effect of diesel-ethanol blends on performance of a diesel engine at different injection pressures

S. Durga Prasad, G. Venkateswara Rao, K. Sri Rama Murthy.

Abstract-- Environmental concerns and limited amount of petroleum fuels have caused interests in the development of alternative fuels for internal combustion (IC) engines. This paper presents a report on the performance of a diesel engine using blends of n-butanol and ethanol with diesel with various blending ratios. The purpose of this is to find the optimum percentage of ethanol that gives simultaneously better performance and lower emissions. The experiments were conducted on a Direct Injection diesel engine using 0% (neat diesel fuel), 10% (Z5E10D85), 15% (Z5E15D80), 20% (Z5E20D75), and 25% (Z5E25D70) ethanol–diesel blended fuels with n-butanol as additive. Experimental tests were carried out to study the performance and emissions of the engine fuelled with the blends compared with those fuelled by diesel. The test results show that the smoke emissions from the engine fuelled by the blends were lower than that fuelled by diesel. The fuel consumptions of the engine fuelled by the blends were higher compared with those fuelled by pure diesel. In case of mechanical efficiency blends has higher mechanical efficiency when compared with diesel. The tests were conducted at two injection pressures 180 bars and 240bar. The engine ran well at both the conditions with all the fuels.

Index Terms-- Blends, diesel engine, emissions, ethanol, fuel properties, n-butanol, and performance.

1 INTRODUCTION

Diesel engines have been widely used in almost all walks of life 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.

Since 19th century, ethanol has been used as a fuel for compression ignition (CI) engines. S. Prasad, Anoop Singh [1] 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. Alan C. Hansen, Qin Zhang, Peter W.L. Lyne [2,3] reported the properties and specifications of ethanol blended with diesel fuel are discussed.

- S.DurgaPrasad,BVC Engineering College, Odalarevu AP India. Email:sdprasad114@gmail.com.
- G.Venkateswara rao,BVC Engineering College Odalarevu AP India Email:venkat.giddi@gmail.com
- K.Sri rama murthy,AIMS college Engg,Mummidivaram APIndia Email: ksrm05@gmail.com

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.

Jincheng Huang, Yaodong Wanga, Shuangding Li, Anthony P.Roskilly [4] 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 [5, 6, 7] reported the effect of ethanol blended diesel fuels on emissions from a diesel engine.i.e the smoke emissions when the engine ran at

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the speed of 1500 r/min. When more ethanol added in, the more reduction of smoke emissions were. J. I. Dominguez, E. Miguel [8] 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.

2 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.

TABLE 1 Specifications of the engine

SL.NO	PARAMETER	SPECIFICATION
1	No. of cylinders	: Two
2	No. of strokes	: Four
3	Bore	:80.0 mm
4	Stroke	:110.0 mm
5	Rated output	: 7.36 kW
6	Connecting rod length	: 230.0 mm
7	Compression ratio	:16.5
8	Speed	:1500 rpm
9	Maximum load	:4.7kgf-m

3 PROCEDURE

The engine performance studies were conducted with electrical loaded dynamometer setup. At the injection pressure of 180bar, engine parameters like speed of the engine, fuel consumption, exhaust gas temperatures and smoke density of the exhaust gases coming out of the engine was measured at different loads for pure diesel and various blends. Now, the injection pressure was changed to 240 bars and the above was repeated. The engine performance parameters were calculated.

3.1 Blends properties

The presence of ethanol generates different physico-chemical modifications of the diesel fuel, notably red 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.

3.1.1 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 Fig.1 below.

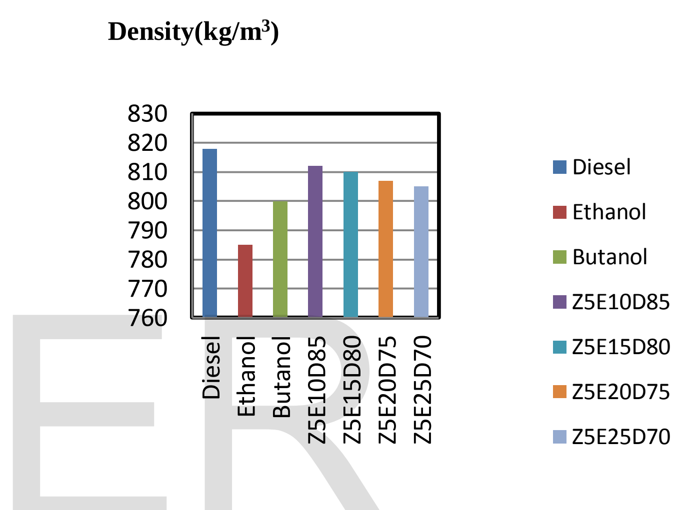

Fig1. Comparison of density of blended fuels with diesel.

3.1.2.Viscosity

Fuel viscosity plays a significant role. 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 can 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.

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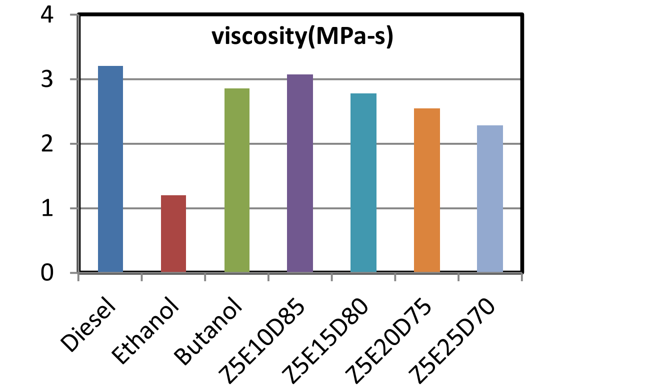

Fig:2. Comparison Viscosity and lubricity of blended fuels with diesel.

3.1.3Energycontent

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 are shown below in Fig.3

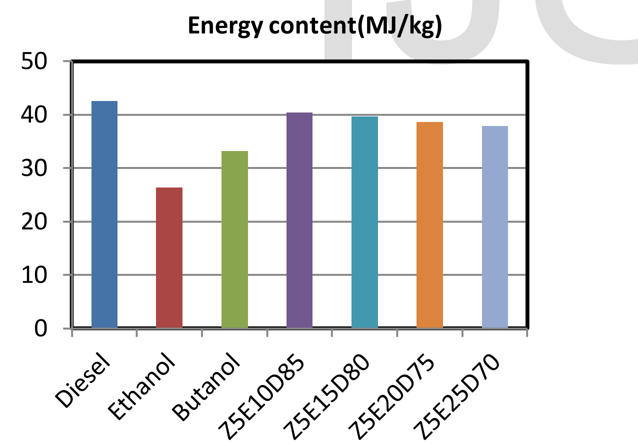

Fig3.Comparison of Energy content of blended fuels with diesel.

3.1.4Flashpoint

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.

Table:2 Properties of diesel and blends

Properties	Diesel	Ethanol	n-Butanol	Z5E10 D85	Z5E15D80	Z5E20D75	Z5E25D70
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

4 RESULTS AND DISCUSSIONS

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 are discussed here. Comparison of engine performance is carried out with the performance parameters. Then the comparison is extended for different injection pressures for each fuel. This comparison at different injection pressures to optimize the injection pressure and injection time at which the performance of the CI engine is satisfactory for each fuel considered separately.

4.1 Fuel consumption

The influence of fuel consumption on torque is represented here. It is observed that, when load increases fuel consumption also increases for the diesel and blended fuels at 180bar as shown in fig.4. 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.

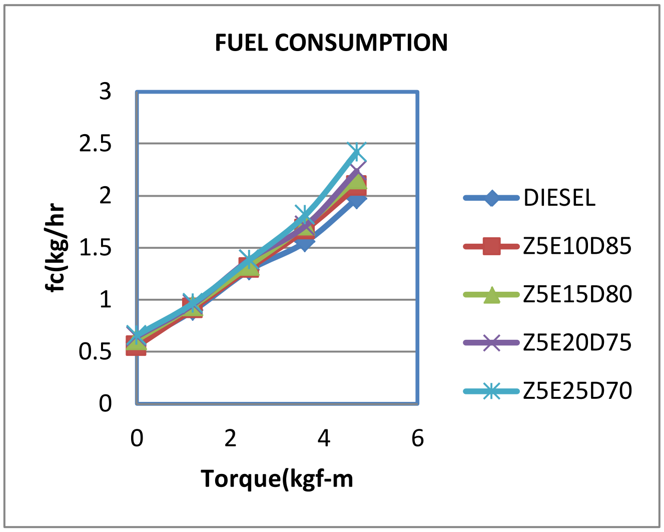

Fig 4 comparsin of fuel consumption of diesel and blends at 180bar injection pressure.

When load increases fuel consumption also increases for the diesel and blended fuels at 240bar as in fig.5. 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 issame at the reaming loads. Finally at240bar fuel consumption is slightly more at lower loads and low consumption at higher loads than180bar.

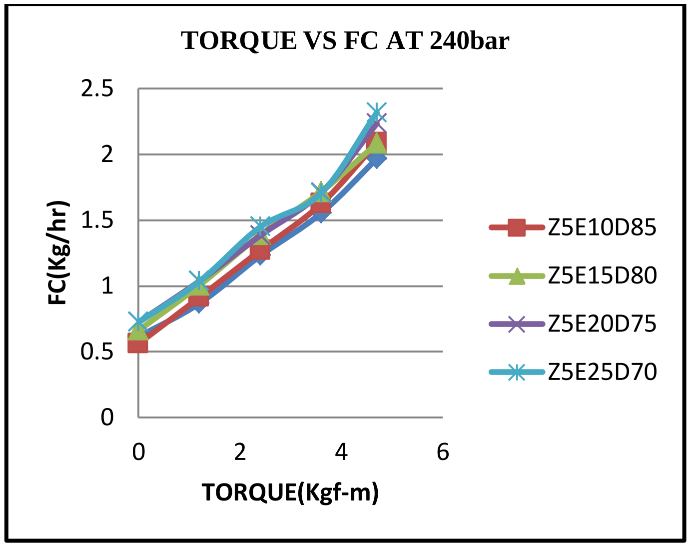

Fig: 5.Comparison of fuel consumption of diesel and blends at 240bar injection pressure.

4.2 Specific fuel consumption

The test results of the BSFCs with the engine power outputs, when the engine fuelled by different fuel blends and diesel are shown in the above fig6 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 diesel, the more fuel consumption was found, compared with those fuelled by pure diesel. When the engine ran at 1500 rpm 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%

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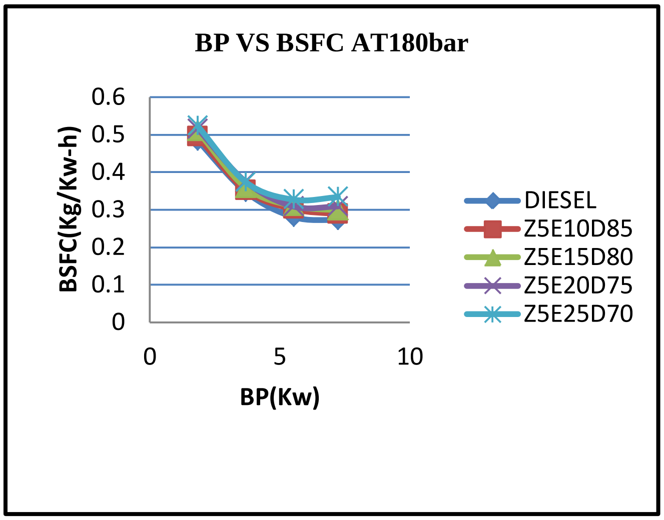

Fig 6: Comparison of specific fuel consumption of diesel and blends at 180bar injection Pressure.

When the engine ran at 1500 rpm 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.

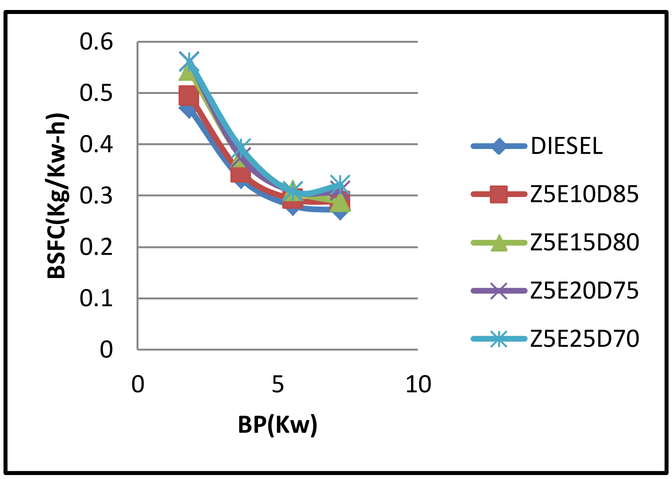

Fig.7.specific fuel consumption of diesel and blend at 240bar.

The results of the brake specific fuel consumptions with the engine power outputs, when the engine fuelled by different fuel blends and diesel are shown in the fig7.above. 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 rpm 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.

4.3 Brake thermal efficiency

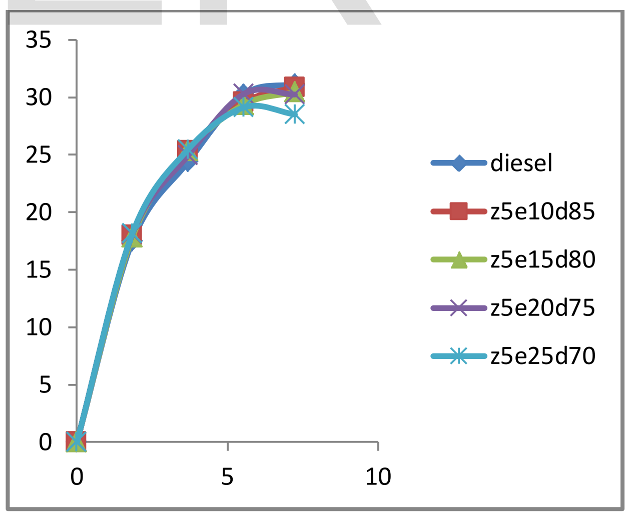

Fig: 8. Comparison of Brake thermal efficiency of diesel and blends at 180bar injection pressure.

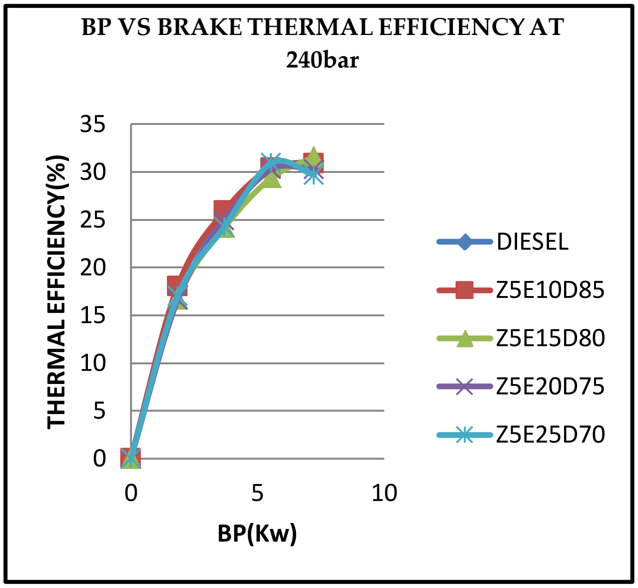

Fig: 9. Comparison of Brake thermal efficiency of diesel and blends at 240bar injection pressure.

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 are plotted on figures 8&9. 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 rpm, 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.

4.4 Exhaust gas temperatures

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.

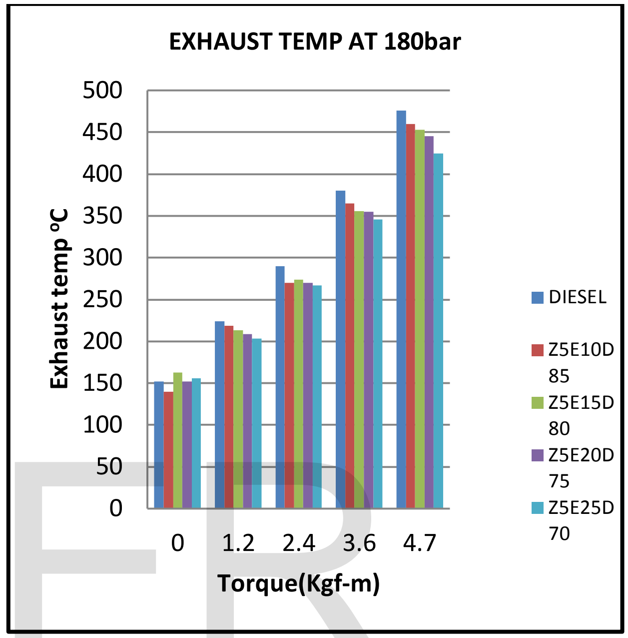

Fig: 10Comparison of exhaust gas temperatures of diesel and blends at 180bar injection pressure.

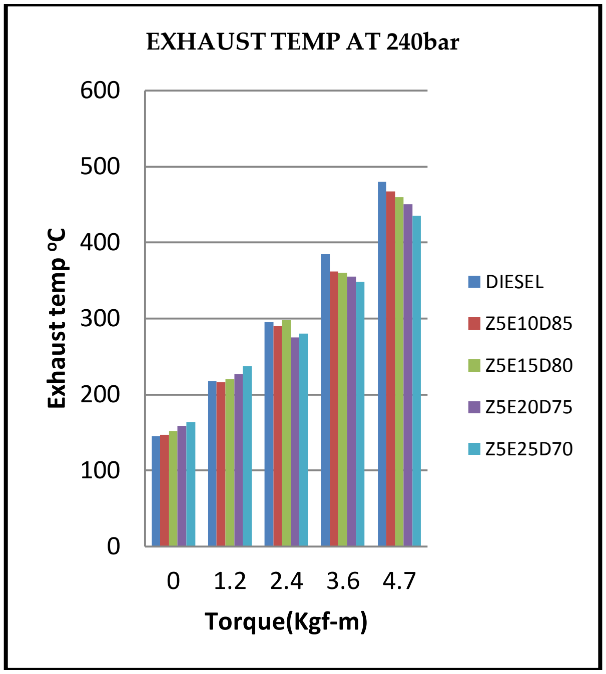

Fig:11 Comparison of exhaust gas temperatures of diesel and blends at 240bar injection pressure.

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.

4.5 Smoke Density

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.

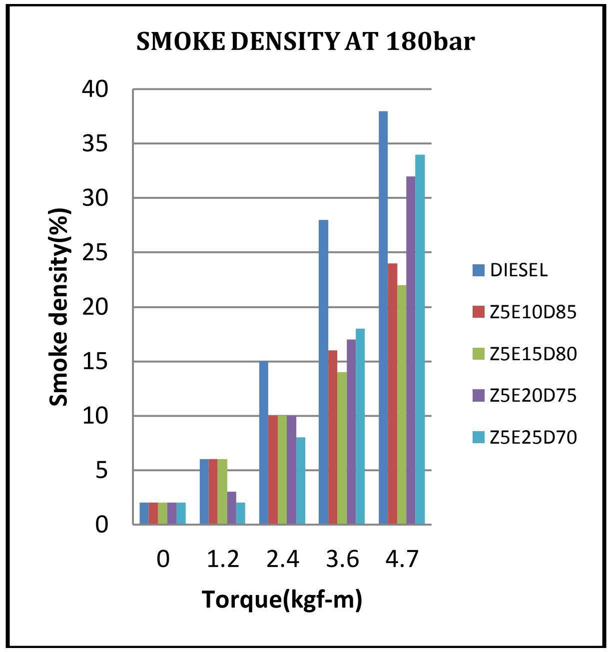

Fig: 12Comparison of smoke density of diesel and blends at 180bar injection pressure

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.

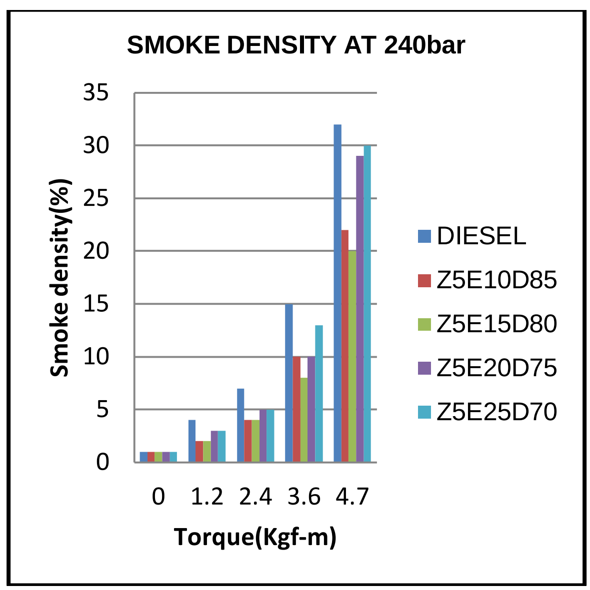

Fig: 13.Comparison of smoke density of diesel and blends at 240bar injection pressure.

4.6 Mechanical Efficiency

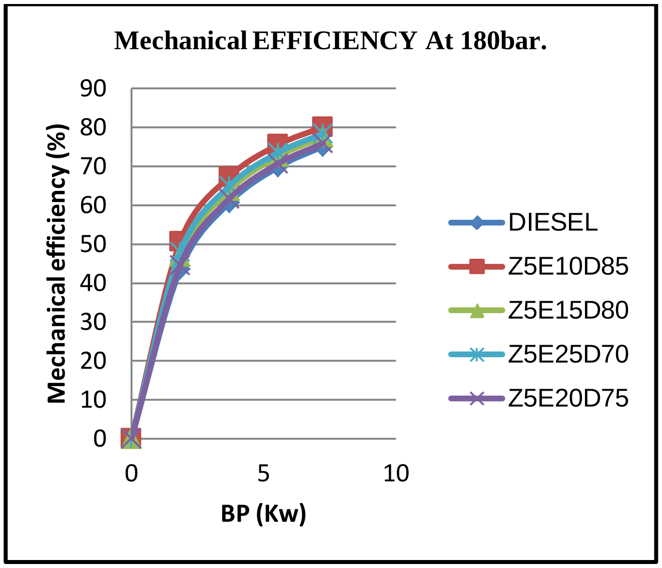

Fig: 14.Comparison of mechanical efficiency of diesel and blends at 180bar injection pressure.

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 is developed 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.

At 240bar injection pressure diesel, blended fuels have higher efficiency when compared to at 180bar, because friction losses are reduced at 240bar as showen in fig.15.In both cases z5e10d85 has higher mechanical efficiency compared with reaming blends.

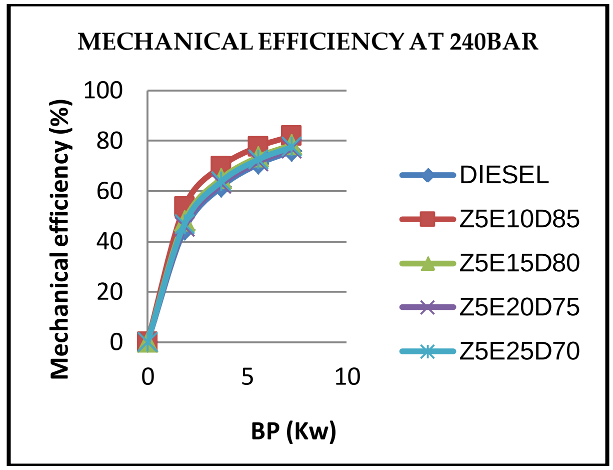

Fig: 15.Comparison of mechanical efficiency of diesel and blends at 240bar injection pressure.

CONCLUSION

An experimental investigation was conducted on the blends of ethanol with diesel and n-butanol as additive, the effects of the application of these blends on the engine performance parameters and smoke density are studied. 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 ran at the speed of 1500 rpm, respectively. From the test results, the following conclusions can be drawn.

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. 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.

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