A Study on Combustion of single droplet and the factors responsible for NO_x generation in E85 fuel

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Abstract

One of the major causes of global warming and several health hazards is due to the generation of nitrogen oxides (NO_x) and its still increasing day by day. In order to reduce the generation of Nitrogen Dioxides (NO_2) or its derivatives, several attempts and analyses of heat and mass transfer been made on single droplet on nitrogen oxides (NO_x) generation. The main objective of this study is to determine the fuel properties and the purpose is to switch from the fossil fuels to E85 without compromising the overall efficiency of the vehicle. So here we have used a blend of renewable fuel (ethanol) and gasoline in the ratio of 85% and 15% respectively with some modifications in it.

Keywords: Diesel engine, exhaust, emission, NO_x

Introduction:

Nitrogen oxide (NO_x) is the sum of nitric oxide (NO) and nitrogen dioxide (NO_2). These compounds are generally colourless and odourless. NO_x is one of the major causes of pollution nowadays and can often be seen as a reddish-brown layer over densely polluted cities. Many researchers have done their work in this field and comes out with results.

Nukiyama et al. [1] derived an empirical equation to determine the size of the droplet which depends on the surface tension, density and viscosity of the liquid with flow rates and relative velocities.

Christian et al. [2] investigated on the incomplete liquid fuel pre vaporization on the emissions of nitric oxides of gas turbine and also designed a combustor. At last the comparison between numerical and experimental data was done to show the behaviour of droplet slip velocities.

Kannan et al. [3] studied the effect of water emulsified fuel on Brake thermal efficiency, fuel consumption and NOx in a diesel engine. The experiments were conducted on a single cylinder diesel engine at constant speed and concluded that use of water emulsified diesel fuel enhance the performance and emission characteristics of diesel engine.

Hsu et al. [4] reported that NOx emissions goes on decreasing as in the emulsion amount of water gets increased. Ghojel et al., [5] reported that the BHP of diesel oil emulsion is higher than the conventional for heavy duty diesel engine used in industries.

Properties of fuel

Fuel of choice = E85

Properties of E85

a) Density of the fuel = 780 $Kg.m^{-3}$
b) Dynamic viscosity(μ) = 0.0015 $Ns.m^{-2}$
c) Kinetic viscosity (k) = 1.935 $mm^2.s^{-1}$
d) Surface Tension (T) = 0.034878 $N.m^{-1}$
e) A/F = 10

Combustion Process

The combustion process in ANSYS includes two major steps: Modelling and combustion.

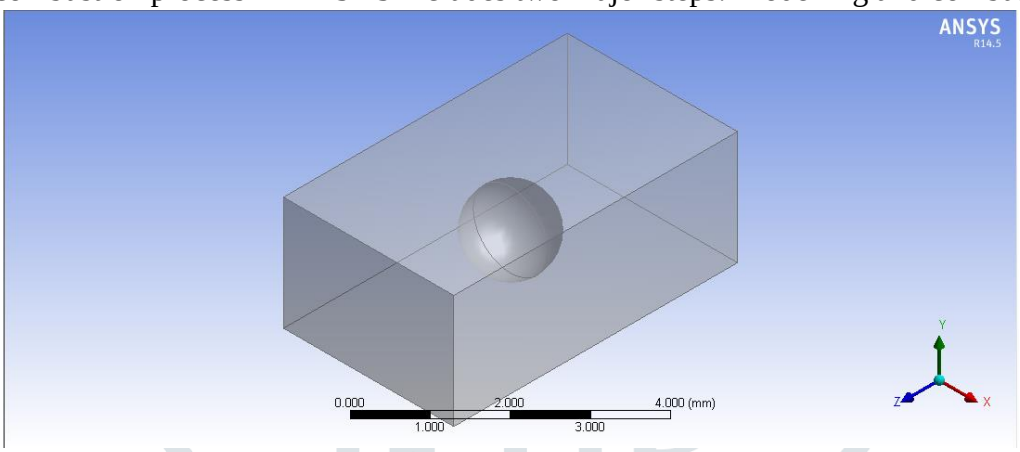

Figure 1. Schematic of geometry

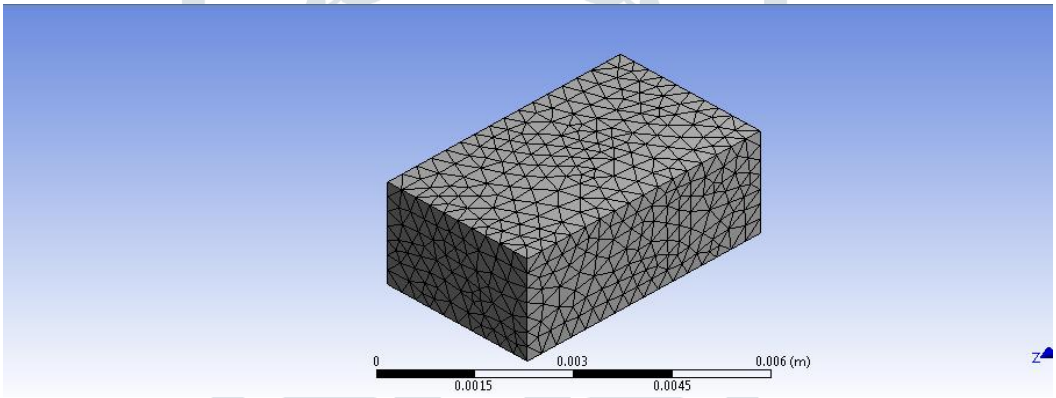

Figure 2. Schematic of meshed geometry

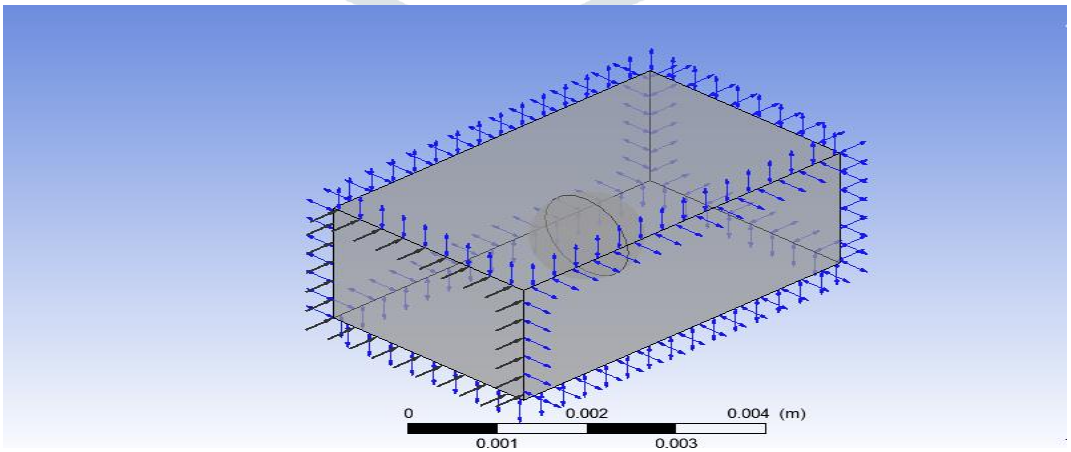

Figure 3. Boundary conditions applied to geometry

Then after this we have to conduct a differential capillary rise method to find out the surface tension of the fuel E85.

Steps used in this experiment

1) **Preparation of E85**: - Firstly, a cylindrical beaker of 100 ml capacity is taken. 100% pure ethanol in filled from the beakers mark 0 to 85 ml, then 25ml of measured gasoline is poured into the cylinder. Then the sample was mixed by means of glass rod. So that the two liquids got to mix well together.
2) **Sampling of E85:**- The prepared sample of E85 in poured in another small beaker.
3) **Measurement of height rise in the capillary tube**:- In this process a capillary tube whose inner diameter is 1mm is dipped on a sample of E85. Through this the height rise is noted down and same procedure is repeated 6 times. And at the end of experiment average height (H) is calculated.

Experiment No.	Height rise in the capillary tube (cm)
1	1.69
2	1.58
3	1.57
4	1.78
5	1.79
6	1.53

Table 1. Height of the capillary rise.

The average height rise in the capillary tube was found out to be

Average height = (1.69 + 1.58 + 1.57 + 1.78 + 1.79 + 1.53)/6 = 1.6566 cm

To calculate the value of surface tension of the fuel E85 by putting the values into the empirical formula: -

$$T = .5(H + (r/3))\, r\, \rho\, g \ N.m^{-1}$$

Where H = average height = 1.6566 cm

r = radius of the bore of the capillary = 0.05 mm

ρ_l = density of E85 = 780 $kg.m^{-3}$

g = acceleration due to gravity = 10 $m.s^{-2}$

by implementing all the above values into the empirical equation, the value of surface tension obtained is;

$$T = 0.034878 \ N.m^{-1}$$

Determination of the droplet diameter

By implementing the value of surface tension into the Sauter mean diameter empirical relation, we get

$$d_o = ((.585\sqrt{T})/(\Lambda u.\sqrt{\rho_l})) + 1.415\,(\mu_l/(\sqrt{T}.\rho_l))^{0.45} + (Q_l/Q_a)^{1.5}$$

T = surface tension of the fuel E85 =0.034878 $N.m^{-1}$

Λu = relative velocity of air and E85 =30 m/s

ρ_l = density of the liquid fuel = 780 $kg.m^{-3}$

μ_l = viscosity of liquid = 0.001509 $Ns.m^{-2}$

Q_l = liquid flow rate, $m^3.s^{-1}$

Q_a = air flow rate, $m^3.s^{-1}$

$(Q_l / Q_a) = 10$

By implementing all the values to the empirical equation the value of Sauter mean diameter is obtained as, d_o = 1.3148 mm [6]

Calculate the heat generated during the process of combustion

As this molecular structure contains12 C-H bonds, 3 C-C bonds, 2 C-O bonds, and 2 O-H bonds.

To calculate the overall heat releases on the combustion of the sampled fuel in air (O_2 + 3.76 N_2) is:

$2\,C_5H_{14}O_2 + 15\,[O_2 + 3.76\,N_2] \rightarrow 10\,CO_2 + 14\,H_2O + 56.4\,N_2$

$2(7647)$ KJ/mol + $15[495 + 3.76(941)]$ KJ/mol → $10(1598)$ KJ/mol + $14(934)$ KJ/mol + $56.4(941)$ KJ/mol

Overall heat = -6337 KJ/mol

(negative sign indicates the amount of heat released from this equation) Heat release from O_2 = 495 KJ/mol, CO =799 KJ/mol, OH = 934 KJ/mol, N_2 = 941 KJ/mol.

Vector representation of Overall fuel flow Vs Temperature

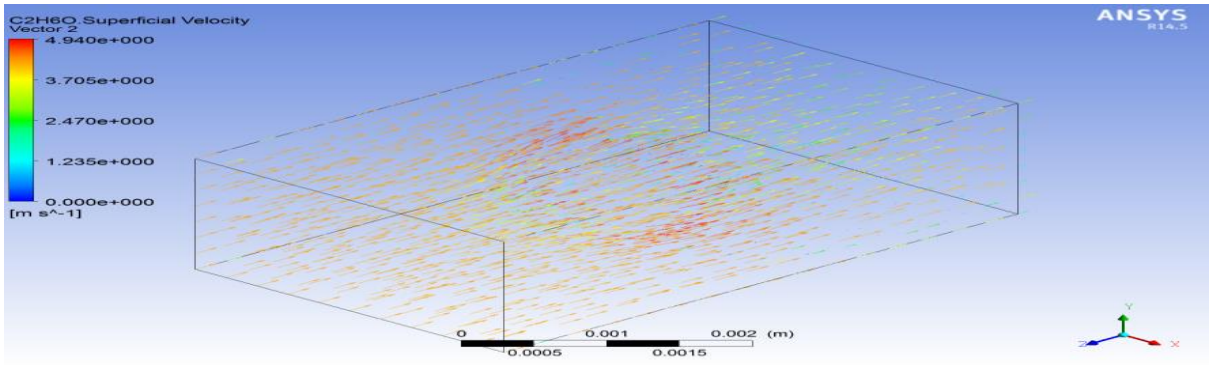

Figure 4. Overall fuel flow vs Temp

Vector representation of N_2 (nitrogen dioxide) Vs Temperature

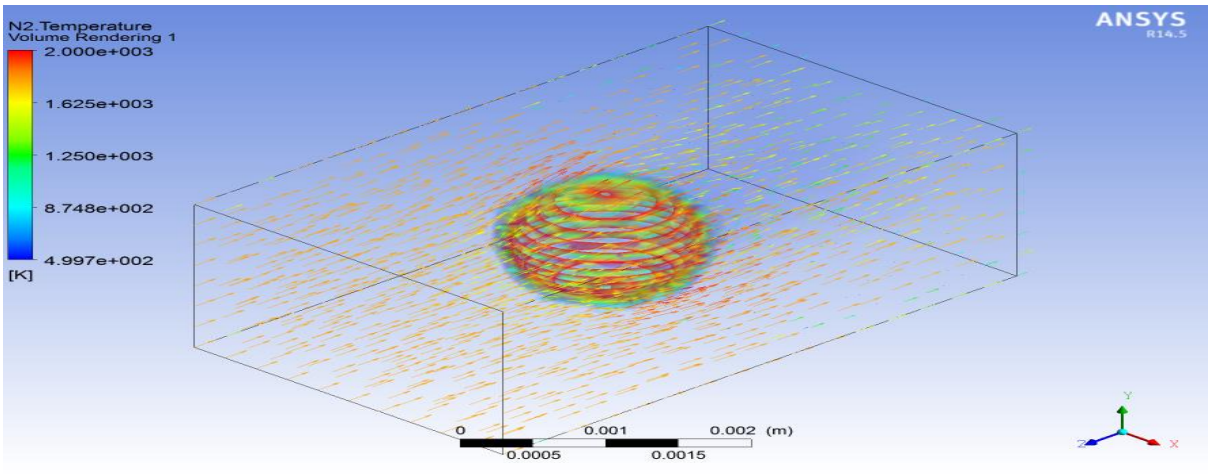

Figure 5. Nitrogen dioxide vs Temp

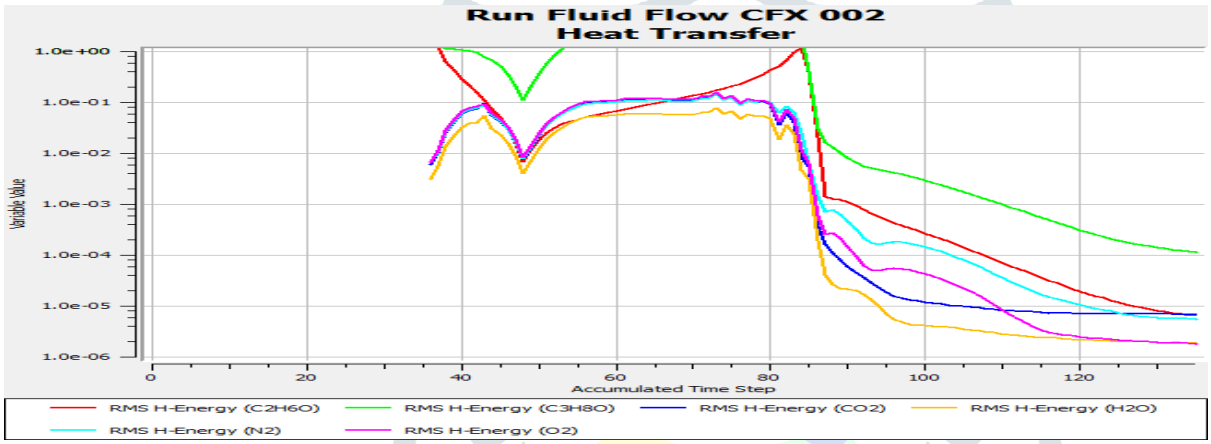

Figure 6. Fluid flow model

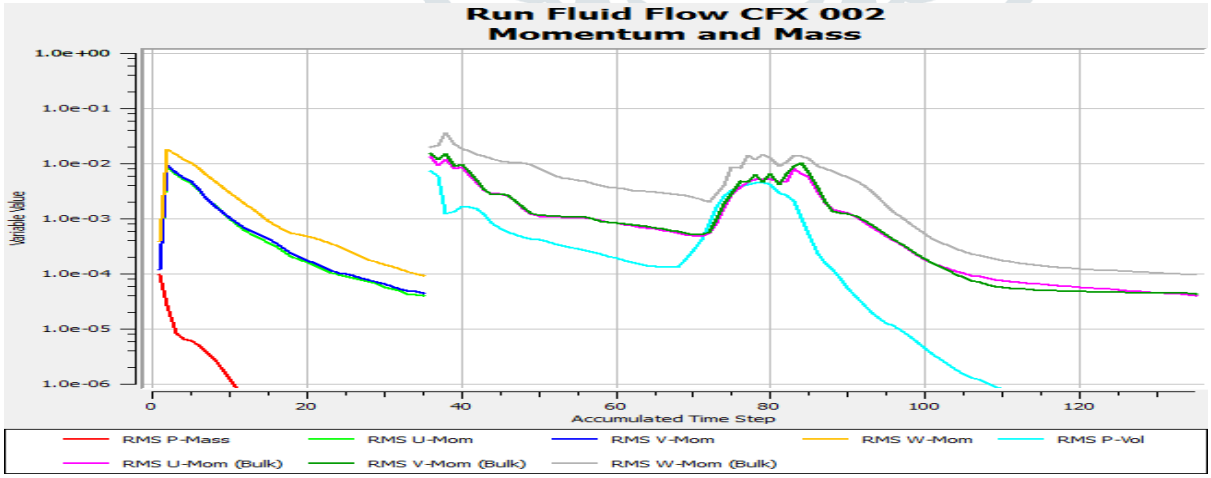

Figure 7. Fluid flow model (Momentum and mass)

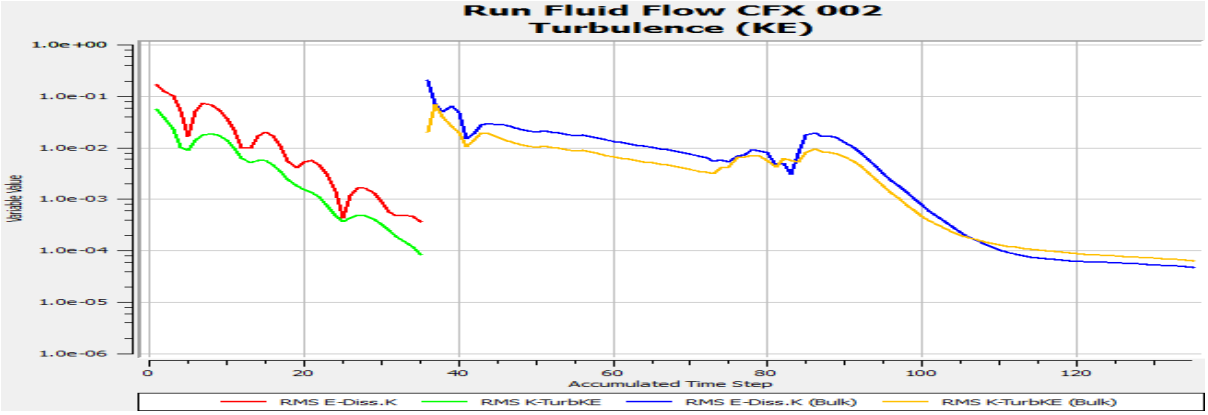

Figure 8. Fluid flow model (Turbulence)

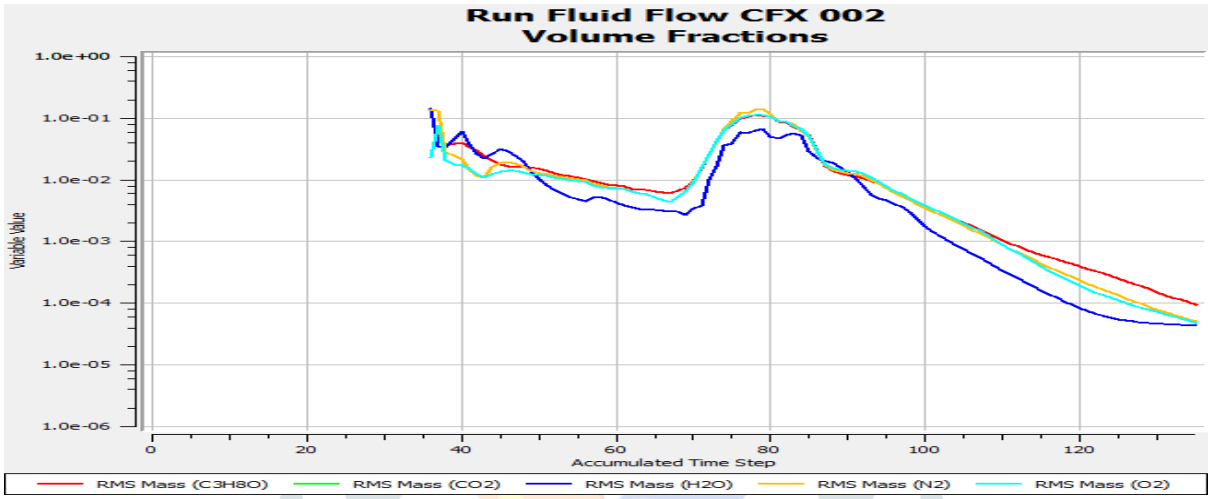

Figure 9. Fluid flow model (Volume)

Conclusion

It has been concluded that by using E85 as fuel, NO_x emission is comparatively less than the conventional fuel due to blending of gasoline with ethanol. Through the analysis done on combustion of single droplet it is seen that the performance of fuel has been enhanced and emission are reduced considerably. Hence the fuel is considered to be eco-friendly due to its low NO_x emission.

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