Experimental and CFD Analysis of Combustion in Diesel Engine for Various Ethanol-Diesel Blends

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Abstract: ***Diesel engines are used widely around the globe as power plants for various purposes due to their excellent drivability and economy. But they are also the major contributors of air pollutants such as CO, NO_x, PM and other harmful compounds. At the same time the global fuel crises and increase in fuel prices have led us to the need of developing an alternate fuel that would give a solution to these problems. For about a decade researches and investigations were conducted on the use of ethanol-diesel blend as a fuel in diesel engines. Many proposals were made and few are commercially implemented. Many of the results comes to a conclusion that ethanol-diesel blend could solve the problems mentioned above. The aim of this project is to find the optimum ethanol-diesel blend that suits the diesel engines presently available in the market and could be used without much modification in the engine. With the help of various methods to find fuel properties, performance test on diesel engine for various fuel blends and software analysis the optimum blend is found out. The blend of fuel found out as the result of this project could be the fuel that drives the future.***

Keywords: Ethanol-Diesel blend

1. Introduction

Ethanol is an attractive alternative fuel because it is a renewable bio-based resource and it is oxygenated, thereby providing the potential to reduce particulate emissions in compression–ignition engines. Ethanol is a renewable energy; it can be made from many raw materials such as sugar cane, molasses, cassava, waste biomass materials, sorghum, corn, barley, sugar beets, etc. by using already improved and demonstrated technologies.The dwindling fossil fuel sources and the increasing dependency on imported crude oil have led to a major interest for many countries in expanding the use of bioenergy.

In this project the properties and specifications of ethanol blended with dieselfuel are discussed. 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.

2. Problems Associated with Implementing Ethanol – Diesel Blend as Fuel in Diesel Engines and Methods to Overcome it

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. 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.

The major problem associated with use of alcohol in diesel engine is, the limited miscibility at lower temperature and the required minor variations in fuel delivery systems restrict the use of ethanol in diesel. One of the effective approaches is adding oxygenated fuel to solve the above problem without any modification of the engine. The selection of oxygenated fuels is based on economic viability, toxicity and fuel blending properties. Ethanol (97 to 99%) is highly soluble in diesel fuel at contents of approximately 0-20% and 80-100% within this region of miscibility; we observe cloudiness in the mixture followed by separation. When the water content of ethanol exceeded 1% the occurrence of this phenomena can be prevented by using additives.

When the ethanol content is more than 45%, misfire is normally observed under some conditions, because the ignition delay is pro-longed due to the low cetane number of ethanol in the blend fuels. The ignition occurs wellafter the top dead center (TDC), especially at high speed.

With the ethanol-diesel blend the engine starts without any problem and it runs smooth, but with the increase in ethanol content upto 50% engine noise develops.

Lower cetane numbers means longer ignition delays, allowing more time for fuel to vaporize before combustion starts. Initial burn rates are higher causing more heat release at constant volume, which is a more efficient conversion process of heat to work.

The flammability characteristics of ethanol-diesel blends were more like those of ethanol than diesel fuel with headspace vapors of these blends being flammable within storage tanks at approximately 12^0-42^0C compared to diesel fuel at 64^0C. Temperatures of fuel in the tank of diesel-fueled vehicles

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are raised because of fuel recirculation needed to cool the fuel injection system. Temperatures as high as 93^0C may be expected. A key hazard of the higher flammability limits is ignition of the plume of vapor leaving the tank during refueling as a result of external sparks, static discharge or smoking materials.

3. Experimental Analysis

The specification of the selected diesel engine is shown in Table 1. Single cylinder four-stroke watercooled diesel engine running at constant speed of 1500 rpm was used for this work. The engine consists of an electric loading arrangement for measuring net load and fuel consumption.

Table 1: Engine Specifications

Bore Diameter	80 mm
Stroke Length	110mm
No. of Strokes	4
No. of Cylinders	1
Rated Power	5 hp (3.73 KW)
Rated Speed	1500 rpm
Type of Cooling	Water Cooled
Type of Loading	Electrical Type
Alternator Efficiency	80%
Energy Meter Constant	300rev/kwhr

a) Properties of the blended fuel used

1) Calorific value

The calorific value of any substance can be found using a bomb calorimeter.

2) Density

Density of the fuel blend can be found out by using a measuring flask and weighing machine.

Table 2: Density and Calorific Value Of Various Blends

Fuel	Density(kg/m^3)	Calorific Value(kJ/kg)
DIESEL	820	44514
E5	818.99	43631
E10	811.60	43192
E15	806.3	42744
E20	803.4	41874

b) Performance test

Performance test is carried out in a single cylinder four stroke diesel engine by using the diesel fuel and ethanol blends such as E5, E10, E15, and E20.

1) Specific fuel consumption

The variation of brake specific fuel consumption with brake power is shown in table 4.1. It is reveals that as the load increases the fuel consumption decrease. At full load condition specific fuel consumption obtained are 0.336 kg/kwhr, 0.316 kg/kwhr, 0.301 kg/kwhr, 0.287 kg/kwhr, 0.282 kg/kwhr for fuels of diesel, E5, E10, E15 and E20 respectively. Brake specific fuel consumption is decreased with the blends when compared to diesel.

Table 3: SFC for Various Blends At Various Loads

DIESEL	E5	E10	E15	E20
1.02	0.880	0.867	0.850	0.890
0.504	0.470	0.425	0.413	0.421
0.439	0.354	0.349	0.337	0.357
0.357	0.306	0.303	0.299	0.306
0.336	0.316	0.301	0.287	0.282

2) BrakeThermal Efficiency (BTE)

The variation of brake thermal efficiency with brake power is shown in table 4.2. From the plot it is observed that as the load increases the brake thermal efficiency increases. At full load condition the brake thermal efficiency obtained are 24.08%, 26.11%, 27.69%, 29.25% and 30.46% for fuels of diesel, E5, E10, E15 and E20 respectively.

Table 4: BTE for Various Blends At Various Loads

DIESEL	E5	E10	E15	E20
0	0	0	0	0
7.96	9.37	9.61	9.90	9.65
16.03	17.53	19.57	20.36	20.41
18.45	23.34	23.82	24.98	24.06
22.71	27.00	27.49	28.16	28.07
24.08	26.11	27.69	29.24	30.46

3) Indicated Thermal Efficiency (ITE)

The variation of indicated thermal efficiency with brake power is shown in table 4.3. It reveals that as the load increases the indicated thermal efficiency increases. At full load condition the indicated Thermal efficiency obtained are 35.90%, 33.92%, 36.02%, 37.89% and 39.36% for fuels of diesel, E5, E10, E15 and E20 respectively.

Table 5: ITE for Various Blends At Various Loads

DIESEL	E5	E10	E15	E20
20.83	13.82	14.53	14.55	14.68
26.59	22.09	22.79	23.42	23.16
32.06	28.18	30.91	32.23	32.34
33.48	33.27	34.17	35.70	34.54
35.18	35.53	36.32	37.25	37.22
35.90	33.92	36.02	37.89	39.36

4) Mechanical Efficiency (ME)

This is the rating that shows how much of the power developed by the expansion of the gases in the cylinder is actuallydelivered 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 remains practically constant throughout the engine's speed range. Therefore, the mechanical efficiency of an engine will be highest when the engine is running at the speed at which maximum bhp is developed. The variation of mechanical efficiency with brake power is shown in table 4.4. It reveals that as the load increases the mechanical efficiency increases. At full load condition the brake thermal efficiency obtained are 67.06%, 76.98%, 76.88%, 77.18% and 77.38% for fuels of diesel, E5, E10, E15 and E20 respectively.

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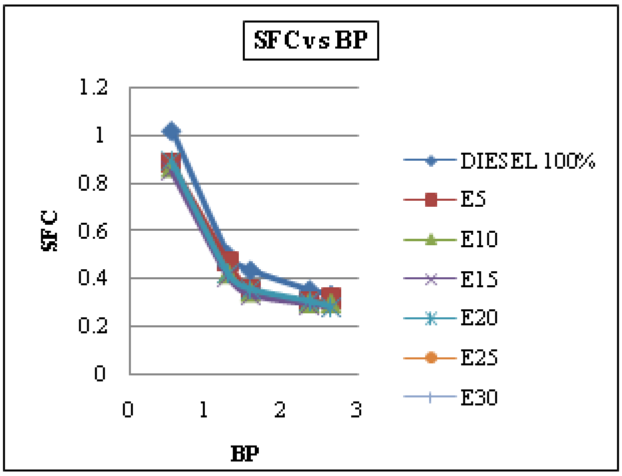
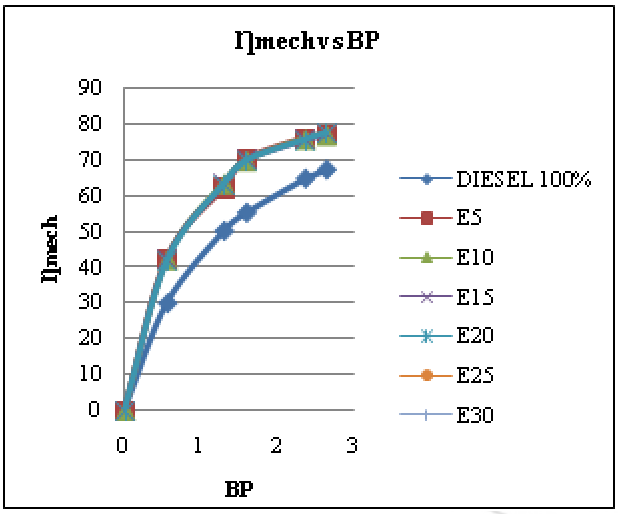
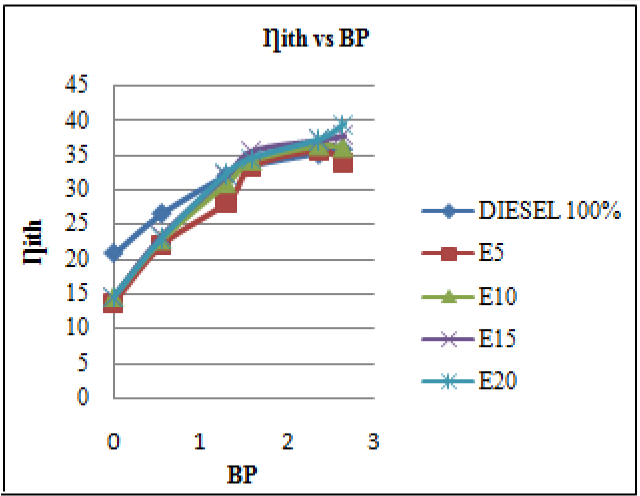
Table 6: ME For Various Blends At Variousloads

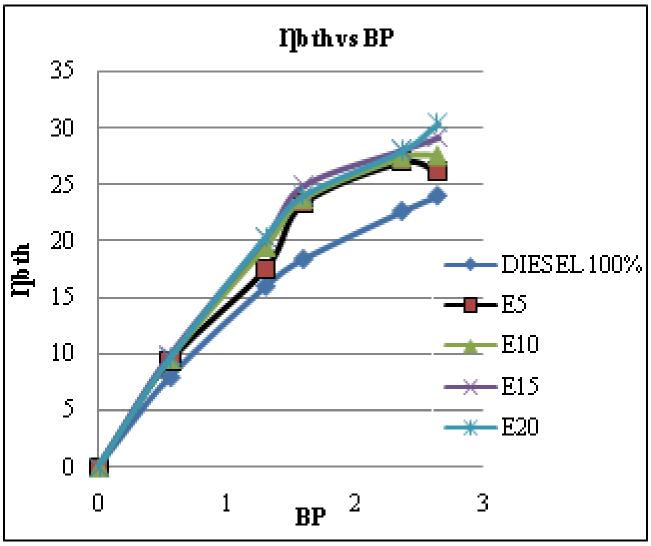
DIESEL	E5	E10	E15	E20
0	0	0	0	0
29.94	42.51	42.16	42.29	41.66
50.01	62.18	63.31	63.18	63.11
55.1	70.14	69.73	69.98	69.65
64.56	75.99	75.70	75.6	75.41
67.06	76.98	76.88	77.18	77.38

c) Performance graphs









4. Software Analysis

Carbon monoxide distribution for various fuel blends along the cylinder cross section is shown below.

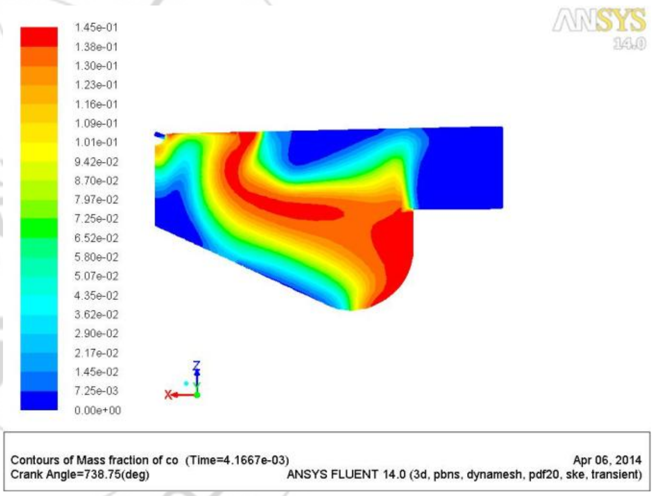


Figure 1: CO distribution when diesel is used

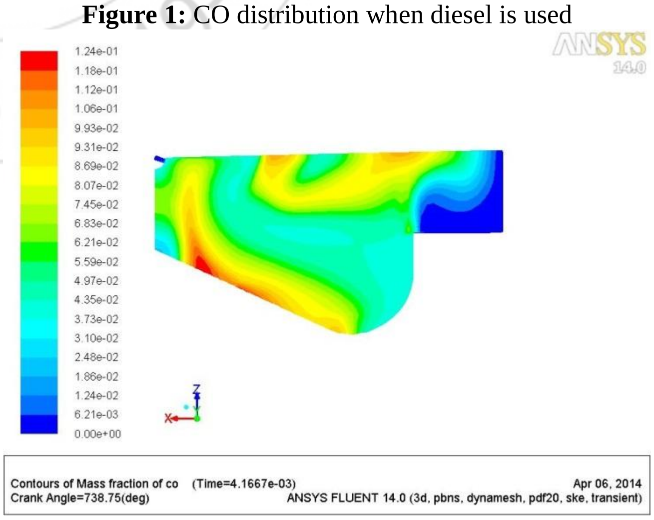


Figure 2: CO distribution when E5 is used

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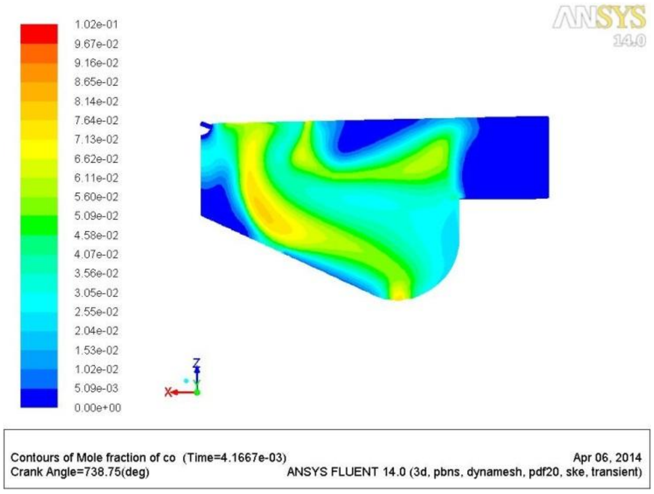

Figure 3: CO distribution when E10 is used

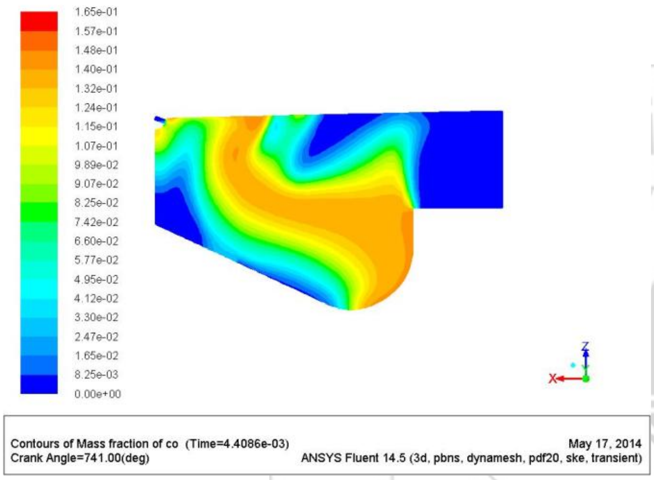

Figure 4: CO distribution when E20 is used

Pressure distribution for various fuel blends along the cylinder cross section is shown below.

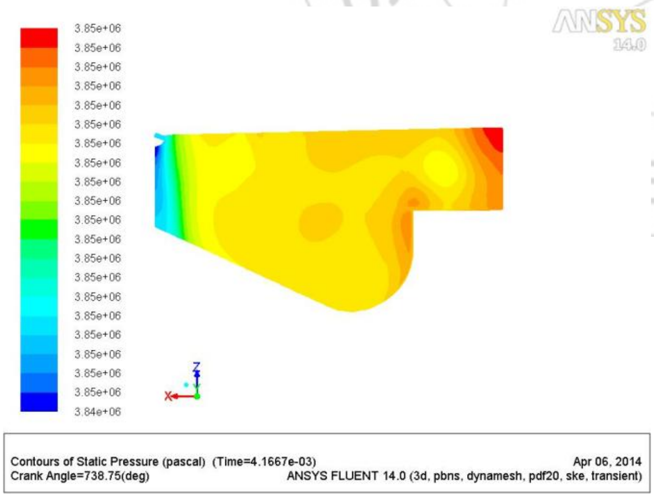

Figure 5: Pressure distribution when diesel is used

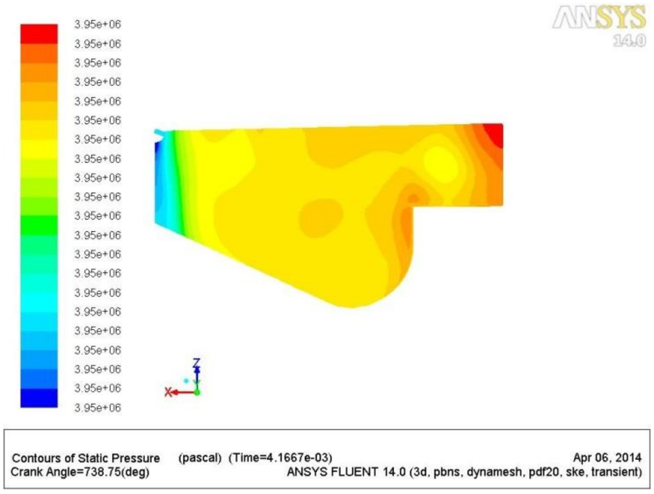

Figure 6: Pressure distribution when E5 is used

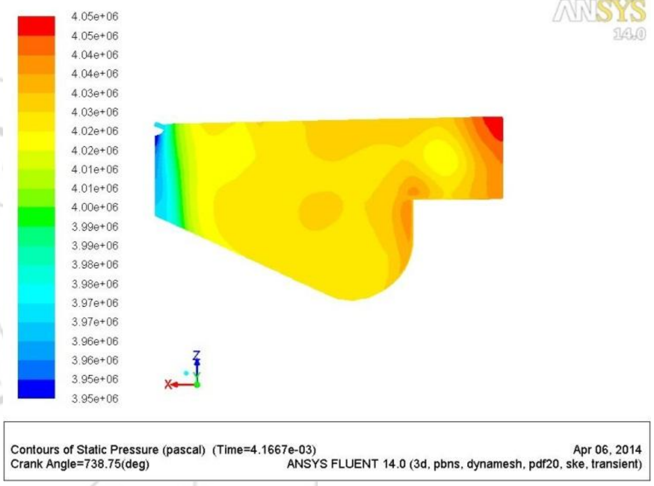

Figure 7: Pressure distribution when E10 is used

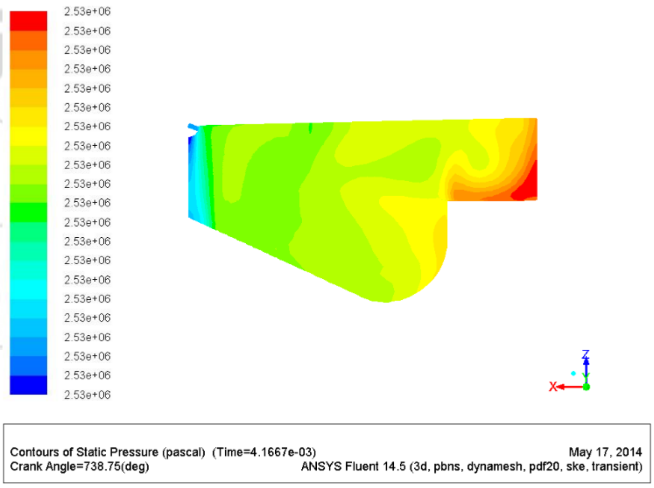

Figure 8: Pressure distribution when E10 is used

Temperature distribution for various fuel blends along the cylinder cross section is shown below.

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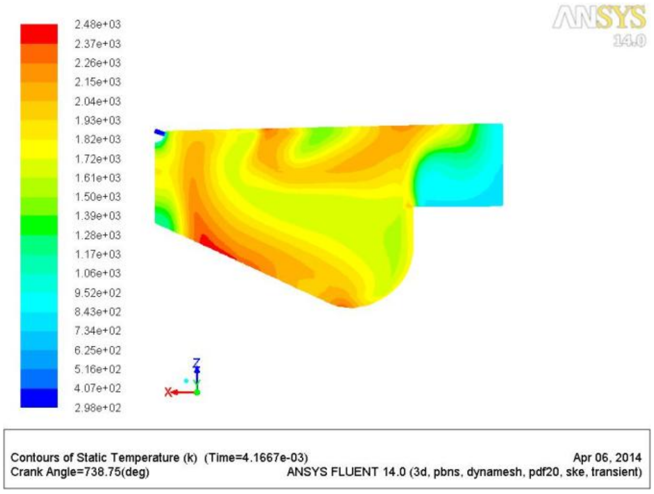

Figure 9: Temperaturedistribution when Diesel is Used

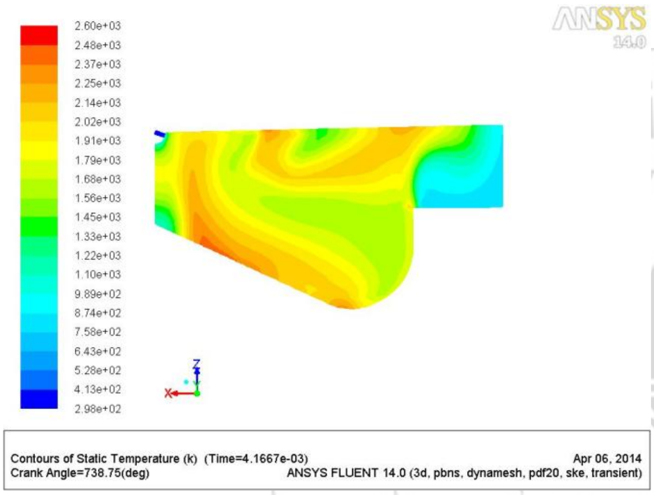

Figure 10: Temperature distribution when E5 is used

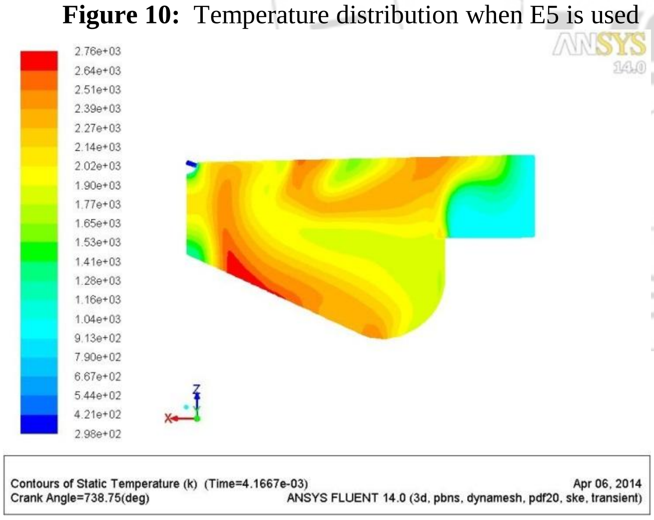

Figure 11: Temperature distribution when E10 is used

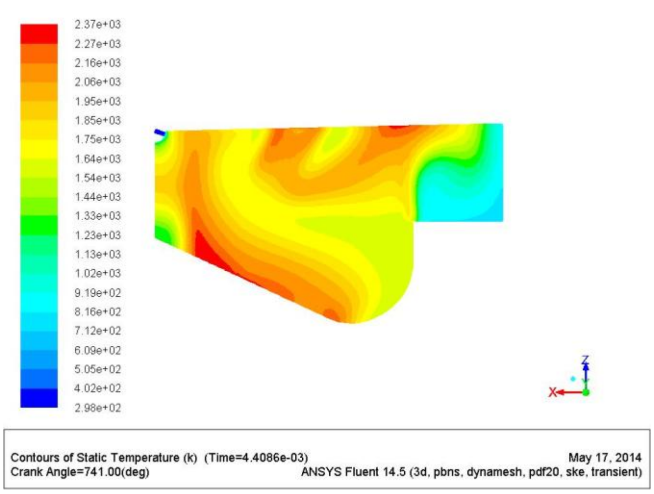

Figure 12: Temperature distribution when E20 is used

NO_x distribution for various fuel blends along the cylinder cross section is shown below.

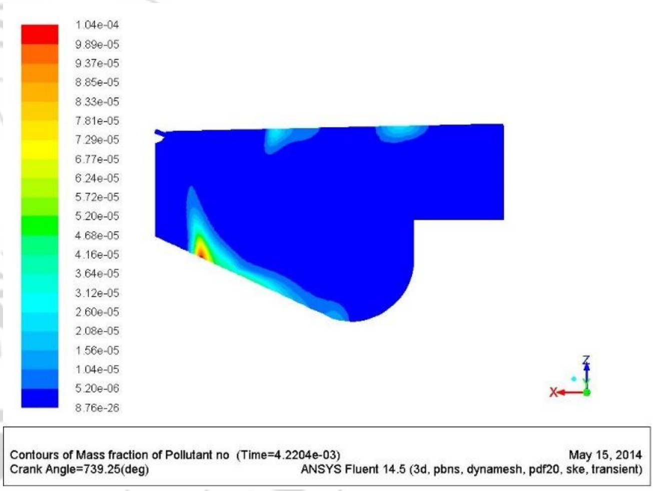

Figure 13: NO_x distribution when diesel is used

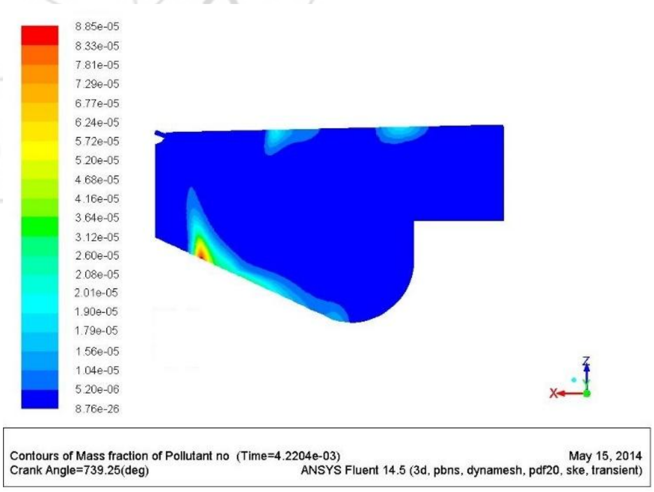

Figure 14: NO_x distribution when E5 is used

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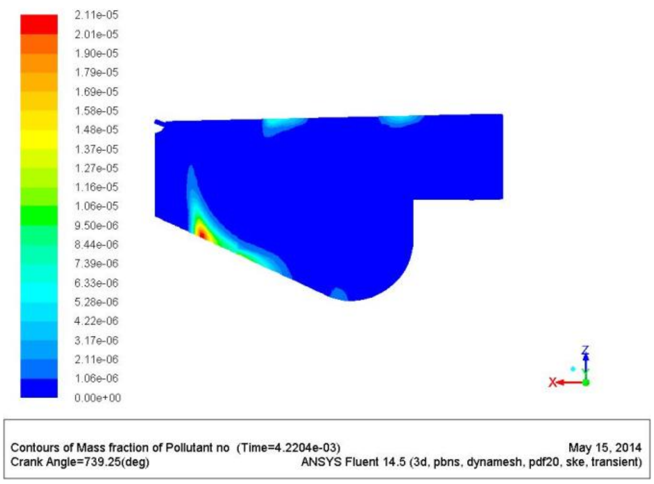

Figure 15: NO_x distribution when E10 is used

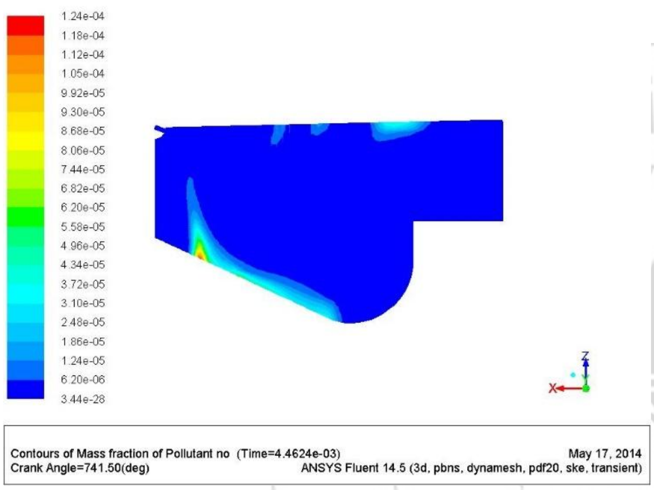

Figure 16: NO_x distribution when E20 is used

5. Conclusion

The conclusions derived from present experimental investigations to evaluate performance characteristics on four stroke single cylinder diesel engine fueled with diesel Ethanol blends are summarized as follows. Brake thermal efficiency increased with all blends when compared to the conventional diesel fuel. The Brakespecific fuel consumption is decreased with the blends when compared to diesel. From the above analysis the blend E20 shows the better performance compared to other blends. From the present study the relative density of all the blends were found to be lower than that of diesel fuel alone. The relative density was dependent on temperature. Calorific values of the blends were lower than that of diesel but the deviation from the calorific value of diesel is approximately less than 5%, which is within acceptable range. In general, blends containing 5, 10, 15 and 20% ethanol have very close fuel properties compared to diesel fuel. From the above analysis it is clear that the efficiency of the diesel engine is increased with increasing the percentage of ethanol.

From the CFD analysis we can see that, as the ethanol content is increasing in the fuel CO level is decreasing after combustion of the fuel. There is not much variation in pressure and temperature levels as the ethanol content is increasing. From the NOx analysis we can see that its content is decreasing with the increase of ethanol content in the fuel.

These analysis help us to confirm that diesel oxygenated with ethanol does not adversely affect engine wear compared to diesel fuel. It is accepted that the addition of ethanol to diesel fuel will have a beneficial effect in reducing the PM emissions at least.

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