F. *Emulsion Preparation*

To get a stable emulsion, with a larger number of droplets of one liquid dispersed into the other liquid, considerable ingenuity must be employed. In a general way, droplets of the required size may be obtained by two different approaches.

One can either start from very tiny nuclei and then allow them to grow to the required size, which is the basic idea of the condensation method, or break up large drops of the bulk liquid into small droplets, which are the basis of the dispersion method.

The common method of preparing emulsions is to apply brute force to breaking up of the interface into fine shreds and globules (dispersion method). This can be achieved by any of the following methods. They are Mixing, Colloid milling and Homogenizing.

It is a known fact that energy is required not only to create new interfaces but also to set the liquid in motion against viscous resistance in the emulsifying machinery. Normally it’s seen that the simple mixers have substantially less power requirement than colloid mills or homogenizers of similar capacity.

Although mixers, colloid mills, and homogenizers are now the standard methods of producing emulsions on a large scale, of late a number of other methods have become available. Foremost among them are the Sonic and Ultrasonic methods. Sound energy is more economical *to* the above mentioned problems and power requirement and the advantages are notable. For this it is sufficient to have generators producing sound waves in liquids. This is achieved by converting electrical energy, into sound energy in the audible frequency range which intern is further converted into mechanical vibration. The intense agitation in the Ultrasonic vibrator which increases the number of collisions between the dispersed droplets, and hence increasing the possibility of coalescence which results in a stable emulsion with very small diameter sizes of fuel droplets.

In this research, fuel modification method was adopted in this project work. Here in this work, Ethanol and Diesel were blended to form an Emulsion and this Emulsion was used as a fuel. Under normal conditions, Ethanol and Diesel remains unmixed. This is due to the density difference between the two liquids. In order to break the surface tension and to blend the two liquids each other an Emulsifying agent was used in this work.

The following Emulsifiers were tried

1) Sodium laurrylsulphate (SLS)
2) Sorbitanemonooleate
3) Tritron -X –100

G. *Emulsified Fuel Mixing Procedure*

Diesel and Ethanol were taken in various ratios viz, 90:10, 80:20, and 70:30. Then accurately weighed quantity of ‘SLS’ was poured into the fuel mixture.

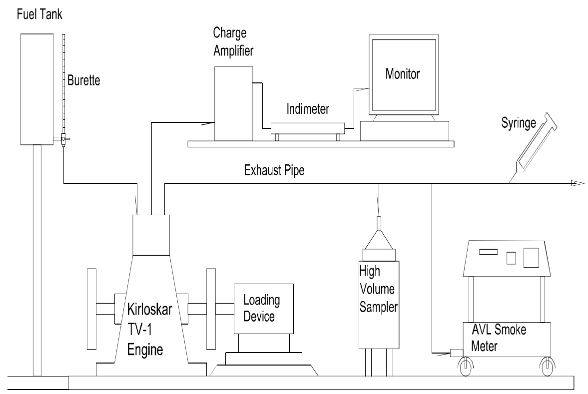
Then the mixture was stirred by using a mechanical stirrer to about one hour. Then the mixture was again stirred by using sonic vibrator. Then the time taken for separation of the two liquids was noted.It was observed that the separation took place within a few minutes after stirring was stopped. Hence SLS was found unfit for this purpose.

Then the second Emulsifying agent, sorbitanemonooelate was tried. The same above procedure for SLS was followed for sorbitanemonooelate. Since sorbitanemonooleate is a liquid, 1ml of the above emulsifier was applied to the mixture. After stirring, it was observed that the Emulsion got separated within a few minutes.Tritron-X-100 a neutral emulsifier was tried at last. It was found that the emulsion lasted for 30 minutes. Hence this emulsion was selected. 1.5% of the total volume of the fuel was the amount of emulsifier added in the case of Tritron-X-100.

A separate fuel tank was fabricated such that mechanical stirrer can be introduced in to the tank. The stirrer was on during the running of engine in order to maintain the emulsion. Then the Load and Emission test were carried out and the observations were tabulated in subsequent chapters.

V. Experimental Setup

A vertical, water cooled, single cylinder, four stroke, Direct Injection Engine was used for the study. The engine was coupled to a eddy current Dynamometer for load measurement .The smoke density was measured using a Hartridge smoke meter. NO_x emissions were measured using exhaust gas analyzer. PM was measured using High volume sampler of experiments were carried out in four different stages. In the first phase, base reading was obtained using neat Diesel fuel. In the other three phases, the engine performance was studied using 10, 20, and 30% of ethanol-diesel emulsions. The results of 10, 20, and 30% of Ethanol-Diesel emulsions have been compared with that of the base fuel.



Experimental Setup

A. Engine Details

Kirloskar TV1 Engine

Engine Specification

Type of Engine	:	Vertical
		Four stroke
		Single acting
		Water cooled
Rated power	:	5.2 Kw @ 1500 rpm
Cylinder dia	:	0.0875 m
Stroke length	:	0.11m
Compression ratio	:	17.5: 1

Loading Device

Eddy current Dynamometer

Dynamometer Arm Length –0.195 m

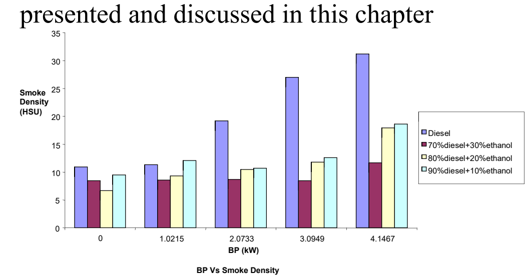
1. The water flow is started and maintained at some flow rate.The load, speed and temperature indicators were switched on.
2. The engine was started by cranking after ensuring there is no load.The engine is allowed to run at the rated speed of 1500 rpm for a period of 20 minutes to reach the steady state.
3. The fuel consumption is measured by a stop watch.Smoke readings were measured using the Hartridge smoke meter at the exhaust outlet.
4. The amount of Particulate Matter was measured using the high Volume Sampler.The amount of NOx was measured by using Exhaust gas Analyser.
5. The exhaust temperature was measured at the indicator by using a sensor.Then the load is applied by adjusting

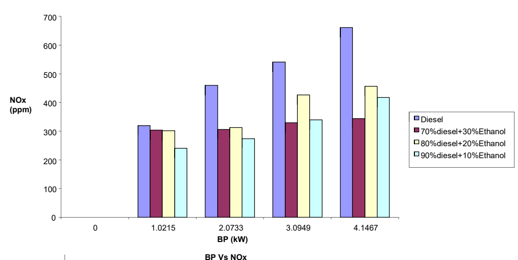
the knob which is connected to the eddy current dynamometer.

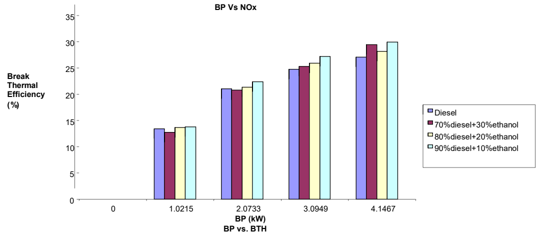
6. Experiments were conducted using neat diesel and Ethanol-diesel emulsions as fuel and the above procedure is adopted.

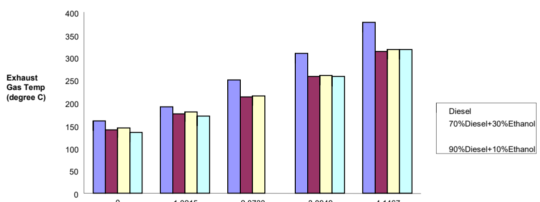
VI. RESULTS AND DISCUSSION

The results obtained from the experimental investigation using Emulsion of different for controlling Emissions are presented and discussed in this chapter









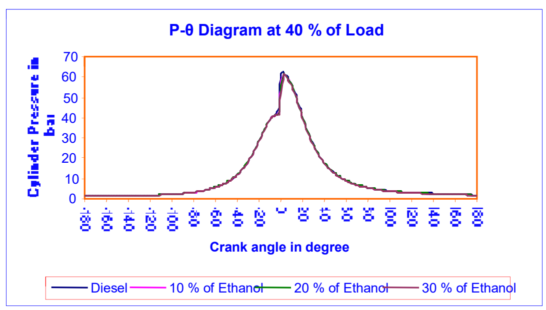
Graph shows the variation of smoke density with different percentages of emulsion with respect to Brake power of the Engine. Smoke level increases the Brake power of the engine increases. This is due to insufficient Oxygen available during combustion.70:30 proportion of emulsion shows maximum reduction of smoke density when compared to other proportions.

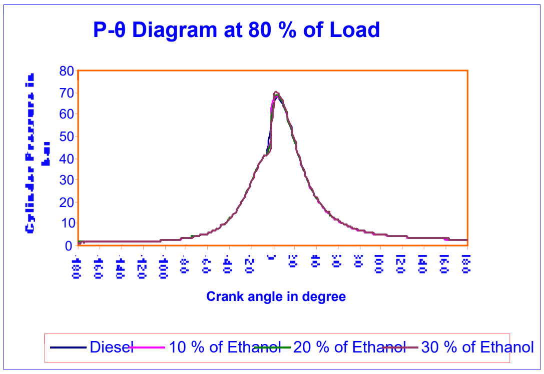
Graph shows the variation of NO_x with Brake power of the Engine. Brake power increases, the NO_x level also increase. This is due to high combustion temperature.70: 30 proportion of emulsion marginally reduces the NO_x emission.

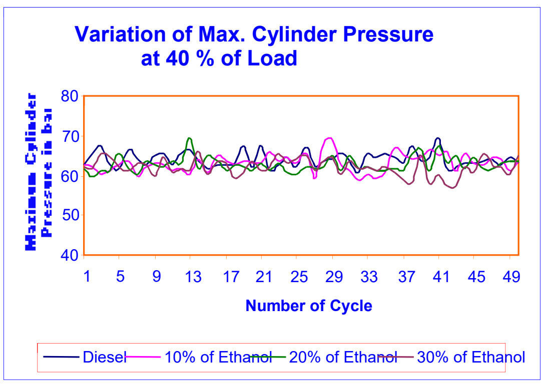
Above graph shows the variation of PM with the Brake power of the engine. Brake power increases, the particular Matter level also increases.70: 30 and 90:10 ratios shows appreciable amount of reduction of particulate matter 80:20 ratio also comparatively reduces the particulate Matter emissions.

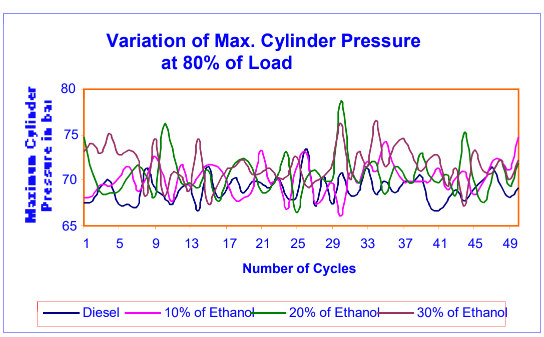
Graph shows the variation of Brake Thermal Efficiency with percentage of emulsion blended with diesel at different Brake power.90: 10 ratio of the emulsion shows Maximum Brake Thermal Efficiency. The other percentages, there is no appreciable changes. Brake power increases the exhaust gas temperature also increases.90:10 proportion of Emulsion shows a great reduction in exhaust gas temperature. 70:30 and 80:20 proportions of emulsions also shows an appreciable change in the exhaust gas temperature.

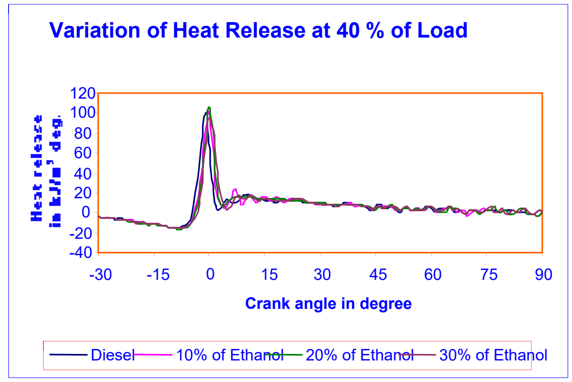
Combustion Analysis

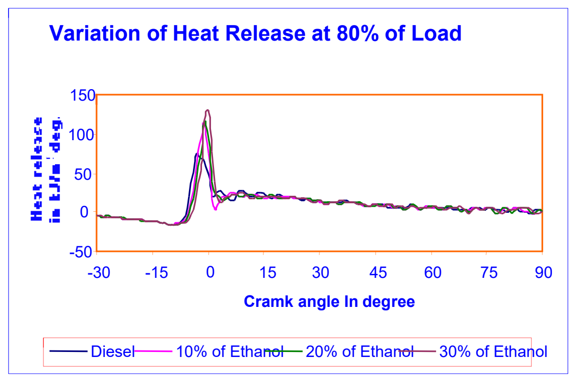












The pressure curve, rate of pressure rise and cumulative heat release rate curve with crank angle are shown in the above figures.It can be observed that the release of heat energy for 70:30 emulsion higher and combustion starts earlier. The rate of pressure rise also increases marginally the same percentage.

VII. CONCLUSION

The above experimental analysis led to the following conclusions.

There was a reduction at the smoke level by 18 HSU with 70:30 proportion, 15 HSU with 80:20 proportions and 14 HSU with 90:10 proportions of emulsions.(for 60%load). The NO_x

got reduced by 200 ppm with70:30 proportion and 90:10 proportion and 100 ppm with 80:20 percentage of emulsion blended with diesel at 60% of the rated Brake power.

A reduction of $2.6x10^{-3}$ g/min for 70:30 proportion, $4x10^{-4}$g/minfor 80:20 proportion and 3.8 $x10^{-3}$ g/minfor 90: 10 ratio of emulsion blended with diesel at 60% of the rated Brake power was deserved in the particulate matter. It was noted that the exhaust gas temperature got reduced by 20 to 70°C with 90: 10 proportion of emulsion blended with diesel. Appreciable decreases in exhaust gas temperature for 70:30 and 80:20 proportions were also observed.

The Brake Thermal Efficiency got increased by 2% with90:10 proportions of emulsion, 1% with 80:20 proportion and 0.5%with 70:30 proportion of emulsion blended with diesel at 60% of the rated Brake power.The cumulative heat release rate started early and the total heat release was higher with emulsion blended with diesel.

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