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Performance Test of Engine Fuelled With Diesel and Ethanol Blends.

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Abstract—

Environmental concerns and limited amount of petroleum fuels have caused interests in the development of alternative fuels for internal combustion (IC)engines. As an alternative, biodegradable and renewable fuel, ethanol is receiving increasing attention. An experimental investigation on the application of the blends of ethanol with diesel to a diesel engine was carried out. First the solubility of ethanol and diesel was conducted with and without the additive of normal butanol (n-butanol). The purpose of this project is to find the optimum percentage of ethanol that gives simultaneously better performance and lower emissions. The experiments were conducted on a water-cooled single-cylinder Direct Injection (DI) diesel engine using 0% (neat diesel fuel), 10% (E10-D), 15%(E15–D), 20% (E20–D), and 25%(E25–D) ethanol–diesel blended fuels. Experimental tests were carried out to study the performance of the engine fuelled with the blends compared with those fuelled by diesel. The test results show that it is feasible and applicable for the blends with n-butanol to replace pure diesel as the fuel for diesel engine.

Keywords—*Diesel, Ethanol, N-butanol*

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,

II. 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 ⁰C 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.

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)

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 solubiliser 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 make it difficult to mix with diesel. To overcome that problem the blends two mixed with the additive of ethanol, and 83.5% diesel. The presence of ethanol generates different physic - chemical modifications of the diesel fuel, notably reductions of cetane number, low heat content, viscosity, flashpoint spray characteristics, combustion performance,and engine emissions. Compared to diesel, ethanol has lower density and lower viscosity. These characters of normal butanol (n-butanol)., 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 normal butanol (n-butanol).

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

Diesel, ethanol were 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.

Fig2.1 Separation of ethanol–diesel fuel blends

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
which were 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.

2.2. 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.

Fig2.2 Ethanol–diesel fuel blends with 5% solvent

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, 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	Z5E1 0 D85	Z5E1 5 D80	Z5E2 0 D75	Z5E 25 D70	Z5E 30 D65
Time for stratifica tion	4mon ths	3mon ths	2mon ths	40da ys	28da ys

Table 2.2 Stratification (or) phase separation of ethanol–diesel fuel blends with 5% solvent

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 in to 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 28 days 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.

III. Blends properties

The presence of ethanol generates different physic - chemical modifications of the diesel fuel, notably reductions of cetanenumber, 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.

3.1Density:

Ethanol has low density the experimental results of blend 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.

Density(kg/m³)

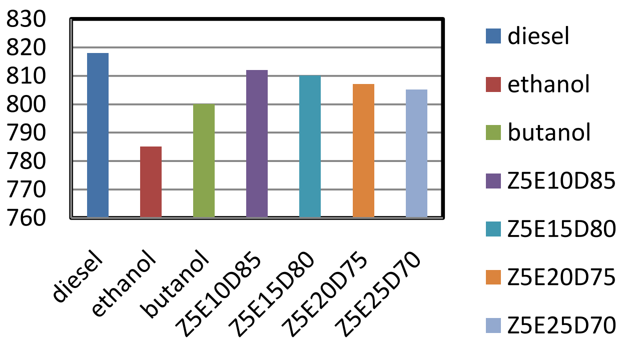

Fig. 3.1. Comparison of density of blended fuels with diesel.

3.2. Lubricity and viscosity:

Kinematic viscosity cans be measured easily shows 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 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.

3.3. 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.

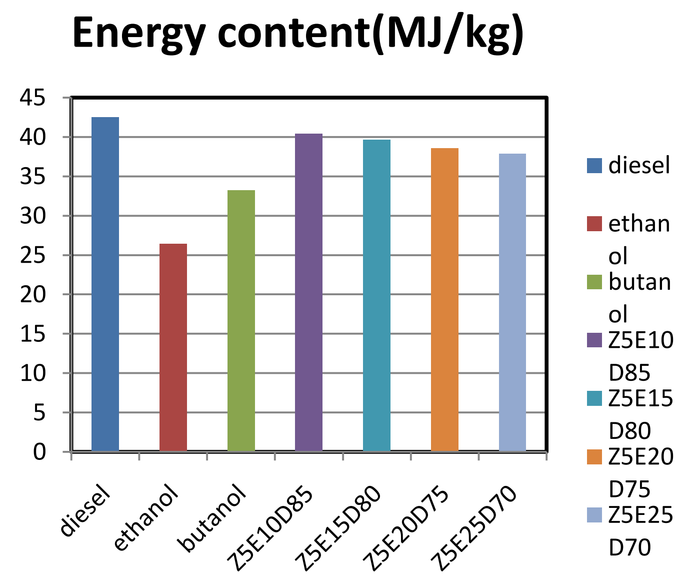

Fig.3.3.Comparison of Energy content of blended fuels with diesel.

3.4. 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.

3.5. 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.

3.6.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.

Comparison of properties of blends with diesel:

Properties	Diesel	Ethanol	n-Butanol	Z5E10D85	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

Table 3.6. Comparison of properties of blends with diesel.

IV. Instrumentation:

4.1Engine 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.

4.2Fuel measurements:

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

4.3Measurement of exhaust gas temperature:

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

4.4Measurement 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).

Fig. 4.4. SMOKE ANALYZER

V. Model calculations:

Rated Brake Power (BP) : 3.68
Speed (N) : 1500 R.P.M.
Bore (D) : 80mm
Stroke (L) : 110mm

Maximum load on the engine:
Brake Power = 2 x Π x N x T / 60
5 x 0.736 = 2 x Π x1550xT / 60
T = 3.33K.W.

Fuel consumption:
Time for 10 ml fuel consumption
= 80
Density of fuel = 820kg/m^3
Calorific value = 42500 kj/kg.

m_f = pipette reding x ρ_D x 60 / T x 1000

m_f = 10 x 0.82 x 60 / 32.6 x 1000
= 0.015Kg/min.

Total fuel consumption (TFC):
TFC = m_f x 60
= 0.015 x 60
= 0.90 in Kg/hr.

Brake specific fuel consumption (BSFC):
B.S.F.C. = T.F.C. / B.P.

= (0.9/3.68)

= 0.244 Kg/KW – hr.

Brake Thermal efficiency = B.P. x 3600 / T.F.C. x C.V.
= 1.73 x 3600 / 0.060 x 44800
= 23.7%

Mechanical efficiency = B.P. x 100
= I.P.
= 0.92 x 100
1.82
= 50.4%

5.1Observations:-

Torque (N-M)	Fuel consumption(Kg/h)	Brake power(kw)	Brake specific fuel consumption(Kg/ Kw-h)	Brake thermal efficiency(%)	Mechanical efficiency (%)	Exhaust temperature (°c)	smoke density
0	0.00615	0	0	0	0	106	2
5.61	0.5729	0.92	0.5749	14.01	43.5	124	6
10.65	0.6024	1.73	0.3482	23.07	60.63	142	15
16.61	0.7979	2.67	0.2988	26.8	69.79	166	28
20.92	0.8945	3.33	0.2686	29.9	75.1	186	38

Table 5.1. The table shows the values for pure diesel

Torque (N-M)	Fuel consumption(Kg/ h)	Brake power (kw)	Brake specific fuel consumption(Kg/ Kw-h)	Brake thermal efficiency(%)	Mechanical efficiency (%)	Exhaust temperature (°c)	smoke density
0	0.3831	0	0	0	0	109	2
5.61	0.4789	0.92	0.5205	16.8	50.6	127	6
10.65	0.6237	1.73	0.3605	24.32	67.25	144	10
16.61	0.7545	2.67	0.2790	31.4	75.49	164	16
20.92	0.865	3.33	0.2598	33.7	80.08	184	24

Table 5.2. The table shows the values for Z5E10D85

Torque (N-M)	Fuel consumption(Kg/h)	Brake power(kw)	Brake specific fuel consumption(Kg/Kw-h)	Brake thermal efficiency(%)	Mechanical efficiency (%)	Exhaust temperature (°c)	smoke density
0	0.4519	0	0	0	0	112	2
5.61	0.6386	0.92	0.6941	30	46.8	127	6
10.65	0.7344	1.73	0.4245	21	63.77	143	10
16.61	0.8901	2.67	0.3334	26.7	72.52	160	14
20.92	0.9792	3.33	0.2940	33.42	77.513	178	22

Table 5.3. The table shows the values for Z5E15D80

Torque (N-M)	Fuel consumption(Kg/h)	Brake power(kw)	Brake specific fuel consumption(Kg/Kw-h)	Brake thermal efficiency (%)	Mechanical efficiency (%)	Exhaust temperature (°c)	smoke density
0	0.4602	0	0	0	0	109	2
6.18	0.6555	0.99	0.6509	13.98	44.5	125	3
11.67	0.7858	1.870	0.4202	40.5	61.64	143	10
16.65	0.9476	2.60	0.3633	25	70.68	155	17
20.94	1.074	3.261	0.3293	27.6	75.88	180	32

Table 5.4. The table shows the values for Z5E20D75

Torque (N-M)	Fuel consumption(Kg/h)	Brake power(kw)	Brake specific fuel consumption(Kg/Kw-h)	Brake thermal efficiency(%)	Mechanical efficiency (%)	Exhaust temperature (°c)	smoke density
0	0.5253	0	0	0	0	109	2
6.18	0.7309	0.99	0.7383	12.5	48	125	2
11.67	0.8621	1.870	0.4610	20.1	64.89	148	8
16.65	1.018	2.60	0.3906	23.7	73.49	162	18
20.94	1.159	3.261	0.3335	26.1	78.35	184	35

Table 5.5. The table shows the values for Z5E25D70

VI. Results and Discussions

6.1Experimental Results:

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.The following table shows the emissions of CO in PPM for diesel other blends:

Brake power(kw)	Diesel	Blend-1	Blend-2	Blend-3	Blend-4
0	0.432	0.492	0.582	0.412	0.812
0.92	0.392	0.422	0.461	0.329	0.426
1.73	0.382	0.352	0.386	0.246	0.284
2.67	0.363	0.363	0.363	0.363	0.363
3.33	0.652	0.520	0.523	0.523	0.523

Table 6.2. The emissions of CO in % for diesel and other blends

6.2.1GRAPH PLOTTED FOR EMISSIONS OF CO IN %:-

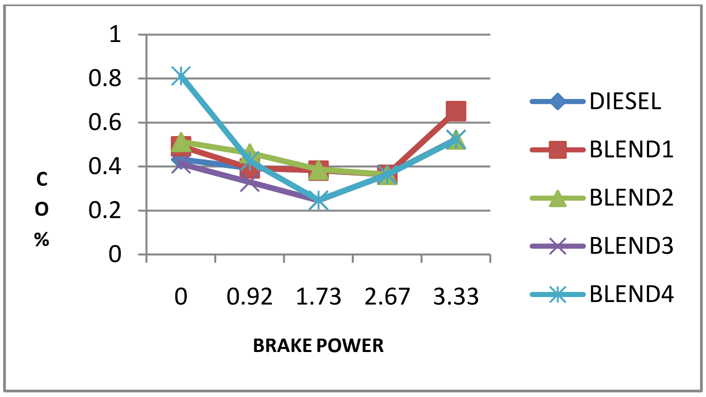

Fig. 6.2.1. Graph plotted for Brake Power Vs CO Emissions

The CO emissions from the engine fuelled by the blends were higher than those fuelled by pure diesel. The higher percentages of the ethanol were more CO emissions happened. But at the engine higher loads which were above half of the engine load, the CO emissions became lower than that fuelled by diesel for all the blend fuels. The carbon monoxide (CO) emissions from the engine. The CO emissions from the engine at the speeds of 1500 when fuelled by different Blends When the engine run at 1500 rpm and at lower loads, the CO emissions from the engine fuelled by the blends were higher than those fuelled by pure diesel.

6.3.The following table shows the emissions of HC in PPM for diesel other blends:

Brake Power(kw)	Diesel	Blend-1	Blend-2	Blend-3	Blend-4
0	23	35	45	48	90
0.92	21	32	42	45	55
1.73	19	32	39	43	43
2.67	18	25	37	38	40
3.33	22	28	35	55	37

Table 6.3. shows the emissions of HC in PPM for diesel other blends.

6.3.1. GRAPH PLOTTED FOR EMISSIONS OF HC IN %:

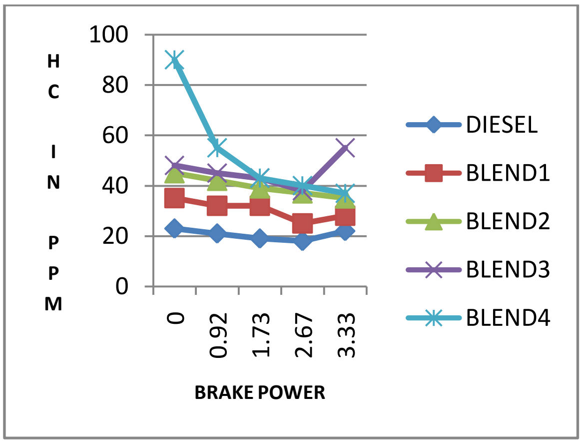

Fig. 6.3.1. Graph plotted for Brake Power Vs O_2Emissions

The results showed that the HC emissions from the engine for the blend fuels were all higher when the engine ran on the speed of 1500 r/min. The HC emissions for all blends were lower than that fuelled by diesel, i.e. from 4.2% for the blend of Z5E30D65 to 33.3% for the blend of Z5E20D75. This is due to the high temperature in the engine cylinder to make the fuel be easier to react with oxygen when the engine ran on the top load and high speed

6.4.The following table shows the emissions of NO_X in PPM for diesel other blends:

Brake Power(kw)	Diesel	Blend-1	Blend-2	Blend-3	Blend-4
0	322	300	200	192	100
0.92	504	504	395	395	200
1.73	801	820	698	730	612
2.67	1498	1601	1300	1528	1100
3.33	1306	1328	1200	1290	1253

Table 6.4. shows the emissions of NO_X in PPM for diesel other blends:

6.4.1 GRAPH PLOTTED FOR EMISSIONS OF NO_x IN %:

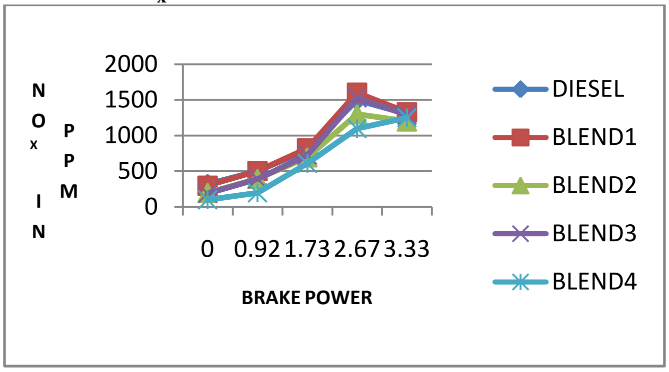

Fig. 6.4.1. Graph plotted for Brake Power vs. NOx Emissions

The NOx emissions from the engine were higher than those of diesel when fuelled by Z5E10D85, when the engine loads were 0.5 and 1.0, the NOx emissions were reduced by 15.8% and 0.8%, respectively. The NOx emissions from the engine were all lower than those of diesel when fuelled by the other blends of Z5E20D75 the reductions were between 0.0% and 44.7% for the blend of Z5E25D70 the reductions were between 3.6% and 75.6%.

6.5.The following table shows the emissions of O_2 for diesel other blends:

Brake Power(kw)	Diesel	Blend-1	Blend-2	Blend-3	Blend-4
0	26.03	15.1	33.81	15.74	12.88
0.92	31.37	18.34	34.33	17.5	18.21
1.73	32.62	24.76	33.21	22.7	19.63
2.67	33.57	28.37	28.39	18.19	23.36
3.33	32.50	32.17	22.37	18.21	25.22

Table 6.5. shows the emissions of O_2 for diesel other blends.

6.5. GRAPH PLOTTED FOR EMISSIONS OF O2 IN %:

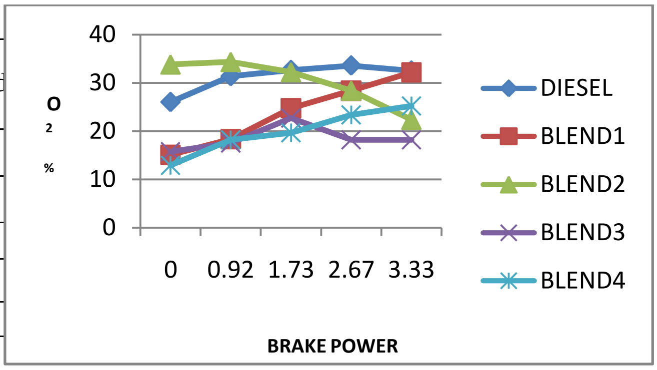

Fig.6.5.1 Graph plotted for Brake Power Vs O_2Emissions

The Oxygen Content decreases for all the Blends except for Blend-3 and Blend-4. Since the oxygen does not effect the environment, these types of emissions do not play a major role.

6.6The following table shows the emissions of CO_2 for diesel other blends:

Brake Power(kw)	Diesel	Blend-1	Blend-2	Blend-3	Blend-4
0	2.35	0.57	0.66	1.89	0.83
0.5	3.05	1.92	0.91	1.41	0.67
1.0	3.4	2.02	1.68	1.02	0.74
1.5	3.74	1.82	1.56	0.45	0.75
2.0	3.76	1.7	1.45	0.45	0.62

Table 6.6. shows the emissions of CO_2 for diesel other blends.

6.6.1. GRAPH PLOTTED FOR EMISSIONS OF CO2 IN %:

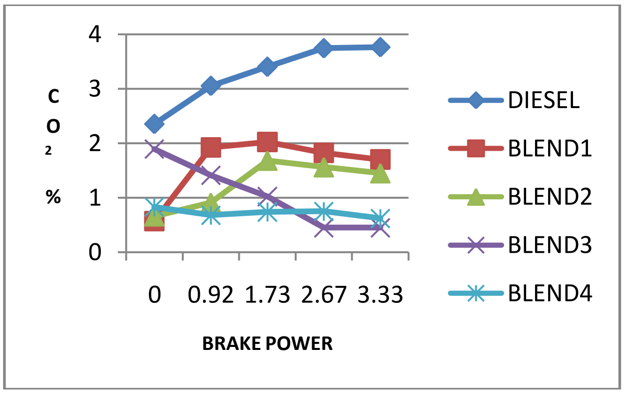

Fig.**6.6.1. Graph plotted for Brake Power Vs CO_2Emissions.**

The variation of carbon dioxide (CO2) with the % of H2/O2 Decreases. Again, the figure shows some overlapping. However, as observed from the figure, at all load levels CO2 is reduced. The reduction in CO2 is due to less carbon concentration in the formed mixture of fuels. Hydrogen is a carbon less fuel and when substituted to diesel formed mixture produces less carbondioxide.The reduction of CO2 is achieved at all load conditions.

6.7. Fuel consumption:

Torque(N-m)	Diesel	Z5E10 D85	Z5E15 D80	Z5E20 D75	Z5E25 D70
0	0.00615	0.3831	0.4519	0.4602	0.5253
5.61	0.5729	0.4789	0.6386	0.6555	0.7309
10.65	0.6024	0.6237	0.7344	0.7858	0.8621
16.61	0.7979	0.7545	0.8901	0.9476	1.018
20.92	0.8945	0.865	0.9792	1.074	1.159

Table 6.7. Fuel consumption of diesel and blends at 180bar injection pressure.

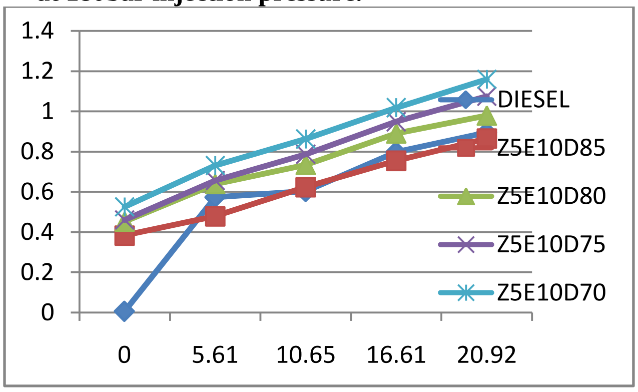

Fig.6.7. TORQUE VS FC

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.

6.8. Specific fuel consumption:

BP(Kw)	Diesel	Z5E10 D85	Z5E15 D80	Z5E20 D75	Z5E25D70
0	0	0	0	0	0
0.921	0.5749	0.5205	0.6941	0.6504	0.7383
1.73	0.3482	0.3605	0.4245	0.4202	0.4616
2.67	0.2988	0.2790	0.3334	0.3633	0.3906
3.33	0.2686	0.2598	0.2940	0.3293	0.3335

Table 6.8. Specific fuel consumption of diesel and blends at 180bar injection pressure

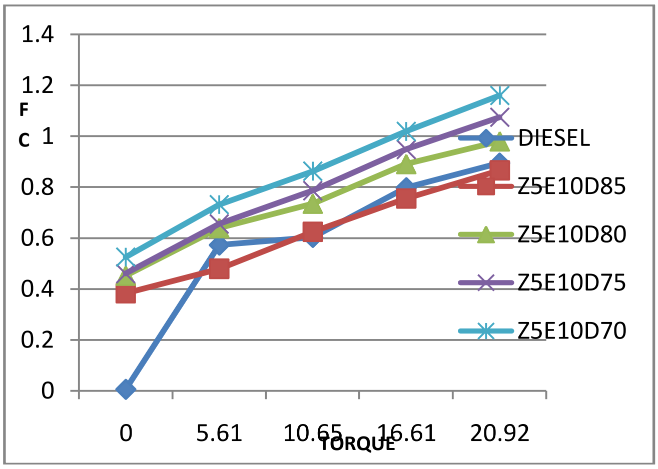

Fig.6.8. B.P. VS B.S.F.C.

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.

6.9. Brake thermal efficiency:

BP(Kw)	Diesel	Z5E10 D85	Z5E15 D80	Z5E20 D75	Z5E25D70
0	0	0	0	0	0
0.92	14.01	16.8	30	13.48	12.5
1.73	23.07	24.32	21	40.5	20.1
2.67	26.8	31.4	26.7	25	23.7
3.33	29.9	33.7	33.42	27.6	26.7

Table 6.9. Brake thermal efficiency of diesel and blends at 180bar injection pressure.

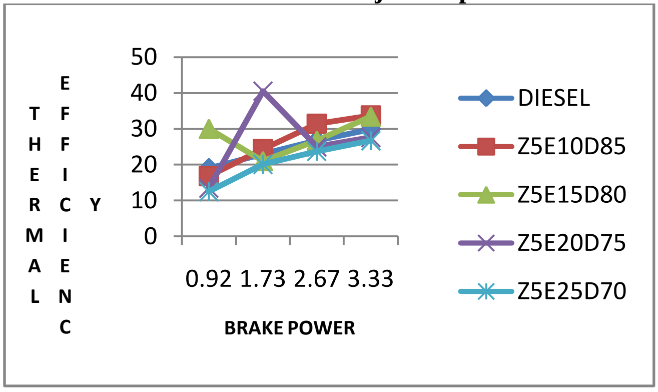

Fig.6.9. B.P.VS BRAKE THERMAL EFFICIENCY

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.

6.10. Exhaust gas temperatures:

Torque (Kgf-m)	Diesel	Z5E10 D85	Z5E15 D80	Z5E20 D75	Z5E25 D70
0	106	109	112	109	109
5.61	124	127	127	126	125
10.658	142	144	143	149	142
16.610	166	164	160	163	162
20.920	186	184	178	182	184

Table 6.10. Exhaust gas temperatures of diesel and blends at 180bar injection pressure.

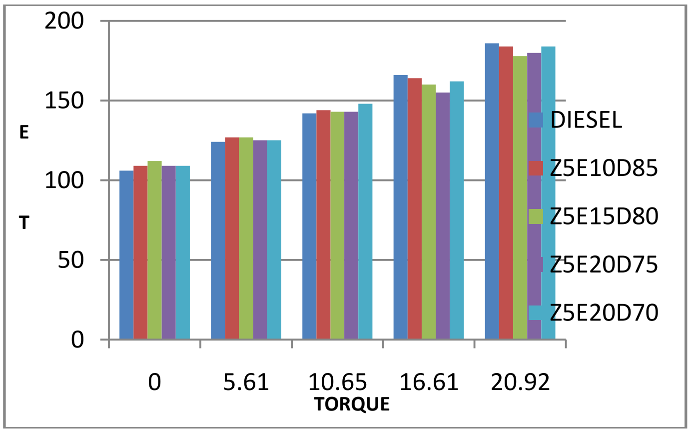

Fig.6.10. EXHAUST TEMPERATURE VS TORQUE

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.

6.11. Smoke density:

Torque (Kgf-m)	Diesel	Z5E10D85	Z5E20 D75	Z5E25 D70
0	2	2	2	2
1.2	6	6	3	2
2.4	15	10	10	8
3.6	28	16	17	18
4.7	38	24	32	34

Table 6.11. Smoke density of diesel and blends at 180bar injection pressure.

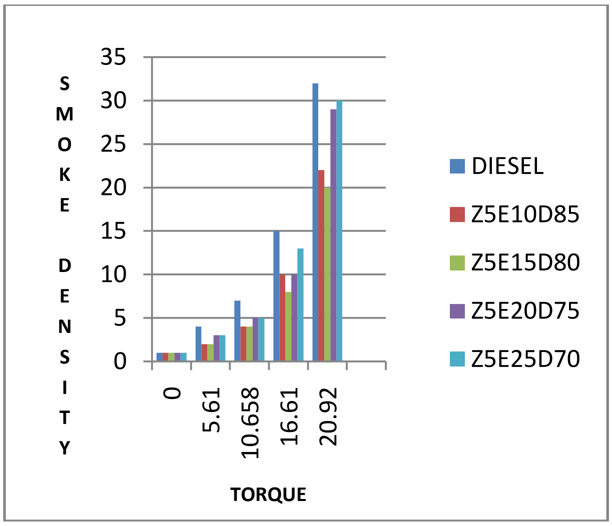

Fig.6.11. COMPARISON OF SMOKE DENSITY AND BLENDS.

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.

6.12. Mechanical Efficiency:

BP(Kw)	Diesel	Z5E10 D85	Z5E15D 80	Z5E20 D75	Z5E25D 70
0	0	0	0	0	0
0.92	43.5	50.6	46.8	44.5	48
1.73	60.632	67.257	63.770	61.643	64.890
2.67	69.790	75.492	72.529	70.680	73.491
3.33	75.100	80.085	77.513	75.887	78.352

Table 6.12 . Mechanical Efficiency of diesel and blends at 180bar injection pressure

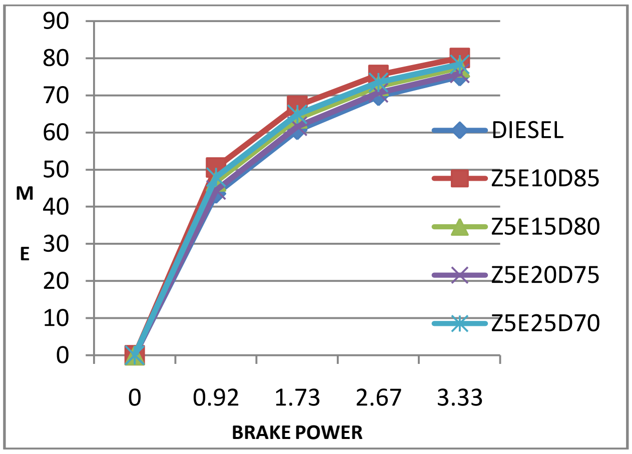

Fig.6.12. MECHANICAL EFFICIENCY VS B.P.

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.

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.

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.

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. In z5e10d85 has 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.

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