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Cfd Analysis of Combustion Process Of 4-Stroke Diesel Engine With Blended Fuels

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Abstract **- In current study investigation was done on the proper mixing of chemical species and the combustion of dual fuel (Diesel + Methanol + Ethanol) with various blend grades. Present study used one conventional and other is Alternate fuels due to challenges in power sector. A cylindrical combustor burning (Diesel + Methanol + Ethanol) in air is studied using the eddy-dissipation model in ANSYS (Fluent). Our main objective of the study is to analyze the dual fuel combustion model. Result shows that methanol participation in combustion process causes an increase in peak pressure value. The net Turbulent Kinetic energy is at its peak at the nozzle, away from the nozzle the turbulence increases. The pollutant emissions (Carbonic oxides) are decreasing in higher percentage of alternate blends as compare to the lower one that shows the complete combustion rate is increased. In current work Ethanol and Methanol can be used as an Alternate fuel which is cheaper in cost and easily available as compare to the conventional fuels.**

Keywords- **Dual fuel, Methanol, Ethanol, CFD, Emission, Turbulence, Pressure, Temperature**

I. INTRODUCTION

The combustion research is more extensive, diverse and interdisciplinary due to a powerful modeling tool like the Computational Fluid Dynamics (CFD). In CI engine, the in-cylinder multiphase fluid dynamics like fuel spray, chemical reaction kinetics influence the combustion. The fluid flow in an internal combustion engine presents one of the most challenging fluid dynamics problems to the model. This is because the flow is associated with large density variations. So, a detailed understanding of the flow and combustion processes is required to improve the performance of the engine [7,9].

Substantial differences in viscosity, surface tension, density and thermal conductivity were obtained relative to reference diesel fuels and among the different source materials. The combustion model revealed differences in the temperature and emissions of biodiesel when compared to reference diesel fuel [1-8]. The combustion chamber flow field and its effect on fuel spray characteristics play an important role in improving the efficiency and reducing the pollutant emission in a direct injection diesel engine, in terms of influencing processes of breakup, evaporation, mixture formation, ignition, combustion and pollutant formation. CFD modeling was a valuable tool for acquiring detailed.

Information about these important processes [2,5]. The longer ignition delay leads to a rapid burning rate and the pressure and temperature inside the cylinder rise suddenly. Hence, most of the fuel burns in premixed mode causes a maximum peak heat release rate, a maximum cumulative heat release and shorter combustion duration [9-17]. The demand for energy, specifically the demand for petroleum fuels around the world is increasing every day. From 2012 to 2015, 41% increase in global energy consumption is forecasted, 30% and 52% increase over last ten and last twenty years respectively. Non-OECD economies will account for 95% of this growth, half of which is expected to come from China and India. Compared to 2012, 69% higher energy will be used in 2035 in the non-OECD economics. Due to having benefits such as adaptability, high combustion efficiency, availability, reliability as well as the handling facilities, fossil fuels results in most energy consumption.

Shares of the major fossil fuels are converging, with natural gas, oil and coal each contributing 27% of the total mix by 2035 and the remaining share supplied by nuclear and renewable energy. Burning of fossil fuels produces emissions that have serious effect on both the environment as well as human health. Fuel, coal and gas each contributes 38% of the increase in emissions and 24% increase is coming from oil. It is predicted that by 2035 global CO2 emissions from energy use will increase 29%.

II. COMPUTATIONAL DOMAIN

The study focuses on the to calculate the NOx percentage and the geometry used for the simulations is therefore only a part of the whole exhaust gas system in order to save computational time. The generation of the model by using ANSYS shown below.

The cylindrical combustor considered in Present study is shown in figure 3.1. The flame considered is a turbulent

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diffusion flame. A small nozzle in the centre of the combustor introduces (Diesel + Ethanol) at 80 m/s.

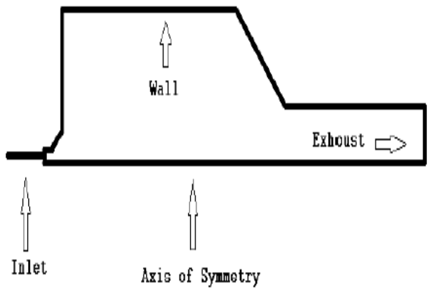

Fig. 1 Sketch of computational domain

Ambient air enters the combustor coaxially at 0.5 m/s .The overall equivalence ratio is approximately 0.76 (approximately 28% excess air).Thehigh-speed methane jet initially expands with little interference from the outer wall and entrains and mixes with the lowspeed air. The Reynolds number based on the dual fuel jet diameter is approximately $5.7x10^{-3}$ mm.

1. Boundary Conditions

The models have been used for the combustion are classified as zero-dimensional, single zone to multi-zone and multi-dimensional models. The Two zone flamelet model is a fractal-based combustion model which considers the possible finite pre-combustion air/fuel mixing and is therefore able to cope with both premixed and non-premixed burning conditions. It also has the advantage of high computational efficiency[2]. The Richardo two zone flame let (RTZF) combustion model is based on a “Two-Zone” assumption whereby each computational cell is notionally divided into burned and unburned zones; the unburned zone is further divided into segregated and mixed regions. It is assumed that only in the mixed region that the air and fuel are mixed at the molecular level and ready for chemical reactions[1,4].

III.MATERIAL

- Diesel+ Ethanol + Methanol- In Present study five different type of blends were used and analyse by CFD tools on the basis of temperature, velocity, pressure and emissions like Cox and NOx.
- Mixture: - Species I H_2O, II-O_2, III-Fuel -EG, IV-CO_2, V-N_2

Reactants	Stoichmetric Coefficient	Rate exponent	Products	Stoichmetric Coefficient	Rate exponent
Fuel	1	1	CO_2	1.022	0
O_2	7.52	1	H_2O	20.22	0

IV.DIMENSION OF ENGINE

The engine specifications, model and operating conditions examined in the present study are provided below.
Engine = IDI engine
Combustion chamber = I-type
Number of Cylinders = 1
Bore &Stroke = 85 and 110 mm
Displacement = 198.49 CC
Valve Train = 2 Intake, 2 Exhaust
Connecting Rod Length= 144.3mm
Crank radius = 45mm
Piston Offset = 0mm
Minimum Lift = 0.5mm
Intake Valve Closing, (IVC) = 35.5° CA after BDC
Exhaust Valve Open, (EVO) = 35.5° CA before BDC
BHP = 3 to 5 HP
Fuel Injection Timing = 23° CA before TDC

V. RESULTS

1. Effect of Blending On Turbulence

Turbulence increases the heat flow to the cylinder walls. It also accelerates the chemical reaction by mixing of fuels and oxygen so that spark advance may be reduced. As the ratio of ethanol increases turbulent kinetic energy, turbulent intensity and turbulent dissipation rate an increase as shown in the result analysis figures4.1, 4.2&4.3, which result in reduced combustion duration and hence minimizes the tendency of abnormal combustion. The turbulent viscosity increases as it moves away from the nozzle section (centre).

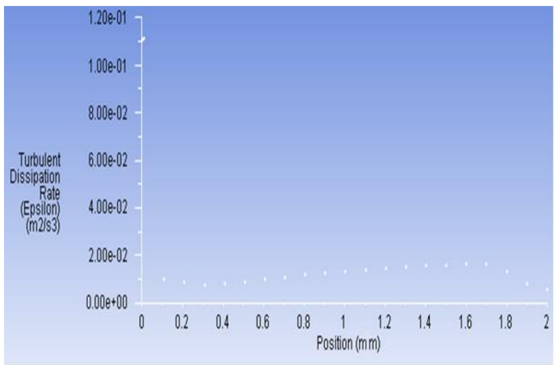

Fig. 1 Effect of ethanol on turbulent dissipation rate

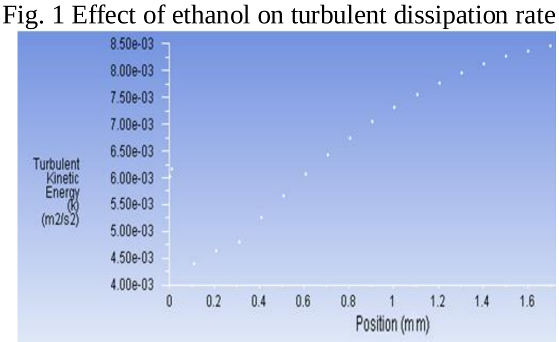

Fig. 2 Effect of ethanol on turbulent kinetic energy

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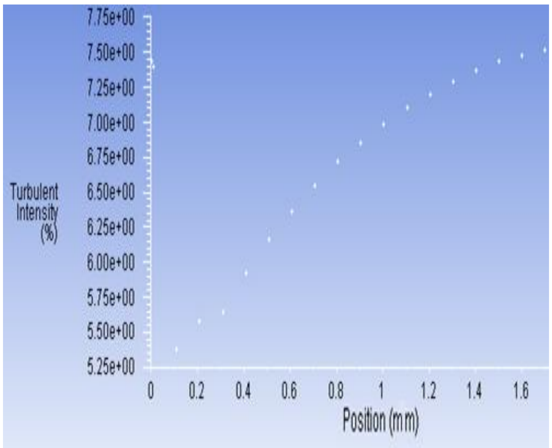

Fig. 3 Effect of ethanol on turbulent intensity.

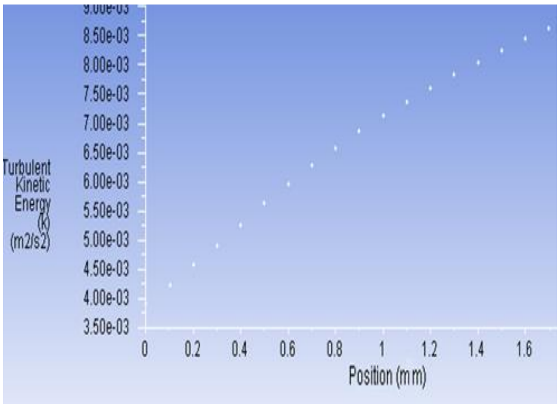

Fig. 4 Effect of methanol on turbulent kinetic energy

As can be seen from figures, as the percentage of ethanol is increased, the turbulent kinetic energy has drastically increased which is a measure of rapid combustion and high rate of energy release. Higher turbulence enhances higher flame front speeds, rapid and complete combustion and higher rate of diffusion..

2. Auto-Ignition Analysis

Fig. 4.5 represents the temporal evolution of the maximum temperature in the vessel. All fuel blends reach the same steady state maximum temperature value, since diesel and gasoline possess similar heating values. However, temporal differences in the temperature rise can be observed for the three different fuel blends.

An important parameter in the autoignitionan alysis is the ignition delay, which is defined as the time between the start of injection and the onset of combustion. Time gap is represented for each fuel blend in Fig. 4.6, where pure diesel fuel shows the short stagnation delay. A progressive increase of ignition delay is observed with increasing ethanol proportion in the blend. Moreover, these results confirm the potential of fuel blending to control the reactivity of the spray.

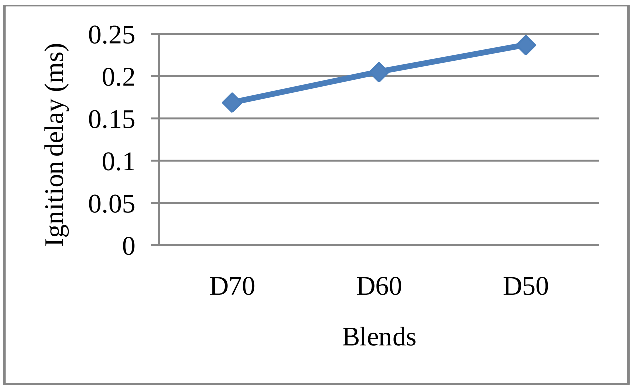

Fig. 5 Effect of ethanol blending on Ignition delay.

Figure 5 shows the effect of ethanol blending on Ignition delay. In this figure x axis shows the blends and y axis shows the ignition delay.

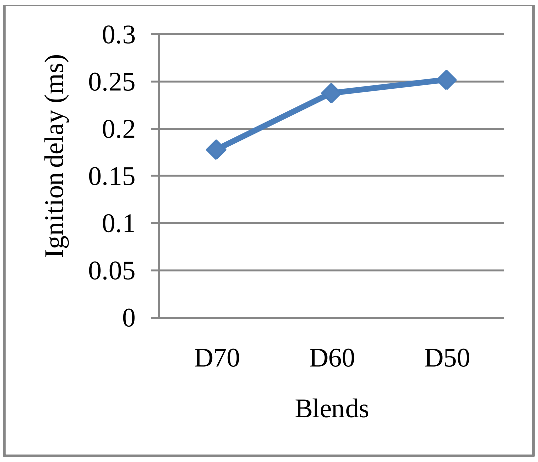

Fig. 6 Effect of methanol blending on Ignition delay.

Figure 6 shows the Effect of methanol blending on Ignition delay. In this figure x axis shows the blends and y axis shows the ignition delay. Ignition delay increases with increase in methanol blend percentage. The trend could be due to the higher auto ignition temperature and higher latent heat of evaporation of methanol compared to diesel.

3. Temperature Distribution

It was observed from the temperature profile that the remaining unburnt fuel mixture burns at the end of the working stroke. The temperature at the end of working stroke increases slightly dueto burning of small quantities of unburnt mixture

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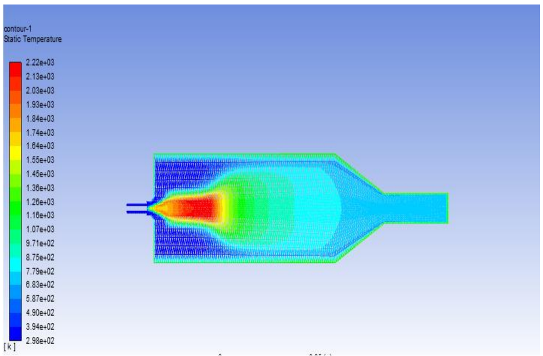

Fig. 7: Temperature contour with 70% Diesel +5% Ethanoland 25%Methanol

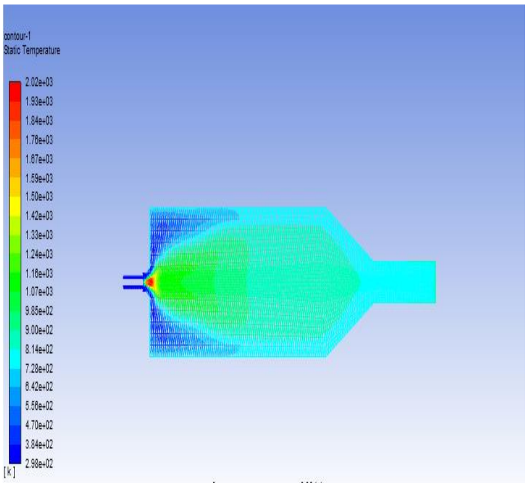

Fig. 8: Temperature contour with 70%Diesel +25%Ethanol+5%Methanol.

The peak temperature, predicted using a constant heat capacity is over 2020 K .This over prediction of the flame temperature can be remedied by a more realistic model for the temperature and composition dependence of the heat capacity. The mixture specific heat is largest where the fuel is concentrated, near the fuel inlet, and where the temperature and combustion product concentrations are large. The increase in heat capacity, relative to the constant value used before, substantially lowers the peak flame temperature.

VI. EXHAUST GAS ANALYSIS

1. Mass Fraction of No

The exhaust gas analysis is done with ANSYS FLUENT. The figure 4.12& 4.13 shows the NO emission. The mass fraction on NO is 2.97e-03. It can see the variation in the concentration of NO from the above diagram.

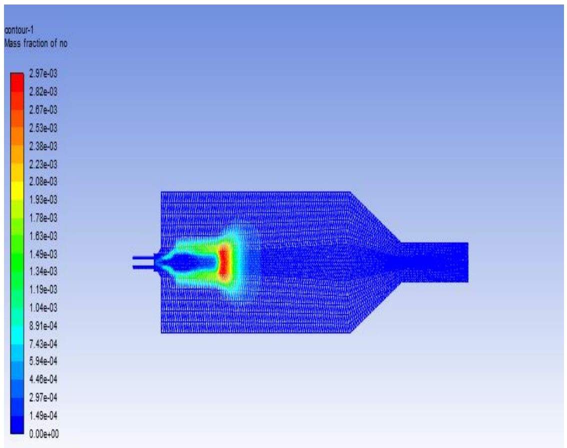

Fig. 9 Mass Fraction of NO with 90% Diesel + 5% Ethanol+ 10% Methanol

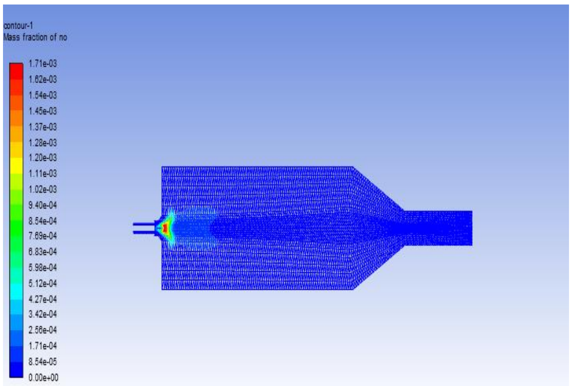

Fig. 10 Mass Fraction of NOwith 70%Diesel +25%Ethanol+ 5% Methanol

2. Mass Fraction of N_2

A mixture of nitric oxide (NO) and nitrogen dioxide (NO_2) are formed due to the oxidation of nitrogen from the intake air in the combustion process. These oxides of nitrogen found in the exhaust emissions are together referred to as NOx.The amount of NOx formed, mostly depends on the combustion temperature, theoxygen concentration and residence time for the reaction totake place.

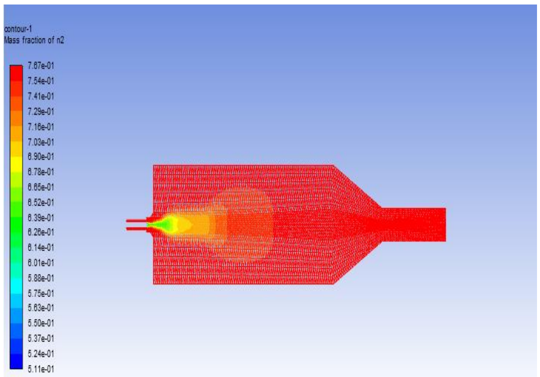

Fig. 11 Mass Fraction of $N_2$with 90%Diesel + 5% Ethanol+ 10% Methanol.

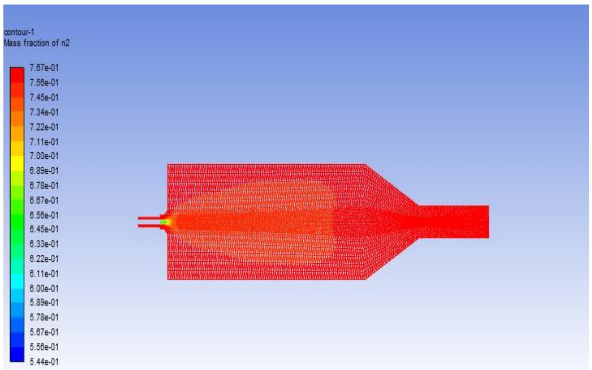

Fig. 12 Mass Fraction of $N_2$with 70%Diesel +25%Ethanol+5%Methanol.

The exhaust gas analysis is done with Ansys Fluent. The figure 6 shows the NO emission. The mass fraction on N_2 is 7.67e-0. It can see the variation in the concentration of N_2 from the above diagram. The concentration is more at the piston head and goes on decreasing upto the cylinder head.

3. Mass Fraction of O_2

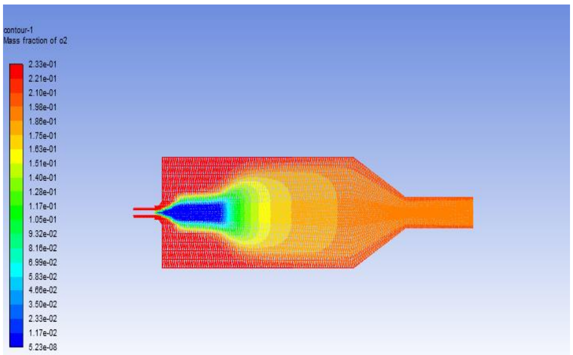

Fig. 13 Mass Fraction of $O_2$with 90% Diesel + 5% Ethanol + 10% Methanol.

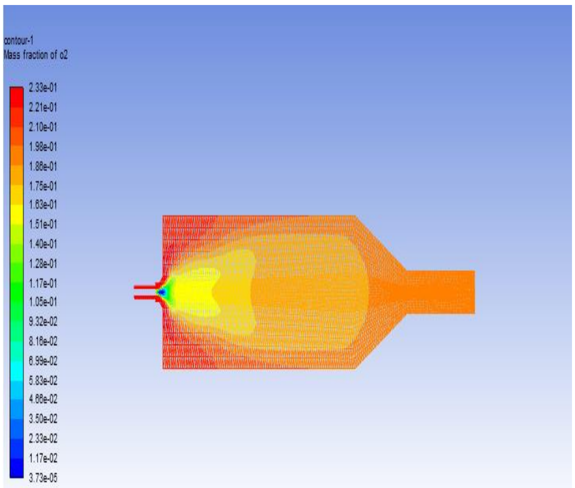

Fig. 14 Mass Fraction of $O_2$with 70%Diesel + 25% Ethanol+ 5% Methanol.

This shows that almost complete combustion is taking place and the injected fuel is fully utilized by the air inside the combustion chamber.

4. Mass Fraction of H_2o

As the percentage of ethanol and methanol increases in the mixture, the mole fraction of H_2O (i.e. the moisture) content Increases. As the moisture increases the peak temperatures of combustion are reduced in the cylinder, which finally reduces the formation of NOx.

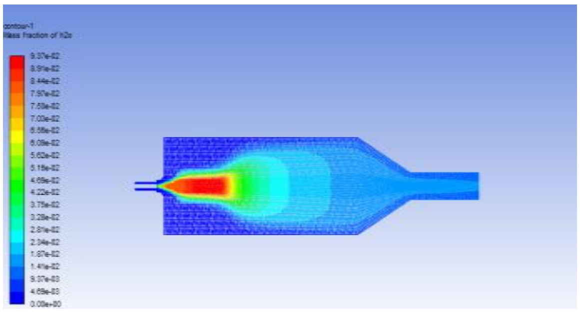

Fig. 15 Mass Fraction of $H_2O$with 90% Diesel+ 5% Ethanol+ 10% Methanol.

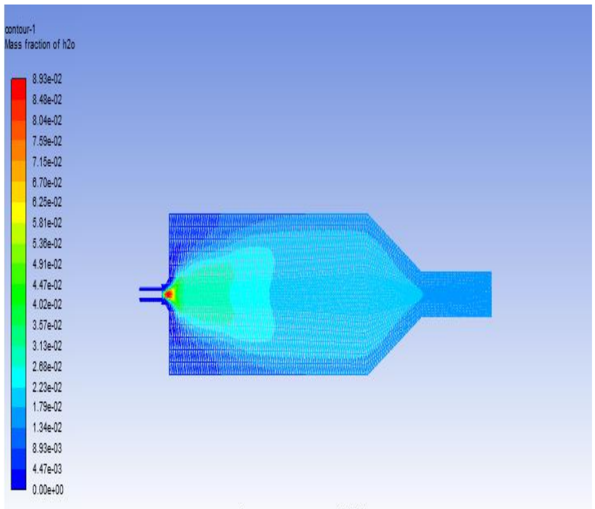

Fig. 16 Mass Fraction of $H_2O$with 70% Diesel+ 25% Ethanol+ 5% Methanol.

5. Mass Fraction of Co_2

Carbon dioxide is the product of complete combustion of fuels inside the combustion chamber. Figure 4.20 shows the variation of CO_2 emission with brake power for different diesel methanol blends. It can be seen from the figure that, the methanol blending, the emission of CO_2 is decreased. The main reason of CO_2 reduction is low C/H ratio and high oxygen content of the blends. Also the high oxygen content helps in better combustion and reduces the phenomena of dissociation due to decrease in temperature resulting in the increase in CO_2 emission.

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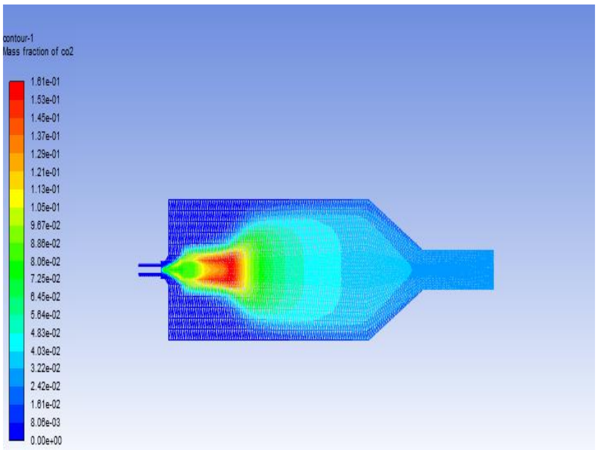

Fig. 17: Mass Fraction of $CO_2$with 90% Diesel + 5% Ethanol + 10% Methanol.

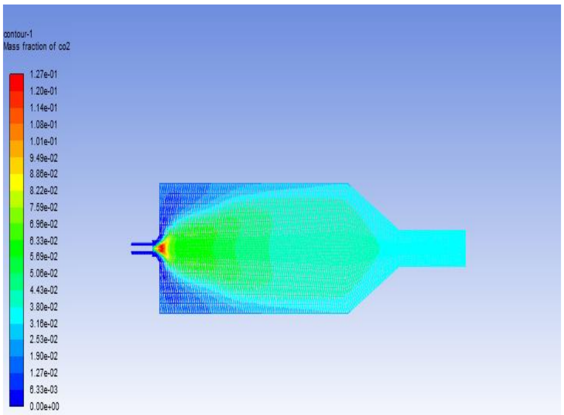

Fig. 18 Mass Fraction of $CO_2$with 70% Diesel+ 25% Ethanol+ 5% Methanol.

6.Mass Fraction of Co

The formation of carbon-dioxide leads to complete combustion and reduces CO emissions. One of the prime advantages of reaction is the hydrogen formation and its effect is very well explained by many researchers by using diesel, ethanol and methanol blends. Diesel and water combination has significant effect on performance and emissions of CI engines.

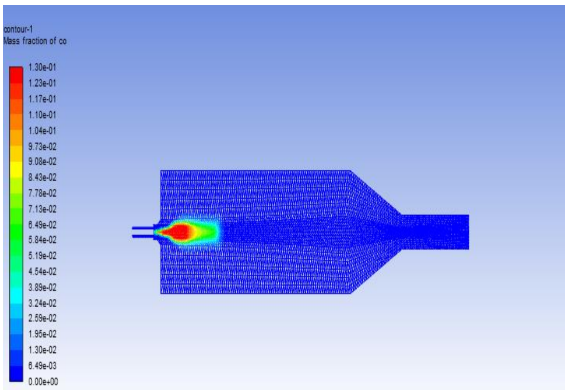

Fig. 19: Mass Fraction of COwith 90% Diesel+ 5% Ethanol+ 10% Methanol

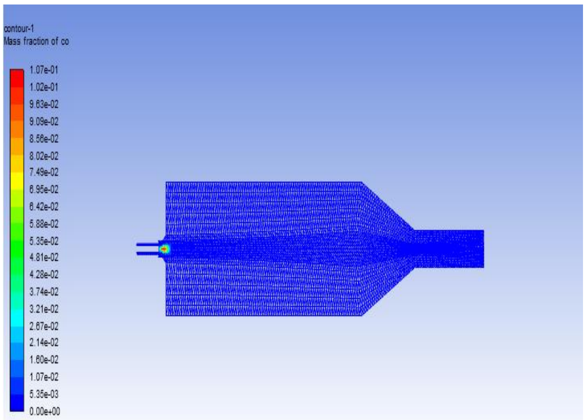

Fig. 20 Mass Fraction of CO with 70% Diesel+ 25% Ethanol+ 5% Methano.
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Figure 20 shows the mass fraction of CO emission in engine. Combustion characteristics of diesel–water blend depend on the difference in boiling points of both the constituents. The boiling point of any constituent is directly related to the evaporation rate of the molecules. Evaporation of water particles is resulted in dispersion of tiny droplets inside the cylinder which is known as micro explosion. Micro explosion is also delineated as the secondary atomization which leads to fast evaporation and improved air fuel mixing. Besides that, micro combustion is also regulated by the heat utilization of water molecules to change into steam.

VII. CONCLUSION

In current study investigation was done on the proper mixing of chemical species and the combustion of dual fuel (Diesel +Methanol + ethanol) with various blend grades. Present study used one conventional and other is Alternate fuels due to challenges in power sector. A cylindrical combustor burning (Diesel + Methanol + ethanol) in air is studied using the eddy-dissipation model in ANSYS (Fluent). Our main objective of the study is to analyze the dual fuel combustion model.

1. The methanol participation in combustion process causes an increase in peak pressure value. It is also visible that the combustion process occurs in shorter time.
2. It can be stated that engine operated on 35% of energetic share of methanol the course of heat release rate is similar to course of classical diesel engine. There is visible both characteristic phases of combustion process, the premixed and diffusion phase.
3. In case of engine operated on 35% energetic share of methanol, the combustion process occurs faster but it still occurs in two stages.
4. The net Turbulent Kinetic energy is at its peak at the nozzle, Away from the nozzle the turbulence increases.
5. Near and away from the nozzle the dissipation rate increases and it is dependent on turbulent kinetic energy.

6. The net Turbulent Kinetic energy is at its peak at the nozzle, away from the nozzle the turbulence increases and its value increases drastically with the increase in ethanol and methanol in fuel mixture.
7. Simulation results shows in table no. 4.3 & 4.4 that temperature is increasing with increase in percentages of alternate fuels and rapid mixing is occurred.
8. The pollutant emissions (Carbonic oxides) are decreasing in higher percentage of alternate blends as compare to the lower one that shows the complete combustion rate is increased. In second part of the study Chemkin (Chemical kinetic) mechanism were used for evaluating the NOx pollutant which is responsible for thermal NOx.
9. In current work Ethanol and Methanol can be used as an Alternatefuel which is cheaper in cost and easily available as compare to the conventional fuels.

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