AN EXPERIMENTAL INVESTIGATION OF ETHANOL-DIESEL BLENDS ON PERFORMANCE AND EXHAUST EMISSIONS OF DIESEL ENGINES

A Project report Submitted in partial fulfilment of The

Requirements for the award of the degree of

BACHELOR OF TECHNOLOGY IN

MECHANICAL ENGINEERING

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This is to certify that the Thesis/Dissertation entitled **" AN EXPERIMENTAL INVESTIGATION OF ETHANOL-DIESEL BLENDS ON PERFORMANCE AND EXHAUST EMISSIONS OF DIESEL ENGINES"** that is being submitted by KARTIK THAKUR (18B21A03B0) in partial fulfilment of the requirement for the award of the degree of Bachelor of Technology in **MECHANICAL ENGINEERING** from the **Kakinada institute of engineering and technology** is a record of Bonafede work carried out by him under my guidance and supervision The results embodied in this thesis have not been submitted to any other university or institute for the award of any degree .

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ACKNOWLEDGEMENT

It is a great pleasure for me to express my gratitude to our honourable CHAIRMAN Sri. P.V VISHAM, for giving the opportunity and platform with facilities in accomplishing the project-based laboratory report. I express the sincere gratitude to our HOD MR. VIRENDRA for his administration towards our academic growth. I express sincere gratitude to CTPO MR. K SUDHAKAR sir for his leadership and constant motivation provided in successful completion of our academic semester. I record it as my privilege to deeply thank for providing us the efficient faculty and facilities to make our ideas into reality. I express my sincere thanks to our project supervisor Dr. M PRASAD sir for his novel association of ideas, encouragement, appreciation and intellectual zeal which motivated us to venture this project successfully. Finally, it is pleased to acknowledge the indebtedness to all those who devoted themselves directly or indirectly to make this project report success.

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ABSTRACT

diesel fuel also called diesel oil, is any liquid fuel specifically designed for use in a diesel engine, a type of internal combustion engine in which fuel ignition takes place without a spark as a result of compression of the inlet air and then injection of fuel. Therefore, diesel fuel needs good compression ignition characteristics. The most common type of diesel fuel is a specific fractional distillate of petroleum fuel oil, but alternatives that are not derived from petroleum, such as biodiesel, biomass to liquid (BTL) or gas to liquid (GTL) diesel are increasingly being developed and adopted. Ethanol is naturally produced by the fermentation of sugars by yeasts or via petrochemical processes such as ethylene hydration. It has medical applications as an antiseptic and d.nfectant. Its formula can be also written as $CH_3{-}CH_2{-}OH$ or C_2H_5OH (an ethyl group linked to a hydroxyl group), and is often abbreviated as EtOH. Ethanol is a volatile, flammable, colourless liquid with a characteristic wine-like oudor and pungent taste. Blends of up to 15% of ethanol in diesel fuel, known as e-diesel, can be used in compression ignition engines. E-Diesel can produce certain reductions in regulated diesel emissions, especially those of diesel particulate matter. Disadvantages of e-diesel include low flash point, which may present a safety issue. Advantages of ethanol-diesel blends are it is renewable and produces less pollutant and it is eco-friendly.

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CHAPTER-I

INTRODUCTION

Diesel engines have been widely used as engineering machinery, automobile and shipping power equipment due to their excellent drivability and economy. Diesel engines are widely used as power sources in medium and heavy-duty applications because of their lower fuel consumption and lower emissions of carbon monoxide (co) and unburned hydrocarbons (HC) compared with gasoline engines. Rudolf Diesel, the inventor of the diesel engine, ran an engine on groundnut oil at the Paris Exposition of 1900.Since then; vegetable oils have been used as fuels when petroleum supplies were expensive or difficult to obtain. With the increased availability of petroleum supplies were expensive or difficult to obtain. With increased availability of petroleum in the 1940s, research into vegetable oils decreased.

Diesel engine combustion produces particulate matter (PM), in which the fine particulates are believed to be the main factor accounting for problems of the human respiratory tract. The fine particles most likely to cause adverse health effects are PM10 andPM2.5 (particles with an aerodynamic diameter smaller than 10 mm and 2.5 mm respectively). Almost all fine particulates are generated as a result of combustion processes, diesel-fuelled engine combustion, and various industrial processes. PM can be reduced when sufficient oxygen is available in the combustion chamber; thus, utilization of oxygen containing fuels in diesel engines is expected to decrease PM10 and PM2.5.

The global fuel crises in the 1970s triggered awareness amongst many countries of their vulnerability to oil embargoes and shortages. Considerable attention was focused on the development of alternative fuel sources, with particular reference to the alcohols. A blend of 10%dry ethanol and unleaded gasoline (E10) was commercially introduced into the US and continues to be marketed mainly in the Midwestern states. The use of ethanol blended with diesel was a subject of research in the 1980s and it was shown that ethanol–diesel blends were technically acceptable for existing diesel engines.

The relatively high cost of ethanol production at that time meant that the fuel could only be considered in cases of fuel shortages. Recently the economics have become much more favourable in the production of ethanol and it is able to compete with standard diesel. Consequently, there has been renewed interest in the ethanol–diesel blends with particular emphasis on emissions reductions.

An additional factor that makes ethanol attractive as a fuel extender or substitute is that it is a renewable resource. The dwindling fossil fuel sources and the increasing dependency of the USA on imported crude oil have led to a major interest in expanding the use of bio energy. The recent commitment by the USA government to increase bio energy three-fold in 10 years has added impetus to the search for viable bio fuels. The European Union (EU) have also adopted a proposal for a directive on the promotion of the use of bio fuels with measures ensuring that bio fuels account for at least 2%of the market for gasoline and diesel sold as transport fuel by the end of 2005, increasing in stages to a minimum of 5.75% by the end of 2010.In the last two decades of the 20th century, major advances in engine technology have occurred, leading to greater fuel economy in vehicles. The reduction of emissions from engines has become a major factor in the development of new engines and manufacturers are focusing considerable energy and resources in order to meet emissions standards specified by the USE environmental Protection Agency (EPA) and by the EU. As a result, the use of non-conventional fuels as a means of meeting these requirements has generated much attention.

When considering an alternative fuel for use in diesel engines, a number of issues are important. These issues include supply and distribution, integrity of the fuel being delivered to the engine, emissions and engine durability. The purpose of this review is to discuss the properties and specifications of ethanol blended with diesel fuel with special emphasis on the factors critical to the potential commercial use of these blends. These factors include blend properties such as stability, viscosity and lubricity, safety and materials compatibility. The effect of the fuel on engine performance, durability and emissions is also considered.

It can be considered as a renewable fuel. As a fuel for CI engines, ethanol has some advantages over diesel fuel, such as the reductions of soot, carbon monoxide (CO) and unburned hydrocarbon (HC) emissions.

1.1 PRODUCTION OF ETHANOL:

Ethanol is a renewable energy; it can be made from many raw materials such as sugarcane, molasses, cassava, waste biomass materials, sorghum, corn, barley, sugar beets, and etc. By using already improved and demonstrated technologies. During combustion ethanol reacts with oxygen to produce carbon dioxide, water and heat.

$$C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O + heat$$

The heat of the combustion of ethanol is used to drive the piston in the engine by expanding heated gases. Ethanol may also be produced industrially from ethane (ethylene). Addition of water to the double bond converts ethane to ethanol.

$$C_2H_4 + H_2O \rightarrow CH_3CH_2OH$$

During ethanol fermentation, glucose is decomposed into ethanol and carbon dioxide

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2 + heat$$

Fermentation:

Ethanol is produced by microbial fermentation of the sugar. Microbial fermentation will currently only work directly with sugars. Two major components of plants, starch and cellulose, are both made up of sugars, and can in principle be converted to sugars for fermentation.

Currently, only the sugar (e.g. sugar cane) and starch (e.g. corn) portions can be economically converted. However, there is much activity in the area of cellulosic ethanol, where the cellulose part of a plant is broken down to sugars and subsequently converted to ethanol.

The fuel ‘‘ethanolisation’’ of the world alcohol industry is set to continue. If all recently announced ethanol projects are implemented, total fuel ethanol production worldwide could grow to 31 billion litres by 2006 against approximately 20 billion litres in2001. The share of ethanol in global gasoline type fuel use increased from 3.7% to 5.4%. In 2009 worldwide ethanol fuel production reached 19.5 billion gallons (73.9 billion litres).

1.2. INJECTION TIMING:

The degree of crank angle before or after at which fuel injected is called injection timing. The physical factors that affect the development of the fuel spray and the air charge state (its presser, temperature, and velocity) will influence the ignition delay. These quantities depend on the design of the fuel-injection system and combustion chamber, and the engine operating conditions. The injection system variables affecting the fuel-spray development are injection timing, quantity, velocity, rate, drop size, and spray form or type. The relevant charge conditions depend on the combustion system employed, the details of the details of the combustion chamber design, inlet air pressure and temperature, compression ratio, injection timing, the residual gas conditions, coolant and oil temperature, and engine speed. For a diesel engine, fuel injection timing is a major parameter that affects the combustion and exhaust emissions. The state of air into which the fuel injected changes as the injection timing is varied, and thus ignition delay will vary. If injection starts earlier, the initial air temperature and pressure are lower, so the ignition delay will increase. If injection starts later (when piston is closer to the TDC) the temperature and pressure are initially slightly higher, a decrease in ignition delay proceeds. Hence, injection timing variation has a strong effect on the exhaust emissions, especially on the NO_X emissions, because of the changing of maximum temperature in the engine cylinder.

1.3. PRESENT WORK:

The objective of this study is to carry out an experimental study to investigate the solubility of diesel with ethanol, the blends mixed with the additive of normal butanol (n-butanol) and the performance and smoke from two cylinder diesel engine using by the blends at different injection pressers compared with that fuelled by pure diesel and also find out the performance and smoke by changing injection time on single presser is the 240bar and compare the blends with the diesel fuel. The blends are 10%, 15%, 20%, 25% ethanol, 5%butanol and diesel.

CHAPTER-II

LITERATURE REVIEW

Diesel engines have been widely used as engineering machinery, automobile and shipping power equipment due to their excellent drivability and economy. At the same time, diesel engines are major contributors of various types of air pollutants such as carbon monoxide

(CO), oxides of nitrogen (NOx), particulate matter (PM), and other harmful compounds. With the increasing concern of the environment and more stringent government regulation on exhaust emissions, the reduction in engine emissions is a major research objective in engine development. Based on the depletion of fossil fuels and environmental considerations has led to investigations on the renewable fuels such as ethanol, hydrogen, and biodiesel [1, 2].

Since 19th century, ethanol has been used as a fuel for compression ignition (CI) engines. S. Prasad, Anoop Singh [3, 4] reported ethanol is regarded as a kind of renewable fuel because it can be made from many kinds of raw materials such as corn, maize, sugar beets, sugar cane, cassava, etc. Frank Rossello-Calle, A. Luis [5-7] reported, it is having been successfully used to mix with petrol as part of the alternative to reduce the consumption of fossil fuel in Brazil since 1975. But ethanol has not been commercially used to replace part of the diesel fuel to diesel engines. Some investigation of the potential application of ethanol to fuel diesel engine have been done but the barriers for the application have not been overcome yet, due to the special properties of the ethanol compared to diesel, ethanol has lower density and lower viscosity.

Alan C. Hansen, Qin Zhang, Peter W.L. Lyne [8-9] reported the properties and specifications of ethanol blended with diesel fuel are discussed. Special emphasis is placed on the factors critical to the potential commercial use of these blends. These factors include blend properties such as stability, viscosity and lubricity, safety and materials compatibility. The effect of the fuel on engine performance, durability and emissions is also considered. Magin Lapuerta, Octavia Aromas, Reyes Garcia Contreras [10] reported the stability of diesel–bio ethanol blends for use in diesel engines; these characters of ethanol make it difficult to mix with diesel. Therefore, further studies are necessary to find the way to make ethanol be mixable with diesel and then applicable to diesel engines.

The main drawback is that ethanol is immiscible with diesel fuel over a wide range of temperatures, leading to phase separation. Consequently, in many cases the presence of a surfactant and co solvent additive in the e-diesel blend becomes necessary. In this paper the conditions in which the e-diesel blends are stable have been studied. The stability of samples is affected by three factors mainly: temperature, water content and initial ethanol content. The results show that the presence of water in the blends, low temperatures and high ethanol contents favour the phase separation whereas the presence of the additive leads to the opposite effect.

Jincheng Huang, Yaodong Wanga, Shuangding Li, Anthony P.Roskilly [11] conducted many experimental investigation on which additive is used for the solubility and the physical stability. The objective of this study is to carry out an experimental study to investigate the solubility of diesel with ethanol, the blends the two mixed with the additive of normal butanol (n-butanol) and the performance and emissions from diesel engine when fuelled by the blends compared with that fuelled by pure diesel.

Bang-Quan HeShi-Jin Shuai, Jian-Xin Wang, Hong [12-14] reported the effect of ethanol blended diesel fuels on emissions from a diesel engine.i.e the smoke emissions when the engine ran at the speed of 1500 r/min. When more ethanol added in, the more reduction of smoke emissions were. Al-Farayedhi AA, Al-Dawood AM, Gandhidasan P.[15] reported the effect of oxygenated fuel on exhaust gas temperature and experimental investigation of CI engine performance using oxygenated fuel.

Cenk Sayin, Kadir Uslu, Mustafa Canak [16] reported the influence of injection timing on the exhaust emission of a single cylinder, four stroke, direct injection, naturally aspirated diesel engine has been experimentally investigated using ethanol blended diesel fuel from 0% to 15% with an increment of 5%.The engine has an original injection timing 27^0 CA BTDC. The tests were performed at five different injection timings (21^0, 24^0, 27^0, 30^0, and 33^0 CA BTDC) by changing the thickness of advance shim. The experimental test results showed that NOx and CO2 emissions increased as CO and HC emissions decreased with increasing amount of ethanol in the fuel mixture. When compared to the results of original injection timing, at the retarded injection timings (21^0 and 24^0 CA BTDC), NOx and CO2 emissions increased, and unburned HC and CO emissions decreased for all test conditions. On the other hand, with the advanced injection timings (30^0 and 33^0 CA BTDC), HC and CO emissions diminished, and NOx and CO2 emissions boosted for all test conditions.

J. I. Dominguez, E. Miguel [17] reported the effects of different ethanol–diesel blended fuels on the performance and emissions of diesel engines have been experimentally evaluated and compared in this study. The different types of unmodified engines have been operated on several diesel blends containing up to 25% bio-ethanol and the results were compared with those of a certification-grade diesel used as the baseline fuel.

CHAPTER-III

PREPARATION OF BLENDS

There are number of fuel properties that are essential for the proper operation of a diesel engine. The addition of ethanol to diesel fuel affects certain key properties with particular reference to blend stability, viscosity and lubricity, energy content and cetane number. Materials compatibility and corrosiveness are also important factors that need to be considered. Ethanol solubility in diesel is affected mainly by two factors, temperature and water content of the blend. At warm ambient temperatures dry ethanol blends readily with diesel fuel. However, below about 10 ^{0}C the two fuels separate, a temperature limit that is easily exceeded in many parts of the world for a large portion of the year. Prevention of this separation can be accomplished in two ways: by adding an emulsifier which acts to suspend small droplets of ethanol within the diesel fuel, or by adding a co-solvent that acts as a bridging agent through molecular compatibility and bonding to produce a homogeneous blend (Lutcher, 1983). Emulsification usually requires heating and blending steps to generate the final blend, whereas co-solvents allow fuels to be ‘‘splash-blended’’, thus simplifying the blending process. Both emulsifiers and co-solvents have been evaluated with ethanol and diesel fuel.

The ethanol used in the tests was limited to essentially anhydrous ethanol because other kinds of ethanol are not soluble or have very limited solubility in the vast majority of diesel fuels. The solubility of ethanol in diesel fuel is dependent on the hydrocarbon composition, wax content and ambient temperature of the diesel fuel. This solubility is also dependent on the water content of the blend fuels. To overcome this problem, a solubilised is indispensable in ethanol–diesel blended fuel. Commercial diesel fuel and analysis-grade anhydrous ethanol (99.9% purity) was used in this test. The compound of ethanol–diesel blends involves solubilizer dosage, ethanol, and diesel fuel. The blending protocol was to first mix the solubilizer (1.5% v/v for all ethanol–diesel blends except for pure diesel fuel) with ethanol, and then blend this mixture into the diesel fuel. For example, 15% ethanol–diesel blends (E15–D) consistsof1.5%solubilizer, 15% ethanol, and 83.5% diesel. The presence of ethanol generates different physico-chemical modifications of the diesel fuel, notably reductions of cetane number, low heat content, viscosity, flashpoint, and pour point, etc. These modifications change the spray characteristics, combustion performance, and engine emissions. Compared to diesel, ethanol has lower density and lower viscosity. These characters of ethanol make it difficult to mix with diesel. To overcome that problem the blends two mixed with the additive of normal butanol (n-butanol).

3.1. STRATIFICATION (OR) PHASE SEPARATION OF ETHANOL–DIESEL FUEL BLENDS WITHOUT 5% SOLVENT:

Diesel, ethanol was used as the materials to form the blends with and without the additive of n-butanol. The properties of diesel, ethanol and n-butanol are shown in Table1.The purity of the ethanol used is of 99.9%. A series of tests was performed to observe the solubility of the two fuels in different mixing ratios. Diesel and ethanol were mixed into a homogeneous blend in a container bestirring it. The blends were kept in a glass container for observing the solubility and the physical stability. The volume percentages tested were 10%, 15%, 20%, 25% and 30% of ethanol with 90%, 85%, 80%, 75%and 70% of diesel, respectively, which were named as E10D90, E15D85, E20D80, E25D75 and E30D70.These are the blends without the additive of n-butanol and observe the time for phase separation of all the blends and write in the table form.

Fuel blend	E10 D90	E15 D85	E20 D80	E25 D75	E30 D70
Time for stratification	96(h)	50(h)	28(h)	5(h)	10(min)

Table: 3.1. Stratification (or) phase separation of ethanol–diesel fuel blends without 5% solvent.

Table: 3.1and Fig.3.1shows the test results of the solubility and the physical stability of the blends. From the figure and the table, it can be seen that all of the blends were stratified into two layers for the blend of ethanol with diesel after some times. E10D90 lasted92 h when it became separated; E15D85maintained 50hbefore separating; E20D80 maintained 28 h before separating; E25D75 and E30D70 were separated after5h and10 min after mixing. The results show that the blends of ethanol with diesel were not stable and were all separated.

3.2. STRATIFICATION (OR) PHASE SEPARATION OF ETHANOL–DIESEL FUEL BLENDS WITH 5% SOLVENT:

In order to solve the problem of phase separation, n-butanol was selected as an additive for further tests. The same processes is repeated for the mixing were performed with the blends of ethanol, diesel and n-butanol, the volume percentages were 10%, 15%,20%, 25% and30% of ethanol with 85%, 75%, 70% and 65% of diesel, respectively, and with a fixed percentage of 5% of n-butanol as a solvent, which were named as Z5E10D85, Z5E15D80, Z5E20D75, Z5E25D70 and Z5E30D65.Table-2 shows time for the stratification or phase separation of diesel and ethanol blends with n-butanol is used as an additive for further tests and same procedure is used for the formation blends.

Fuel blend	Z5E10 D85	Z5E15 D80	Z5E20 D75	Z5E25 D70	Z5E30 D65
Time for stratification	4months	3months	2 months	40days	28days

Table: 3.2. Stratification (or) phase separation of ethanol–diesel fuel blends with 5% solvent.

Table 3.2. Show the test fuels and the test results of the solubility and the physical stability of the blends. Shows the status when ethanol and diesel were added into the containers. It showed that the liquids in the containers were stratified into two layers when the blends were formed after the n-butanol were added in and stirred. The photos showed that ethanol and diesel were mixed well with the aid of n-butanol. It shows the states of the blends after being mixed for some days. The table showed that the phase separation of blends of diesel, ethanol and n-butanol. Z5 E10D85lasted 4months when it became separated. Z5E15D80 maintained 3months before separating; Z5E20D75 maintained 2months before separating; Z5E25D70 and Z5E30D65 were separated after 40days and 28days after mixing.

The results show that all of the blends with n-butanol were all lasted longer before the stratification happened. The blend of Z5E10D85 was of the best stability with very little and almost unseen stratification.

Fig: 3.1. Separation of ethanol–diesel fuel blend without 5% solvent.

Fig: 3.2. Ethanol–diesel blend with 5% solvent (after stirring and mixed).

CHAPTER-IV

BLENDS PROPERTIES

The presence of ethanol generates different physio-chemical modifications of the diesel fuel, notably reductions of cetane number, low heat content, viscosity, flashpoint, and pour point, etc. These modifications change the spray characteristics, combustion performance, and engine emissions. By addition of ethanol and n-butanol to diesel then those effects on diesel properties can be shown below.

1. Density:

Ethanol has low density compared with the diesel so the blend has no stability. To overcome this problem n-butanol is added to ethanol, diesel blend then it has good stability compare to diesel, ethanol blend. So, the variation of density of the blends by adding n-butanol as shown in figure below.

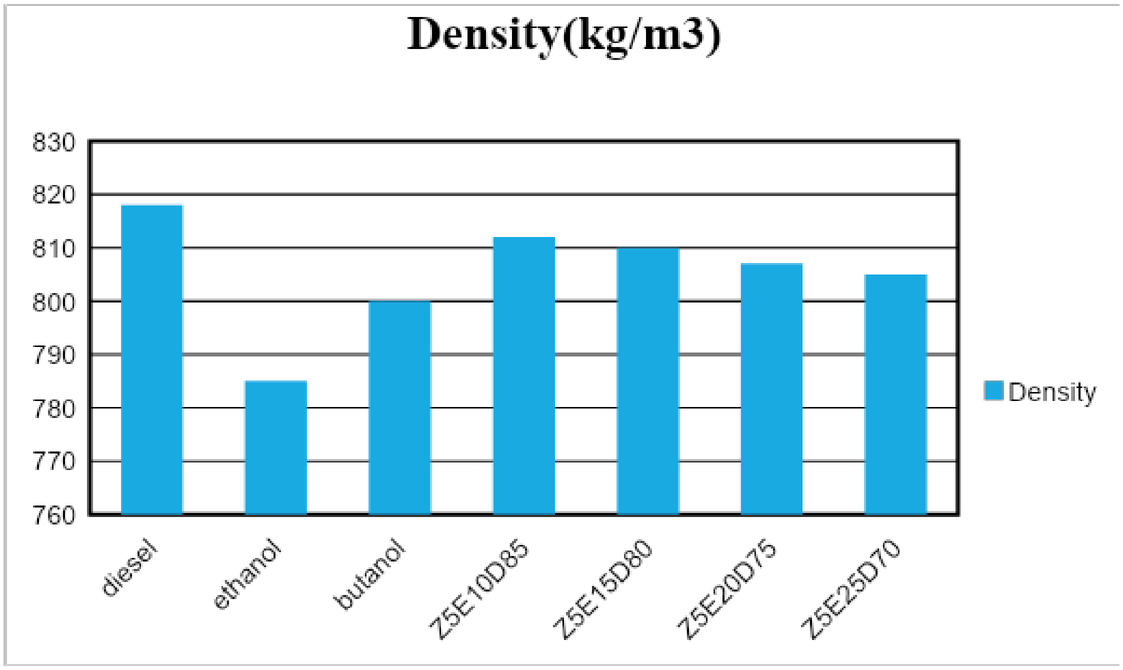

Fig: 4.1. Comparison of density of blended fuels with diesel.

2. Lubricity and viscosity:

Lubricity is a potential problem with oxygenated blended fuels. Fuel viscosity and lubricity characteristics play significant roles in the lubrication of fuel systems, particularly those incorporating rotary distributor injection pumps that rely fully on the fuel for lubrication within the high-pressure mechanism. Lower fuel viscosities lead to greater pump and injector leakage, which reduces maximum fuel delivery and power output. Lubricity is mainly governed by the kinematic viscosity. Kinematic viscosity cans be measured easily. Fig.2 shows the experimental results of blend fuels. As shown inFig.2, the addition of ethanol to diesel lowers fuel viscosity. With an ethanol contents of10–20%, the viscosity does not reach the minimum requirements for diesel fuels.

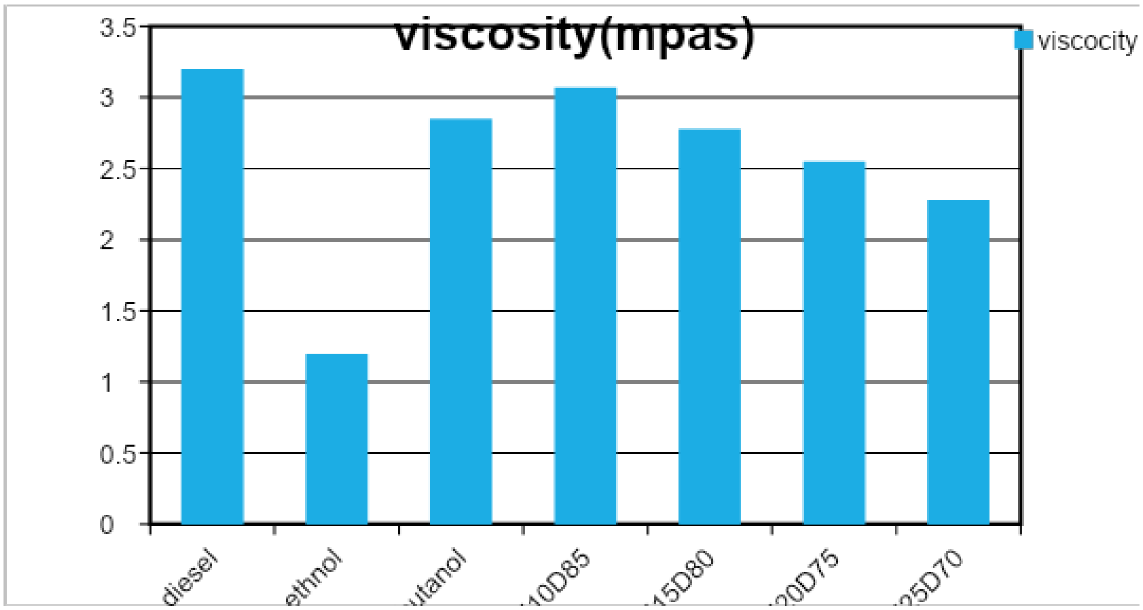

Fig: 4.2. Comparison Viscosity and lubricity of blended fuels with diesel.

3. Energy content:

The energy content of a fuel has a direct influence on the power output of the engine. The energy content of ethanol–diesel blends decreases by approximately 2% for each 5% of ethanol added, by volume, so that an additive n-butanol included in the blend then it increases the energy content than diesel, ethanol blend so it is also used for increase the energy content. Energy content of different blends as shown given below.

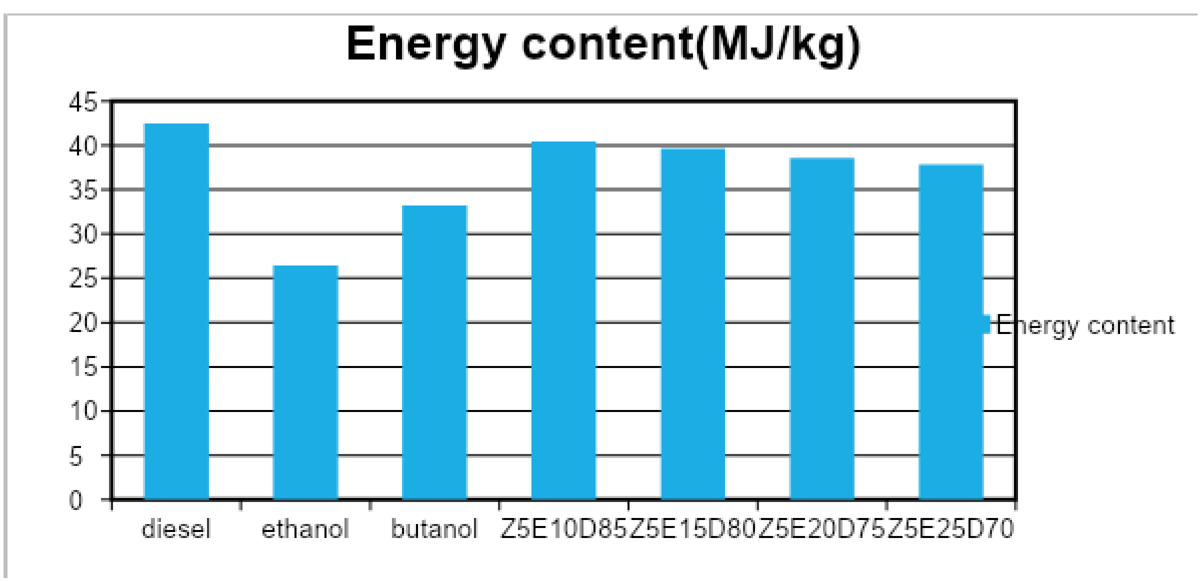

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Fig: 4.3. Comparison of Energy content of blended fuels with diesel.

4.Flash point:

The flash point is the lowest temperature at which a fuel will ignite when exposed to an ignition source. The flashpoint of the fuel affects the shipping and storage classification of fuels and the precautions that should be used in handling and transporting the fuel. In general, flash point measurements are typically dominated by the fuel component in the blend with the lowest flash point. The flashpoint of ethanol–diesel blend fuels is mainly dominated by ethanol.

5. Cetane number:

The cetane number is an important fuel property for diesel engines. It has an influence on engine start-ability, emissions, and peak cylinder pressure and combustion noise. A high cetane number ensures good cold starting ability, low noise and long engine life. Cetane numbers of blended fuel depend on the amount and type of additive used in the blends. So, n-butanol is added to ethanol, diesel blend. Because it has higher cetane number compare to the ethanol. Since the cetane number of ethanol is extremely low, the cetane number of the ethanol–diesel blends fuel reduces significantly. According to research carried out by Cork well, each 10-vol% ethanol added to the diesel fuel, results in a 7.1-unit reduction in cetane number of the resulting blend. However, they estimated that the cetane number of ethanol was between 5 and 15. Lower cetane numbers mean longer ignition delays, allowing more time for fuel to vaporize before combustions tarts.

6. Materials compatibility:

The use of ethanol in gasoline engines in the early1980s resulted in numerous materials compatibility studies, many of which are also applicable to the effect of ethanol–diesel blends in diesel engines and particularly in the fuel injection system. The quality of the ethanol has a strong influence on its corrosive effects. So, to avoid that problem anhydrous ethanol is used.

7.Comparison of properties of blends with diesel:

Properties	Diesel	Ethanol	n-Butanol	Z5E10 D85	Z5E15 D80	Z5E20 D75	Z5E25 D70
Density (Kg/m^3)	820	785	800	812	810	807	805
Viscosity (mpa-s)	3.20	1.2	2.86	3.07	2.78	2.55	2.28
Heat content (Mj/kg)	42.5	26.4	33.2	40.425	39.620	38.560	37.850

Table: 4.1. Comparison of properties of blends with diesel.

CHAPTER-V

EXPERIMENTAL PROGRAMME

5.1. The Experimental Setup:

A twin cylinder, four stroke, constant speed, water cooled, direct injection diesel engine is used for the experiments conducted. The technical specifications of the engine are as below.

Engine specifications:	
No. of cylinders	two
Bore	80.0 mm
Stroke	110.0 mm
Rated output	7.36 kW (10 hp)
Connecting rod length	230.0 mm
Compression ratio	16.5
Exhaust valve opens at	340°
Exhaust valve closes at	554°
Inlet valve opens at	527°
Inlet valve closes at	750°
Injection advance	18° BTDC
Speed	1500 rpm

Table: 5.1. Specifications of the test engine

5.2. INSTRUMENTATION:

5.2.1. Load measurement:

Electrical loaded dynamometer was used to load the engine. In this work, for the given engine specifications, the maximum load that can be applied on the engine is calculated as 4.7kgf-m

5.2.2. Engine speed measurement:

Engine speed was measured with the help of a tachometer. Here, the engine was run at rated speed i.e., at 1500 rpm throughout the experiment.

5.2.3. Fuel measurements:

The fuel flow i.e. diesel and blends were measured using a calibrated burette (of capacity 50c.c) and a stopwatch.

5.2.4. Measurement of exhaust gas temperature:

Thermocouples are arranged at the outlet of the exhaust port for sensing the corresponding temperature.

5.2.5. Measurement of exhaust gas smoke density:

Smoke density of the exhaust gas of the engine was measured when the engine was run at different injection pressures, with different fuels (diesel and blends) and with TBC and without TBC using KOMYO smoke meter.

Fig: 5.1. Smoke meter.

5.3 . Experimental Procedure:

- Before starting the engine, the injection pressure was set at 180 bar
- Then, the engine was started using diesel as fuel and is allowed to run for 20 minutes so as to attain steady state condition.
- Now the digital indicators were switched on for reading the temperatures (exhaust gases) sensed by thermocouples.

- Time taken for the consumption of 10cc of fuel was measured with the help of a stop watch and burette.
- Readings were taken from the engine at no load, 25%, 50%, 75% and 100% load, applied on the engine with the help of electrical dynamometer.
- All the readings that are taken when the engine was run at 180 bar injection pressure, using diesel as fuel were tabulated and various performance characteristics such as fuel consumption, brake thermal efficiency, mechanical efficiency, etc. were calculated.
- Now the above procedure will be repeated for blended fuels ie. z5e10d85, z5e15d80, z5e20d75 and z5e25d70.
- All the readings that are taken when the engine was run at 180 bar injection pressure, using z5e10d85, z5e15d80, z5e20d75 and z5e25d70 as fuels were tabulated and various performance characteristics such as fuel consumption, brake thermal efficiency, mechanical efficiency, etc. were calculated.
- Now, the injection pressure was changed to 240 bar and the other parameters were left unchanged.
- Above procedure was repeated, readings were tabulated and various performance characteristics were calculated when the engine was run at 240 bar injection pressure using diesel as fuel.
- All the readings that are taken when the engine was run at 240 bar injection pressure, using diesel as fuel were tabulated and various performance characteristics such as fuel consumption, brake thermal efficiency, mechanical efficiency, etc. were calculated.
- After the completion of experiments with diesel, same procedure will be followed to the blended fuels i.e., z5e10d85, z5e15d80, z5e20d75 and z5e25d70.
- Smoke density of the exhaust gases coming out of the engine was measured using KOMYO smoke meter for all the above experiments.
- All the results were plotted and compared.

- The engine has an original injection timing of 18^0 CABTDC. Thickness of advance shim, located in the connection place between engine and fuel pump is 0.15mm and adding one shim advances the injection timing by 3^0 CA.
- By repeated above procedure, readings were tabulated and various performance characteristics were calculated when the engine was running at 240 bar injection pressure, but injection timing is changed to 24^0CA BTDC by removing two shims and compared the performance characteristics of diesel and blended fuels with the injection timing at 18^0CABTDC.

5.4 Model calculations:

Rated Brake Power (BP) : 7.36 kW

Speed (N) : 1500 rpm

Bore (D) : 80 mm

Stroke (L) : 110 mm

Maximum load on the engine:

- Brake Power (BP) (Rated 10 HP) = $\dfrac{2 \times \Pi \times N \times T_{max}}{60}$ kW

$$10 \times 0.736 = \frac{2 \times \Pi \times N \times T}{60}$$

$$T_{max} = \frac{60 \times (10 \times 0.736)}{2 \times \Pi \times 1500}$$

$$T_{max} = 46.855 \text{ Nm} = 4.77 \text{ Kgf-m}$$

Fuel consumption:

- Time for 10cc fuel consumption (t) = 31sec

  Density of fuel (diesel) @ 33^{o} C (d) = 820kg/m^3

  Calorific value of fuel (C.V.) = 42500 kJ/kg

- Fuel consumption $= \dfrac{10 \times 820 \times 3600 \times 10^{-6}}{t}$ kg/h

  $= \dfrac{10 \times 820 \times 3600 \times 10^{-6}}{31}$ kg/h

  = 0.952 Kg/hr

- Brake specific fuel consumption (BSFC) = $\dfrac{\text{Fuel consumption}}{\text{Brake Power}}$ kg/kW-hr

  $= \dfrac{0.952}{1.848}$

  = 0.515 Kg/KW-hr

- Brake Thermal efficiency $= \dfrac{\text{BP} \times 3600}{}$

FC x CV

$$= \frac{1.848 \times 3600}{0.952 \times 42500}$$

= 16.46 %

- Mechanical efficiency = $\frac{B.P \times 100}{I.P}$

$$= \frac{1.848 \times 100}{3.648}$$

= 50.665

Fig: 5.2. Double cylinder Kirloskar diesel engine

Fig: 5.3. Advanced Shims of thickness 0.15mm.

5.5. Observation Tables:

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{o}c)	Smoke density (%)
0	0.5904	0	0	0	0	152	2
1.2	0.8945	1.848	0.484	17.50	43.505	224	6
2.4	1.2835	3.696	0.347	24.395	60.632	290	15
3.6	1.554	5.545	0.280	30.228	69.790	380	28
4.7	1.968	7.238	0.272	31.157	75.100	476	38

Table: 5.2. Performance of engine with diesel at 180bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.551	0	0	0	0	140	2
1.2	0.913	1.848	0.494	18.017	50.660	219	6
2.4	1.299	3.696	0.351	25.337	67.251	270	10
3.6	1.670	5.545	0.301	29.559	75.492	365	16
4.7	2.088	7.238	0.288	30.874	80.085	460	24

Table: 5.3. Performance of engine with Z5E10D85 blend at 180bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.613	0	0	0	0	163	2
1.2	0.941	1.848	0.508	17.853	46.811	213	6
2.4	1.325	3.696	0.358	25.339	63.770	274	10
3.6	1.715	5.545	0.309	29.371	72.529	356	14
4.7	2.160	7.238	0.298	30.450	77.513	453	22

Table: 5.4.Performance of engine with Z5E15D80 blend at 180bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.645	0	0	0	0	152	2
1.2	0.952	1.848	0.515	18.115	44.554	209	3
2.4	1.383	3.696	0.374	24.945	61.643	270	10
3.6	1.708	5.545	0.308	30.290	70.680	355	17
4.7	2.234	7.238	0.309	30.241	75.887	445	32

Table: 5.5.Performance of engine with Z5E20D75 blend at 180bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.658	0	0	0	0	156	2
1.2	0.966	1.848	0.523	18.197	48.027	203	2
2.4	1.38	3.696	0.373	25.476	64.890	267	8
3.6	1.811	5.545	0.327	29.115	73.491	346	18
4.7	2.415	7.238	0.334	28.509	78.352	425	34

Table: 5.6.Performance of engine with Z5E25D70blend at 180bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.615	0	0	0	0	145	1
1.2	0.868	1.848	0.469	18.031	44.554	218	4
2.4	1.23	3.696	0.333	25.455	61.643	295	7
3.6	1.553	5.545	0.280	30.228	70.680	385	15
4.7	1.968	7.238	0.272	31.157	75.887	480	32

Table: 5.7.Performance of engine with diesel at 240bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.562	0	0	0	0	147	1
1.2	0.913	1.848	0.494	18.017	53.599	216	2
2.4	1.271	3.696	0.344	25.900	69.790	290	4
3.6	1.624	5.545	0.293	30.404	77.605	362	10
4.7	2.088	7.238	0.288	30.874	81.897	467	22

Table: 5.8.Performance of engine with Z5E10D85blend at 240bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{o}c)	Smoke density (%)
0	0.662	0	0	0	0	152	1
1.2	1.005	1.848	0.544	16.701	48.027	220	2
2.4	1.388	3.696	0.375	24.188	64.890	298	4
3.6	1.715	5.545	0.309	29.371	73.491	360	8
4.7	2.083	7.238	0.287	31.578	78.352	460	20

Table: 5.9.Performance of engine with Z5E15D80blend at 240bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{o}c)	Smoke density (%)
0	0.726	0	0	0	0	159	1
1.2	1.037	1.848	0.561	16.630	45.654	227	3
2.4	1.383	3.696	0.374	24.945	62.689	275	5
3.6	1.708	5.545	0.308	30.290	71.593	355	10
4.7	2.234	7.238	0.309	30.241	76.691	450	29

Table: 5.10.Performance of engine with Z5E20D75blend at 240bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{o}c)	Smoke density (%)
0	0.725	0	0	0	0	164	1
1.2	1.035	1.848	0.560	16.984	46.811	237	3
2.4	1.413	3.696	0.382	24.869	63.770	280	5
3.6	1.705	5.545	0.307	30.935	72.529	348	13
4.7	2.318	7.238	0.320	29.697	77.513	435	30

Table: 5.11.Performance of engine with Z5E25D70blend at 240bar.

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{o}c)	Smoke density (%)
0	0.642	0	0	0	0	204	4
1.2	1.054	1.848	0.570	14.849	41.549	288	10
2.4	1.736	3.696	0.469	18.031	58.906	378	34
3.6	1.968	5.545	0.355	23.864	68.0777	408	65
4.7	2.270	7.238	0.313	27.002	73.574	490	72

Table: 5.12.Performance of engine with diesel at 24^{0} BTDC (240bar).

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.664	0	0	0	0	188	3
1.2	1.124	1.848	0.608	14.639	45.654	264	5
2.4	1.827	3.696	0.494	18.017	62.689	325	10
3.6	2.088	5.545	0.376	23.647	71.593	380	35
4.7	2.657	7.238	0.367	24.257	76.692	480	48

Table: 5.13.Performance of engine with Z5E10D85 at 24^0 BTDC (240bar).

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.694	0	0	0	0	182	4
1.2	1.125	1.848	0.657	13.822	44.554	248	4
2.4	1.715	3.696	0.464	19.580	61.644	310	6
3.6	2.083	5.545	0.375	24.188	70.681	370	12
4.7	2.650	7.238	0.366	24.812	75.888	470	33

Table: 5.14.Performance of engine with Z5E15D80 at 24^0 BTDC (240bar).

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.745	0	0	0	0	180	4
1.2	1.320	1.848	0.714	13.066	46.811	230	4
2.4	1.708	3.696	0.462	20.194	63.771	293	5
3.6	2.234	5.545	0.403	23.164	72.529	358	9
4.7	2.768	7.238	0.382	24.425	77.513	435	22

Table: 5.15.Performance of engine with Z5E20D75 at 24^0 BTDC (240bar).

Torque (Kgf-m)	Fuel consumption (Kg/h)	Brake power (kw)	Brake specific fuel Consumption (Kg/Kw-h)	B_{th} efficiency (%)	Mechanical Efficiency (%)	Exhaust temperature (^{0}c)	Smoke density (%)
0	0.805	0	0	0	0	166	2
1.2	1.449	1.848	0.784	12.131	48.027	215	2
2.4	1.811	3.696	0.490	19.410	64.890	276	4
3.6	2.229	5.545	0.402	23.656	73.491	348	7
4.7	2.898	7.238	0.400	23.757	78.352	410	18

Table: 5.16.Performance of engine with Z5E25D70 at 24^0 BTDC (240bar).

CHAPTER-VI

RESULTS AND DISCUSSIONS

6.1. Experimental Results:

The chapter gives the results obtained from the experiments conducted on twin cylinder naturally aspirated direct injection diesel engine with diesel, blends of diesel, ethanol and n-butanol in the blend ratios of 10%, 15%, 20%,25%ethanol,5% n-butanol and 85%, 80%, 75% ,70%Diesel (volume basis), as fuels at different injection pressures and injection times. Comparison of engine performance is carried with the performance parameters such as fuel consumption, brake specific fuel consumption, brake thermal efficiency, mechanical efficiency, engine exhaust temperatures and smoke density for diesel, blends of diesel, ethanol and n-butanol i.ez5e10d85,z5e15d80,z5e20d75,z5e25d70 as fuels. Then the comparison is extended for different injection pressures and injection times for each fuel. This comparison at different injection pressures and injection times is done, to optimize the injection pressure and injection time at which the performance of the CI engine is satisfactory for each fuel considered separately.

6.2. Fuel consumption:

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0.590	0.552	0.614	0.645	0.658
1.2	0.895	0.913	0.941	0.952	0.966
2.4	1.284	1.229	1.325	1.383	1.38
3.6	1.554	1.670	1.715	1.708	1.811
4.7	1.968	2.088	2.16	2.234	2.415

Table: 6.1. Fuel consumption of diesel and blends at 180bar injection pressure.

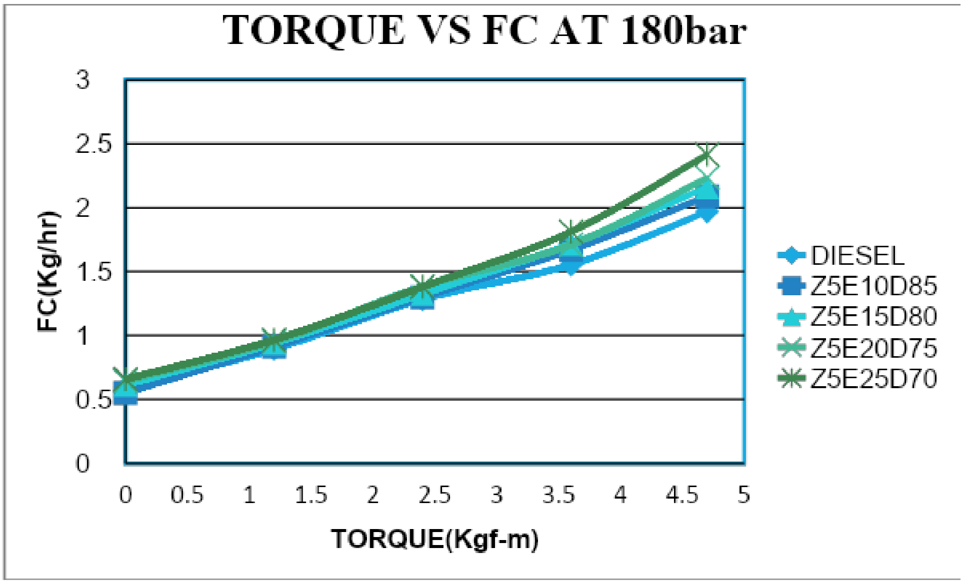

Fig: 6.1.Comparison of fuel consumption of diesel and blends at 180bar injection pressure.

When load increases fuel consumption also increases for the diesel and blended fuels at 180bar. From the results among all the blends, z5e25d70 has higher fuel consumption and also compare to the diesel at constant speed. The increases of fuel consumption are due to the lower heating value of ethanol than that of pure diesel. The results show the trend of the increasing fuel consumption with the increasing percentage of ethanol in the blends.

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0.615	0.562	0.662	0.726	0.725
1.2	0.868	0.913	1.005	1.037	1.035
2.4	1.23	1.271	1.338	1.383	1.413
3.6	1.553	1.624	1.715	1.708	1.705
4.7	1.968	2.088	2.083	2.234	2.318

Table: 6.2. Fuel consumption of diesel and blends at 240bar injection pressure.

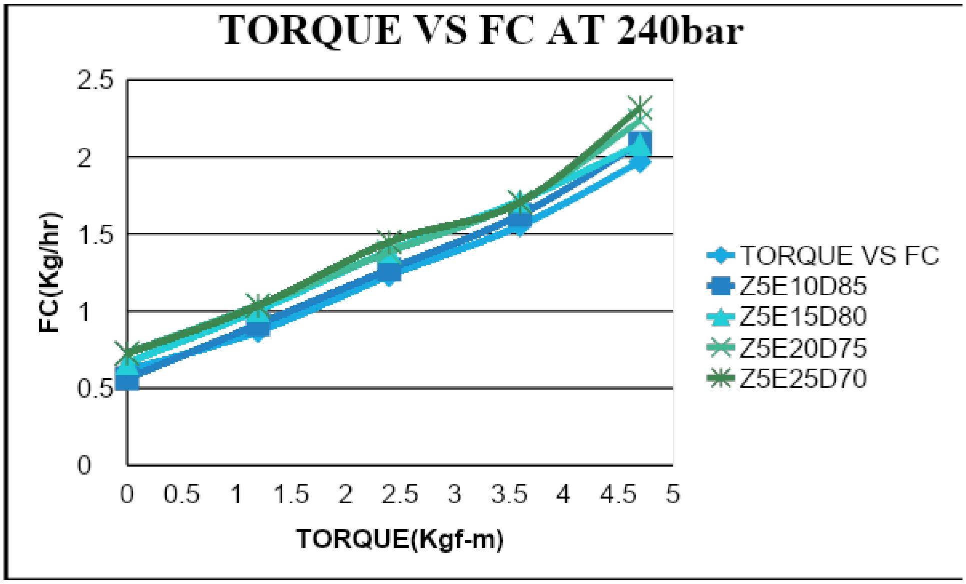

Fig: 6.2.Comparison of fuel consumption of diesel and blends at 240bar injection pressure.

When load increases fuel consumption also increases for the diesel and blended fuels at 240bar. From the results among all the blends, z5e25d70 has higher fuel consumption and also compare to the diesel at constant speed. At higher loads the fuel consumption of z5e15d80 has lower fuel consumption than z5e10d85 at 240bar. In the same way z5e25d70 has lower fuel consumption than z5e20d75 at 1.2 and 3.6 loads.

Diesel has lower fuel consumption up to 3.6 load at 240bar than fuel consumption at180bar and same fuel consumption at full load. In the same way for the blend of z5e10d85 has more fuel consumption at 240bar than 180bar only at the load of 2.4load and fuel consumption is same at reaming loads, for the blend of z5e15d80 has higher fuel consumption at 240bar than 180bar at the loads of 1.2&2.4. This blend has lower fuel consumption at full load than 180bar, for the blend of z5e20d75has more fuel consumption at 240bar than 180bar only at the load of 1.2load and fuel consumption is same at the reaming loads, for the blend of z5e25d70 has more fuel consumption at 240bar than 180bar only at the load of 1.2 load and fuel consumption is same at the reaming loads. Finally at240bar fuel consumption is slightly more at lower loads and low consumption at higher loads than180bar.

6.3. Specific fuel consumption:

BP(Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0
1.848	0.484	0.494	0.508	0.515	0.523
3.696	0.347	0.351	0.358	0.374	0.373
5.545	0.280	0.301	0.309	0.308	0.327
7.238	0.272	0.288	0.298	0.309	0.334

Table: 6.3. Specific fuel consumption of diesel and blends at 180bar injection pressure.

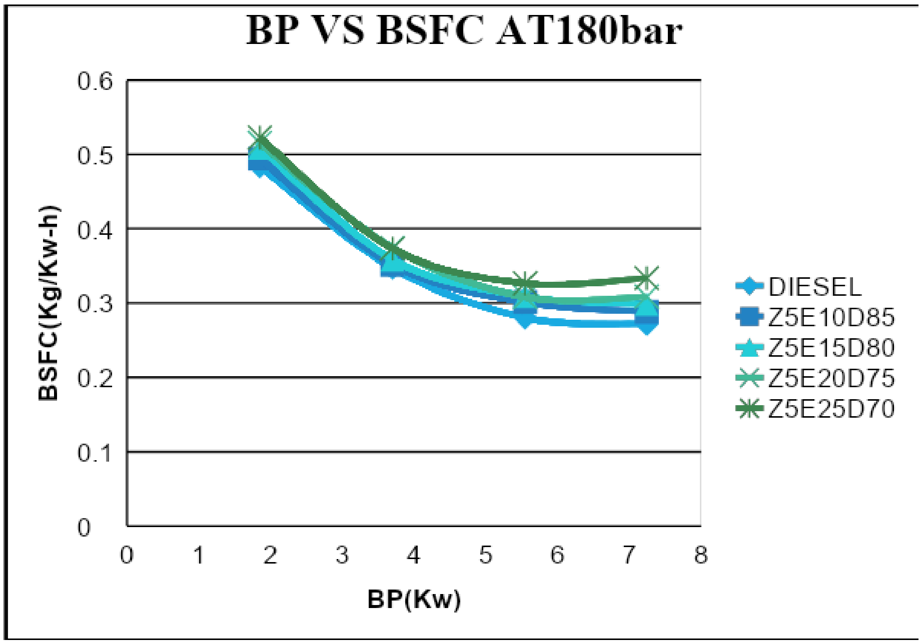

Fig: 6.3. Comparison of specific fuel consumption of diesel and blends at 180bar injection pressure.

The test results of the brake specific fuel consumptions (BSFCs) with the engine power outputs, when the engine fuelled by different fuel blends and diesel. From the results, it can be seen that the engine power could be maintained at the same level when fuelled by different fuel blends with some extent increases of fuel consumption; the more ethanol was added in, the more fuel consumption was found, compared with those fuelled by pure diesel. When the engine ran at 1500 r/min on different engine loads, for the blend of Z5E10D85, the BSFCs were increased from 2.0% to 5.55%; for the blend of Z5E15D80, the BSFCs were increased from 4.7% to 8.7%; for the blend of Z5E20D75, the BSFCs were increased from 6.1% to 11.6%; for the blend of Z5E25D70, the BSFCs were increased from 7.4% to 18.5%. These increases of fuel consumption are due to the lower heating value of ethanol than that of pure diesel. The results show the trend of the increase of fuel consumption with the increase percentage of ethanol in the blends.

BP(Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0

1.848	0.469	0.494	0.544	0.561	0.560
3.696	0.333	0.344	0.375	0.374	0.382
5.545	0.280	0.293	0.309	0.308	0.307
7.238	0.272	0.288	0.287	0.309	0.320

Table: 6.4. Specific fuel consumption of diesel and blends at 240bar injection pressure.

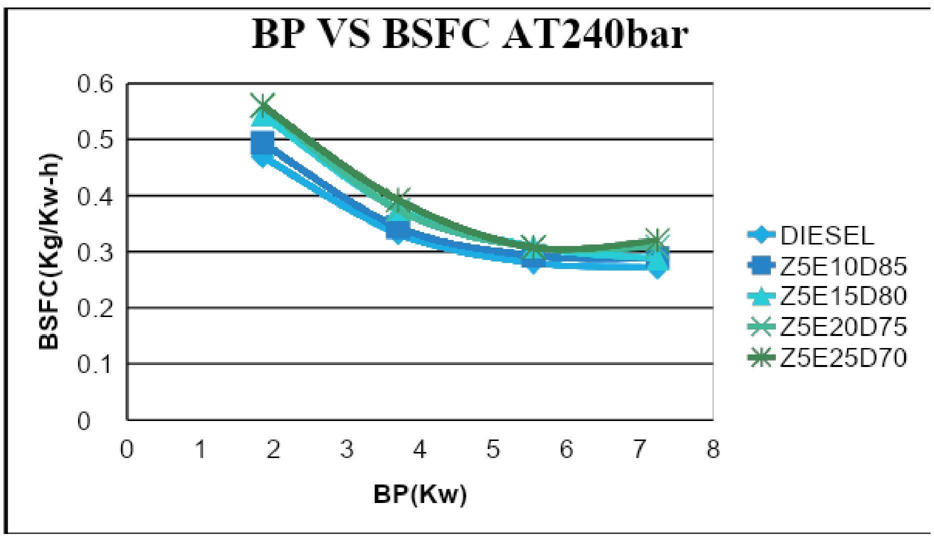

Fig. 6.4. Comparison of specific fuel consumption of diesel and blends at 240bar.

The test results of the brake specific fuel consumptions (BSFCs) with the engine power outputs, when the engine fuelled by different fuel blends and diesel. From the results, it can be seen that the engine power could be maintained at the same level when fuelled by different fuel blends. the more ethanol was added in, the more fuel consumption was found, compared with those fuelled by pure diesel. When the engine ran at 1500 r/min on different engine loads, for the blend of Z5E10D85, the BSFCs were from 5.06% to 5.55%; for the blend of Z5E15D80, the BSFCs were from 13.7% to 5.22%; for the blend of Z5E20D75, the BSFCs were from 16.3% to 11.68%; for the blend of Z5E25D70, the BSFCs were from 16.25% to 15%. These increases of fuel consumption are due to the lower heating value of ethanol than that of pure diesel. The results show the trend of the increase of fuel consumption with the increase percentage of ethanol in the blends.

Brake specific fuel consumption for the blends is higher than the diesel because ethanol has lower heating value. So increase in ethanol concentration, decreases heating value of blend. At 240bar brake specific fuel consumption is higher at lower loads than at 180bar but specific fuel consumption is lower at higher loads when compared to at 180bar.Finally injection presser is increased, fuel consumption is decreased at higher loads to the blends.

6.4. Brake thermal efficiency:

BP(Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0
1.848	17.50	18.017	17.853	18.115	18.197
3.696	24.395	25.337	25.339	24.945	25.476
5.545	30.228	29.559	29.371	30.290	29.115
7.238	31.157	30.874	30.450	30.241	28.509

Table: 6.5. Brake thermal efficiency of diesel and blends at 180bar injection pressure.

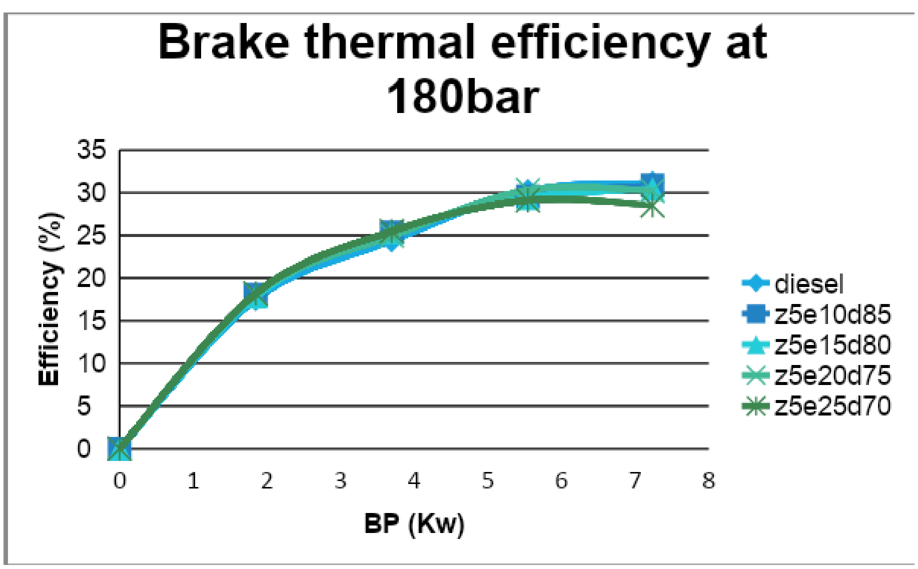

Fig: 6.5. Comparison of Brake thermal efficiency of diesel and blends at 180bar injection pressure.

The results of the thermal efficiencies of engine with the engine power on two injection pressers when fuelled by different fuel blends and the pure diesel. The test results show that there are some differences for the brake thermal efficiencies for different blends compared with those of diesel. When the engine ran at the speed of 1500 r/min, for the blend of Z5E10D85, the thermal efficiency were increased by 2.86%–3.72% at the engine low loads from 1.8-3.6kw, but at the high loads from 5.5-7.2kw the thermal efficiencies were decreased by 2.2%-0.9%,respectively; for the blend ofZ5E15D80, the thermal efficiencies were increased by 1.97%–3.72% at the engine low loads from 1.8to 3.6 kW, but at the high loads from 5.5 to 7.2 kW the thermal efficiencies were decreased by 2.835–2.269%,respectively; similar trends can be found for the blends ofZ5E20D75, the decreases were from 3.39% to 2.93%; and for Z5E25D70, the increases were from 3.83% to 4.24% at the low loads of the engine (from 1.8 to3.6 kW), the decreases were from 3.68% to 8.49% at the high loads of the engine (from 5.5 to 7.2 kW). These results show the differences of the thermal efficiencies between the blends and diesel was relatively small; they were comparable with each other, with some extent increases or decreases at different loads. At lower loads brake thermal efficiency of blends are higher than diesel because ethanol has low boiling point and it has oxygen atom but at higher loads blends have slightly lower than diesel. In case of blends z5e10d85 has higher efficiency than remaining blends, because injector leakage is obtained due to viscosity is decreased by the concentration of ethanol content is increased

BP(Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0
1.848	18.031	18.017	16.701	16.630	16.984
3.696	25.455	25.900	24.188	24.945	24.869

5.545	30.228	30.404	29.371	30.290	30.935
7.238	31.157	30.874	31.3578	30.241	29.697

Table: 6.6. Brake thermal efficiency of diesel and blends at 240bar injection pressure.

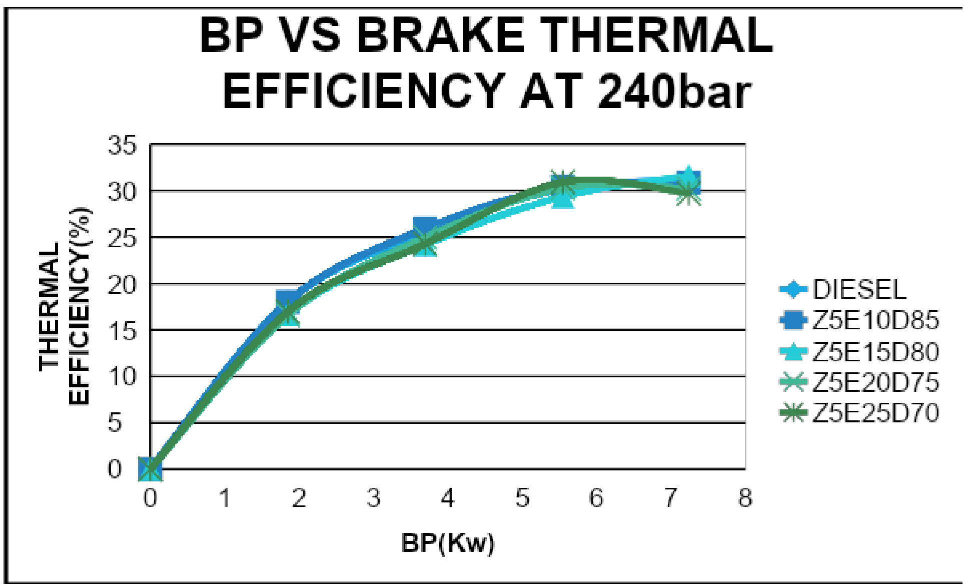

Fig: 6.6. Comparison of Brake thermal efficiency of diesel and blends at 240bar injection pressure.

The results of the thermal efficiencies of engine with the engine power on two injection pressers when fuelled by different fuel blends and the pure diesel. The test results show that there are some differences for the brake thermal efficiencies for different blends compared with those of diesel. When the engine ran at the speed of 1500 r/min, for the blend of Z5E10D85, the thermal efficiency were increased up to 5.5kw and decreased at the engine full load; for the blend ofZ5E15D80, the thermal efficiencies were decreased up to 5.5kw and increased at the engine full load; similar trends can be found for the blend ofZ5E20D75, the decreases in thermal efficiency up to full load; and for Z5E25D70, the decreases in thermal efficiency up to full load except at 5.5kw,these are compared with the diesel at 240bar. These results show the differences of the thermal efficiencies between the blends and diesel was relatively small; they were comparable with each other, with some extent increases or decreases at different loads. Finally blends have thermal efficiency slightly lower than the diesel.

The blends at 240bar have slightly lower efficiency at lower loads when compared with the blends at 180barbecause incomplete combustion of fuel .But brake thermal efficiency is high at higher loads compared with the 180bar because complete combustion of fuel. So finally some better efficiency is obtained at240bar compared to 180bar due to better atomization of fuel which leads to the complete combustion of fuel. So finally z5e10d85 is better one than remaining blends based on brake thermal efficiency.

6.5. Exhaust gas temperatures:

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	152	140	163	152	156
1.2	224	219	213	209	203
2.4	290	270	274	270	267
3.6	380	365	356	355	346
4.7	476	460	453	445	425

Table: 6.7. Exhaust gas temperatures of diesel and blends at 180bar injection pressure.

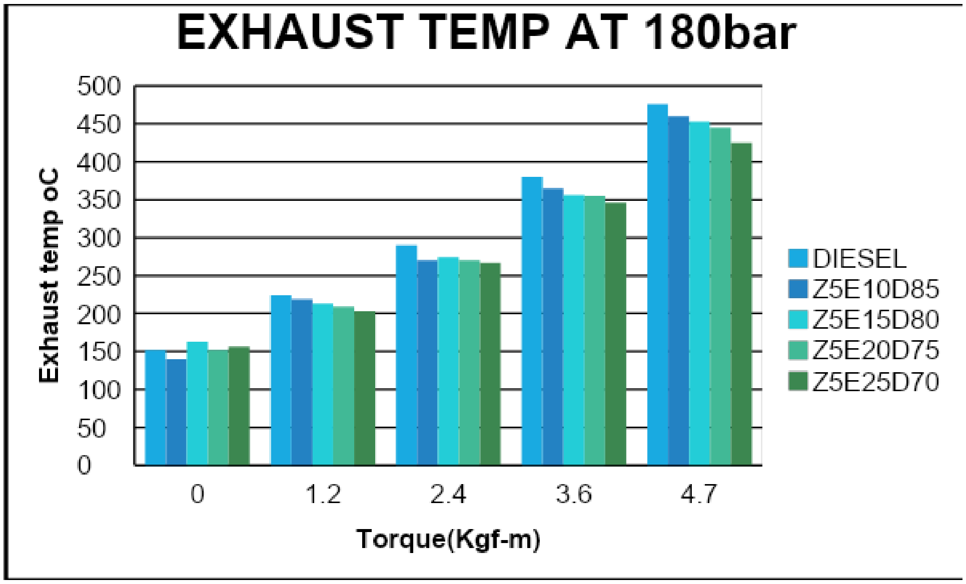

Fig: 6.7. Comparison of exhaust gas temperatures of diesel and blends at 180bar injection pressure.

Exhaust gas temp of blends are lower than the diesel except no load condition because the oxygenate ratio in the blend increases due to percentage of ethanol in blend increases. So the highest exhaust temperature is observed with the diesel fuel, and the lowest with the blended fuel.

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	145	147	152	159	164
1.2	218	216	220	227	237
2.4	295	290	298	275	280
3.6	385	362	360	355	348
4.7	480	467	460	450	435

Table: 6.8. Exhaust gas temperatures of diesel and blends at 240bar injection pressure.

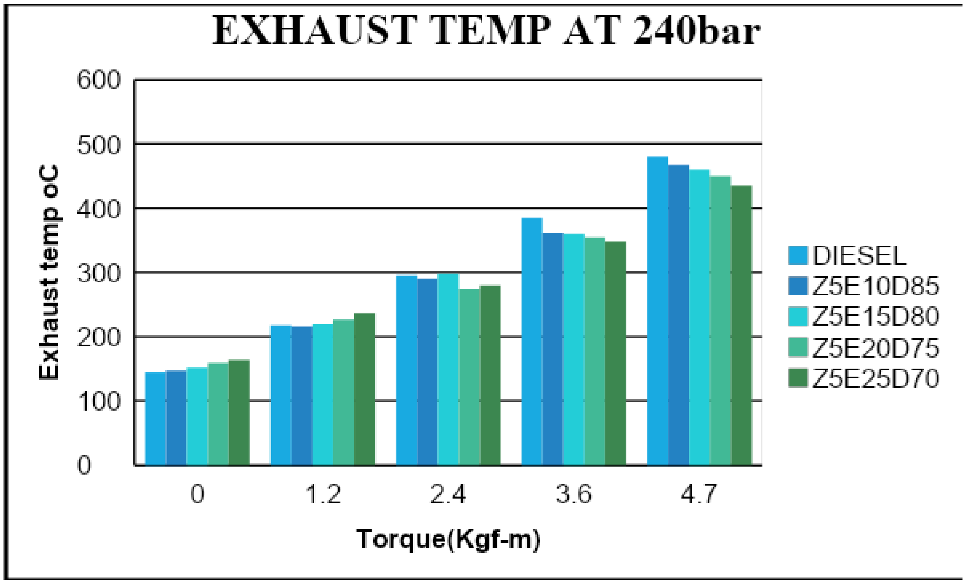

Fig: 6.8. Comparison of exhaust gas temperatures of diesel and blends at 240bar injection pressure.

Exhaust gas temp of blends are lower than the diesel except no load condition because the oxygenate ratio in the blend increases due to percentage of ethanol in blend increases. So the highest exhaust temperature is observed with the diesel fuel, and the lowest with the blended Fuel. The variation of exhaust gas temperature with respect to the load is indicated in Figs. The exhaust gas temperature for all the fuels tested increases with increase in the load. The amount of fuel injected increases with the engine load in order to maintain the power output and hence the heat release and the exhaust gas temperature rise with increase in load. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber.

6.6. Smoke density:

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	2	2	2	2	2
1.2	6	6	6	3	2
2.4	15	10	10	10	8
3.6	28	16	14	17	18

4.7	38	24	22	32	34

Table: 6.9.Smoke density of diesel and blends at 180bar injection pressure.

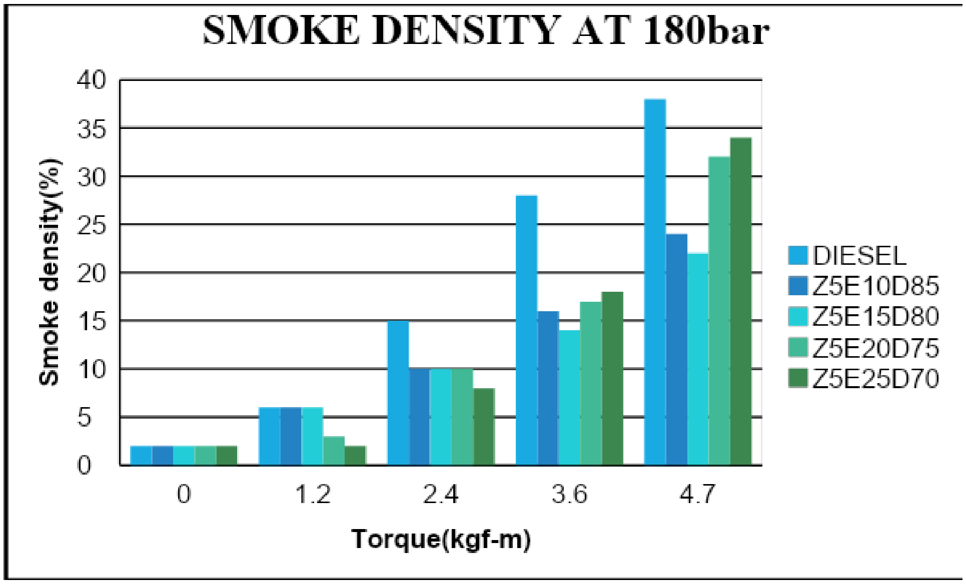

Fig: 6.9.Comparison of smoke density of diesel and blends at 180bar injection pressure.

Blended fuels have lower density when compared to diesel fuels, because ethanol is added to diesel it reduces viscosity and boiling point of diesel. So blended fuels has lower smoke density compare to diesel, but in case of blends higher percentage of ethanol blends has higher smoke density at higher loads because ethanol percentage increases viscosity decreases, at lower viscosity injector leakage is obtained. Due to that incomplete combustion takes place.

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	1	1	1	1	1
1.2	4	2	2	3	3
2.4	7	4	4	5	5
3.6	15	10	8	10	13

4.7	32	22	20	29	30

Table: 6.10.Smoke density of diesel and blends at 240bar injection pressure.

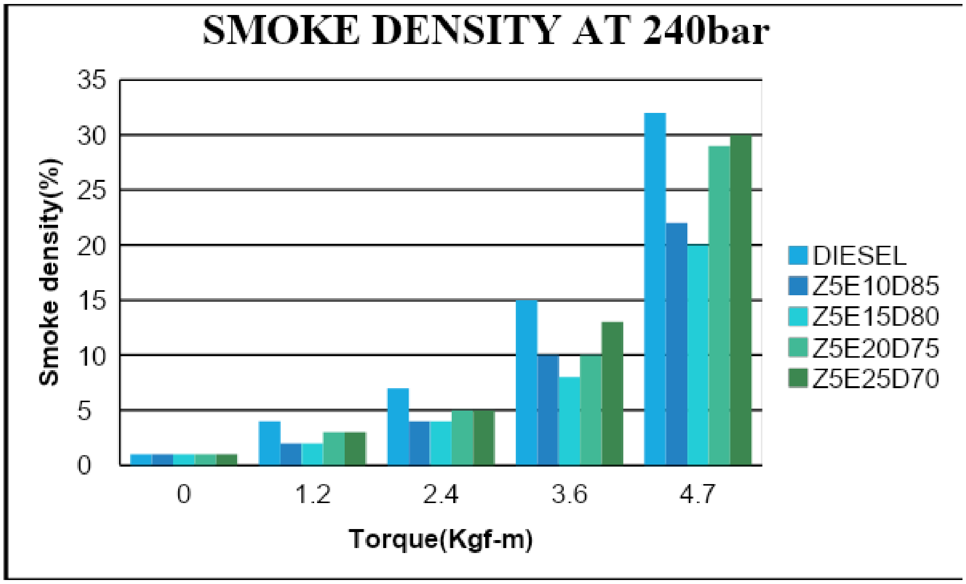

Fig: 6.10.Comparison of smoke density of diesel and blends at 240bar injection pressure.

Blended fuels have lower smoke density when compared to diesel fuels, because ethanol is added to diesel it reduces viscosity and boiling point of diesel. So blended fuels has lower smoke density compare to diesel, but in case of blends higher percentage of ethanol blends has higher smoke density at higher loads because ethanol percentage increases viscosity decreases, at lower viscosity injector leakage are obtained. Due to that incomplete combustion takes place.

Smoke density at 240bar decreases comparatively smoke density at 180bar, because injection presser increases then atomization of fuel increases, so better combustion is takes place. Among all the blends z5e10d85, z5e15d80 has lower smoke density. The little difference of smoke density between these blends.

6.7. Mechanical Efficiency:

BP(Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0
1.848	43.505	50.660	46.811	44.554	48.027

3.696	60.632	67.257	63.770	61.643	64.890
5.545	69.790	75.492	72.529	70.680	73.491
7.238	75.100	80.085	77.513	75.887	78.352

Table: 6.11.Mechanical Efficiency of diesel and blends at 180bar injection pressure.

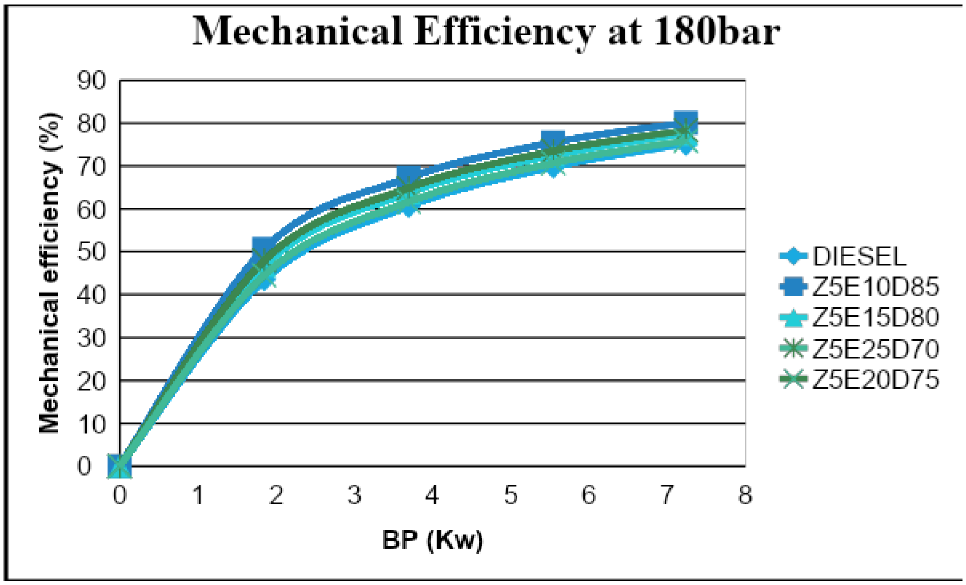

Fig: 6.11.Comparison of mechanical efficiency of diesel and blends at 180bar injection pressure.

This is the rating that shows how much of the power developed by the expansion of the gases in the cylinder is actually delivered as useful power. The factor which has the greatest effect on mechanical efficiency is friction within the engine. The friction between moving parts in an engine. A blended fuel has higher mechanical efficiency when compared to diesel, because lower friction losses by using blended fuels. Among blends z5e10d85 has higher mechanical efficiency, because it has lower friction losses among blends.

BP(Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0

1.848	44.554	53.599	48.027	45.654	46.811
3.696	61.643	69.790	64.890	62.689	63.710
5.545	70.680	77.605	73.491	71.593	72.529
7.238	75.887	81.897	78.352	76.691	77.513

Table: 6.12.Mechanical Efficiency of diesel and blends at 240bar injection pressure.

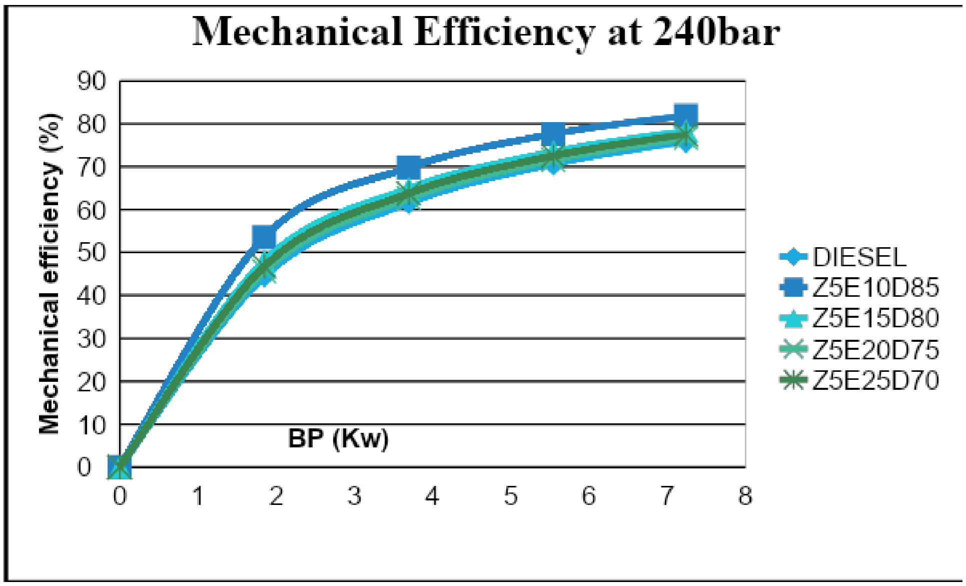

Fig: 6.12.Comparison of mechanical efficiency of diesel and blends at 240bar injection pressure.

This is the rating that shows how much of the power developed by the expansion of the gases in the cylinder is actually delivered as useful power. The factor which has the greatest effect on mechanical efficiency is friction within the engine. The friction between moving parts in an engine. A blended fuel has higher mechanical efficiency when compared to diesel, because lower friction losses by using blended fuels. Among blends z5e10d85 has higher mechanical efficiency, because it has lower friction losses among blends.

At 240bar diesel, blended fuels have higher efficiency when compared to at 180bar, because friction losses are reduced at 240bar.In both cases z5e10d85 has higher mechanical efficiency compared with reaming blends.

6.8. Fuel consumption at 24^0 BTDC (240bar):

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0.642	0.664	0.694	0.745	0.805
1.2	1.054	1.124	1.215	1.320	1.449
2.4	1.736	1.827	1.715	1.708	1.811
3.6	1.968	2.088	2.083	2.234	2.229
4.7	2.270	2.657	2.650	2.768	2.898

Table: 6.13.Fuel consumption of diesel and blends at 24^0 BTDC (240bar).

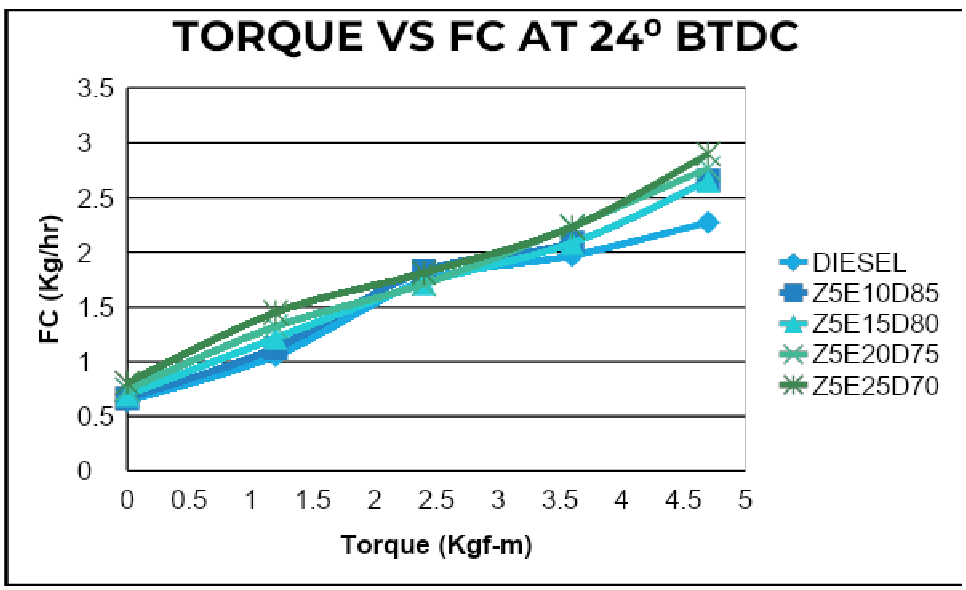

Fig: 6.13.Comparison of fuel consumption of diesel and blends at 24^0 BTDC (240bar).

When load increases fuel consumption also increases for the diesel and blended fuels at 240bar. From the results among all the blends, z5e25d70 has higher fuel consumption and also compare to the diesel at constant speed. When injection time is retarded to 24^0 BTDC then fuel consumption is higher when compared to injection time at 18^0 BTDC.

6.9. Specific fuel consumption at 24^0 BTDC (at 240bar):

BP (Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0
1.848	0.570	0.608	0.657	0.714	0.784
3.696	0.469	0.494	0.464	0.462	0.490
5.545	0.355	0.376	0.375	0.403	0.402
7.238	0.313	0.367	0.366	0.382	0.400

Table: 6.14.Specific fuel consumption of diesel and blends at 24^0 BTDC (at 240bar).

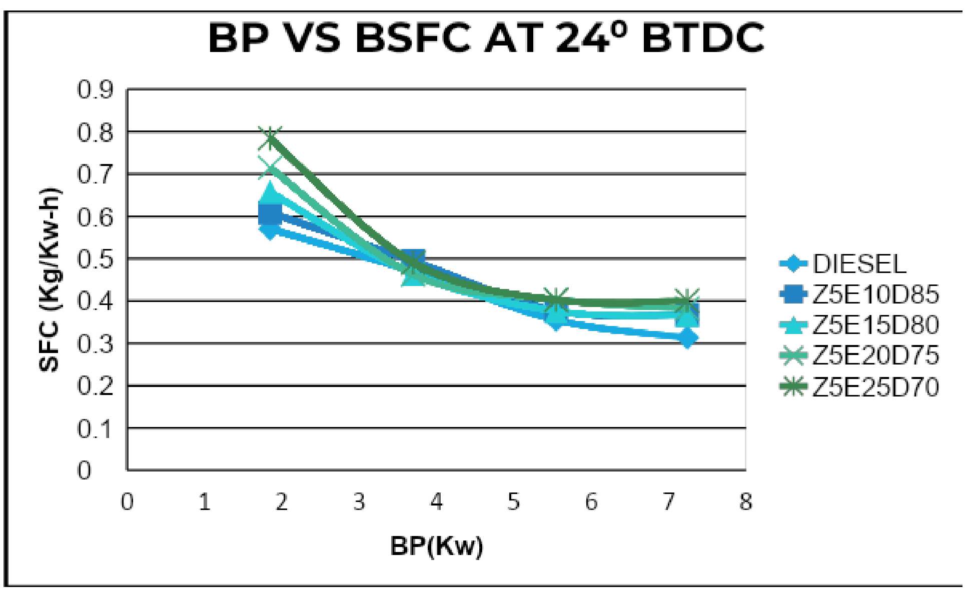

Fig: 6.14.Comparison of specific fuel consumption diesel and blends at 24^0 BTDC (at 240bar).

The test results of the brake specific fuel consumptions (BSFCs) with the engine power outputs, when the engine fuelled by different fuel blends and diesel. From the results, it can be seen that the engine power could be maintained at the same level when fuelled by different fuel blends. The more ethanol was added in, the more fuel consumption was found, compared with those fuelled by pure diesel. When the engine ran at 1500 r/min on different engine loads. When injection time is retarded to 24⁰ BTDC then brake specific fuel consumption is higher when compared to injection time at 18⁰ BTDC.

6.10. Brake thermal efficiency at 24⁰ BTDC (240bar):

BP (Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0
1.848	14.849	14.639	13.822	13.066	12.131
3.696	18.031	18.017	19.580	20.194	19.410
5.545	23.864	23.647	24.188	23.164	23.656
7.238	27.002	24.257	24.812	24.425	23.757

Table: 6.15.Brake thermal efficiency of diesel and blends at 24⁰ BTDC (240bar).

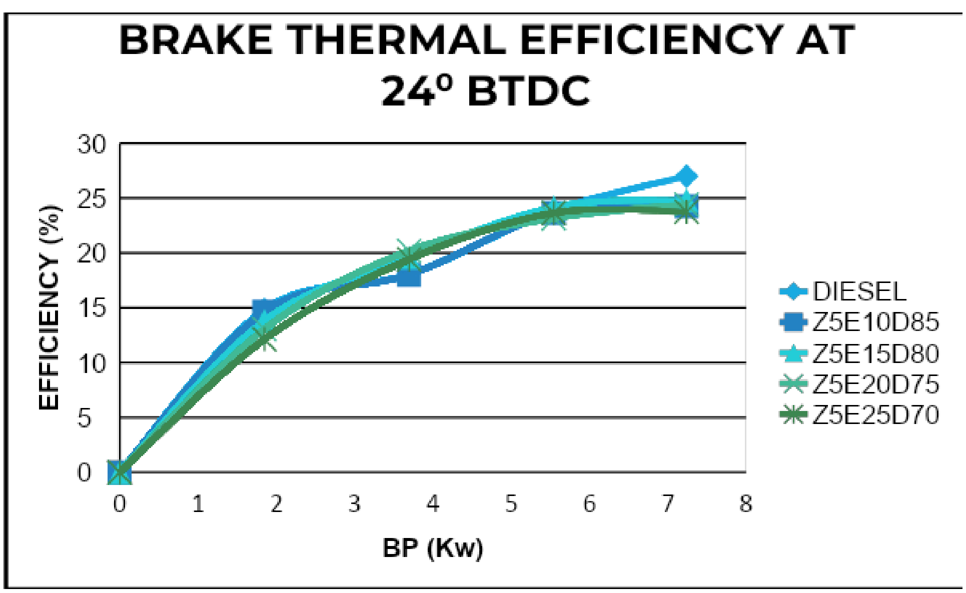

Fig: 6.15.Comparison of brake thermal efficiency of diesel and blends at 24⁰ BTDC (240bar).

The results of the thermal efficiencies of engine with the engine power on two injection times when fuelled by different fuel blends and the pure diesel. The test results show that there are some differences for the brake thermal efficiencies for different blends compared with those of diesel. When the engine ran at the speed of 1500 r/min. When injection time is retarded to 24^0 BTDC then brake thermal efficiency is lower when compared to injection time at 18^0 BTDC. Because injection starts earlier, the initial air temperature and pressure are lower, so the ignition delay will increase. Due to incomplete combustion efficiency decreases.

6.11. Exhaust gas temperatures at 24^0 BTDC (240bar):

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	204	188	182	180	166
1.2	288	264	248	230	215
2.4	378	325	310	293	276
3.6	408	380	370	358	348
4.7	490	480	470	435	410

Table: 6.16. Exhaust gas temperatures of diesel and blends at 24^0 BTDC (240bar).

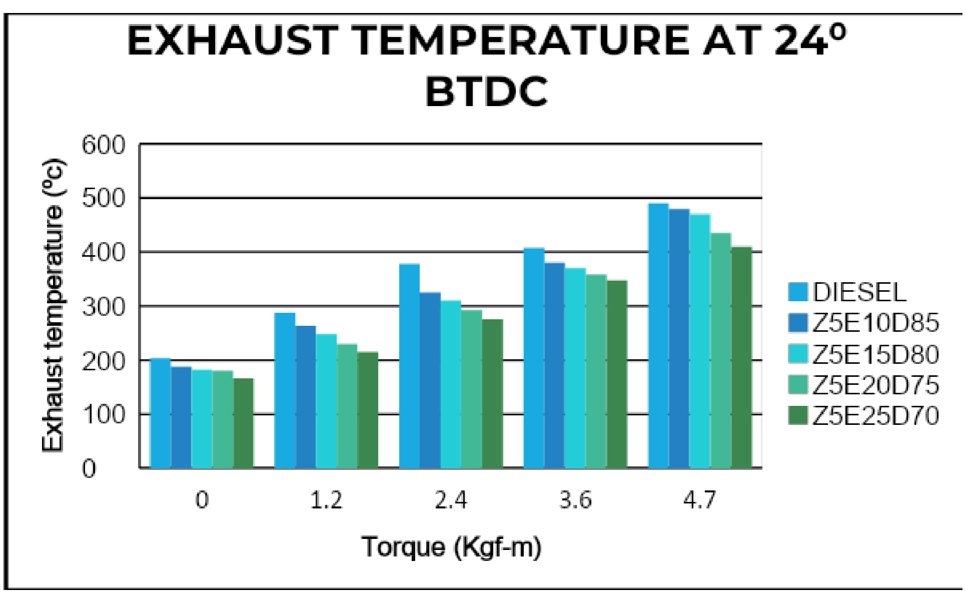

Fig: 6.16.Comparesion of exhaust gas temperatures of diesel and blends at 24^0 BTDC (240bar).

Exhaust gas temp of blends are lower than the diesel except no load condition because the oxygenate ratio in the blend increases due to percentage of ethanol in blend increases. So the highest exhaust temperature is observed with the diesel fuel, and the lowest with the blended fuel. When injection time is retarded to 24^0 BTDC then exhaust gas temperature is higher when compared to injection time at 18^0 BTDC except of the blend z5e25d70, because incomplete of combustion.

6.12. Smoke density at 24^0 BTDC (240bar):

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	4	3	4	4	2
1.2	10	5	4	4	2
2.4	34	10	6	5	4
3.6	65	35	12	9	7
4.7	72	48	33	22	18

Table: 6.17.Smoke density of diesel and blends at 24^0 BTDC (240bar).

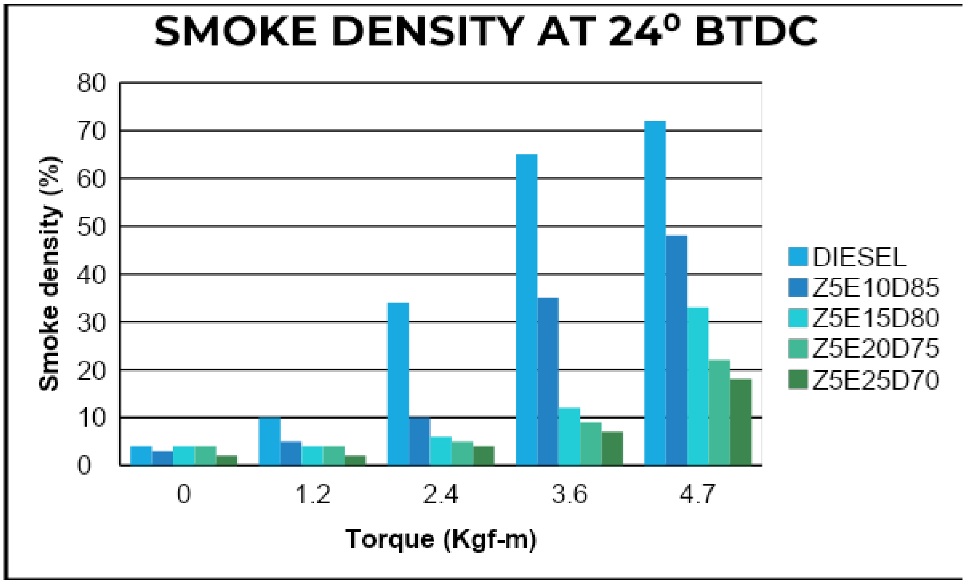

Fig: 6.17.Comparison of smoke density of diesel and blends at 24^0 BTDC (240bar).

Blended fuels have lower smoke density when compared to diesel fuels, because ethanol is added to diesel it reduces viscosity and boiling point of diesel. So blended fuels has lower smoke density compare to diesel. When injection time is retarded to 24^0 BTDC then smoke density of blended fuels reduced when compared to diesel. In case of blends z5e25d70has lower smoke density, i.e., ethanol percentage increased smoke density reduced when compared to injection time at 18^0 BTDC.

6.13. Mechanical Efficiency at 24^0BTDC (240bar):

BP(Kw)	Diesel	Z5E10D85	Z5E15D80	Z5E20D75	Z5E25D70
0	0	0	0	0	0
1.848	41.549	45.654	44.554	46.811	48.027
3.696	58.906	62.689	61.644	63.771	64.890
5.545	68.077	71.593	70.681	72.529	73.491
7.238	73.574	76.692	75.888	77.513	78.352

Table: 6.18.Mechanical Efficiency of diesel and blends at 24^{0}BTDC (240bar).

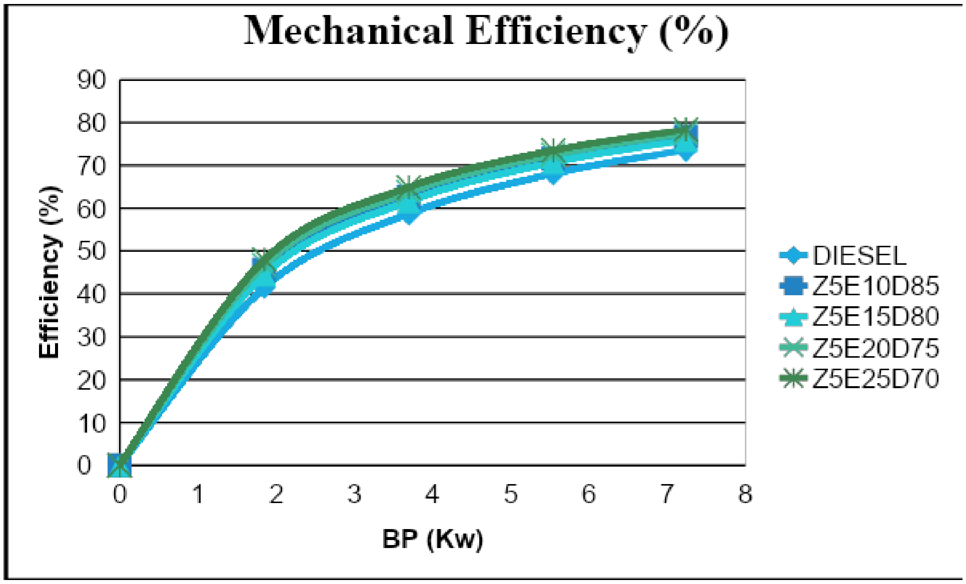

Fig: 6.18.Comparison of mechanical efficiency of diesel and blends at 24^{0}BTDC (240bar).

This is the rating that shows how much of the power developed by the expansion of the gases in the cylinder is actually delivered as useful power. The factor which has the greatest effect on mechanical efficiency is friction within the engine. The friction between moving parts in an engine. A blended fuel has higher mechanical efficiency when compared to diesel. When injection time is retarded to 24^0 BTDC then mechanical efficiency is lower to diesel, first two blends lower and the reaming two blends have slightly higher efficiency when compared to injection time at 18^0 BTDC.

CHAPTER-VII

CONCLUSION

An experimental investigation was conducted on the solubility and physical properties of the blends of ethanol with diesel and the effects of the application of these blends on the engine performance parameters and smoke density. The tested blends were from 10% to 25% of ethanol by volume and also with 5% of the additive of normal butanol. The engine was operated with each blend at different loads on which the engine speed ran at the speed of 1500 r/min, respectively. From the test results, the following conclusions can be drawn.

Ethanol cannot be blended with diesel without the assistance of additive such as normal butanol. With the blends tested, the blends of 10%, 15%, 20% and 25% ethanol (by volume) with diesel were all separated into two layers, when 5% butanol were added into the above blends, they were all lasted longer and no less than 25 days without the phase separation problem.

The study showed that the n-butanol is a good additive for mixing diesel with ethanol, although the price of n-butanol was higher than that of diesel when the tests were carrying on. From long term point of view, fossil fuels including diesel will be less and less due to the limited sources; more and more bio fuels will be used gradually as the alternatives to replace the fossil fuels. It might not be economical to use n-butanol today but it would be in the future.

The fuel consumptions of the engine fuelled by the blends were higher compared with those fuelled by pure diesel. The more ethanol was added in, the higher fuel consumptions take place, because ethanol has low heating value so more fuel consumption takes place when ethanol percentage increases. At 240bar slightly lesser fuel consumption when compared with the fuels at 180bar.

The brake specific fuel consumption of the engine fuelled by the blends was higher compared with those fuelled by pure diesel. The more ethanol was added in, the higher fuel consumptions take place, because ethanol has low heating value so more fuel consumption takes place when ethanol percentage increases. At 240bar slightly more specific fuel consumption takes place at lower loads, but at higher loads specific fuel consumption is lower when compared with 180bar.

The thermal efficiencies of the engine fuelled by the blends were comparable with those fuelled by pure diesel, has slightly higher efficiency at lower loads and lower efficiency at higher loads. Among blends z5e10d85 has higher efficiency compared to remaining blends because some injector leakages and lower cetane number, when ethanol percentage increases. At 240bar some blends have lower efficiency at lower loads and higher efficiency at higher loads of all the blends when compared with 180bar. In both cases z5e10d85has better efficiency and approximately near to diesel.

In case of mechanical efficiency blends has higher mechanical efficiency when compared with diesel, because of lower friction power losses by the blends. Among all the blends z5e10d85 has higher mechanical efficiency.

In case of smoke density, blends have lower smoke density when compared with diesel, because ethanol has lower boiling point and firing point. In both injection pressure cases, 240bar injection pressure has lower smoke density because better atomization takes place, so complete combustion will obtained.

When injection time is changes to 24^0 BTDC at 240bar by removing shims under the fuel pump, the fuel consumption, break specific fuel consumption, brake thermal efficiency increases and smoke density decreases with increasing percentage of ethanol in blended fuel, when compared to injection time 18^0BTDC.

CHAPTER-VIII

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