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CFD Analysis and Experimental Validation of Ethanol Diesel Blend in CI Engine

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Abstract- This paper describes the CFD analysis and experimental validation for a blend of Ethanol and Diesel in CI Engine. Ethanol is the alcohol found in alcoholic beverages but it also makes an effective motor fuel. Since, ethanol possess low Cetane number it fails to auto ignite. In order to overcome this Diesel is blended with Ethanol. Thus the Diesel will ignite and thus facilitate the Ethanol to start burning. In this work a CFD model was created and the combustion analysis was carried out and the results were validated with experimental data. The Ethanol and Diesel fuels were mixed in different proportions and they were injected to the combustion chamber of a normal diesel engine. A single cylinder PC based VCR Engine was operated with this Ethanol - Diesel blend in different concentrations and at various loads. The experiment was successful and it showed that the Ethanol could be mixed with Diesel and could be injected without any engine modification. The difference between CFD and the experimental results obtained was found within acceptable range.
Key Words: Ethanol, Diesel, CFD, Combustion

1.0.Introduction

Fossil fuels are very important to us today. The increase on energy demand and increasing petroleum price in the worldwide has increased the study of alternative fuels for internal combustion engines. Biodiesel and DEB (Diesel – Ethanol Blend) have received much attention among these alternative fuels for Compression Ignition (CI) diesel engines. Ethanol is one of a renewable fuel because we get it from raw materials such as corn, sugar cane, sugar beets, molasses, cassava, waste biomass materials, sorghum, barley, maize, etc. Ethanol can reduce the consumption of conventional gasoline and it has been successfully used to blend with gasoline fuel as part of its alternative. However, due to the difference in chemical and physical properties, it has not been commercially used yet. At present, significant investigations of the potential application of DEB on diesel engine have been carried out.

Hansen et al. [1] found that the engine power decreases by about of 7 to 10 % and the brake thermal efficiency increases by about of 2-3% at rated speed when investigated the Cummins engine performance with 15 % ED fuel In the same model engine with two and backgrounds.

blends. In the same model engine with two blends containing 10 % and 15 % ethanol, Kass et al. [2] tested the torque output and got an approximate 8 % engine power reduction for both fuel blends. Huang et al. [3] experimented by 10%, 20%, 25% and 30% ethanol-blended diesel fuels and examined the engine performance and exhaust emissions of diesel engine. It results; increasing amount of ethanol in the blended fuels decreased the brake thermal efficiencies. Also Rakopoulos et al. [4] studied the effects of ethanol blends with diesel fuel, with 5% and 10% (v/v) on the performance and emissions of a turbocharged direct injection diesel engine. It results the increasing the amount of ethanol in the fuel blend decreased the brake thermal efficiency and increased the specific fuel consumption. Diesel fuel blended with ethanol up to 10 vol. % results [5–7] to increase the engine efficiency, improve fuel economy and reduce its harmful emissions. Also yield a significant reduction of carbon monoxide and nitrogen oxide [8] and particulate matter emissions [9, 10].

The major drawback of ethanol in diesel engines is less solubility of ethanol in diesel fuel and it leads the phase separation and water tolerance in ethanol–diesel blend fuel. The phase separation can be prevented by adding an emulsifier or co- solvent. Here by adding an emulsifier that acts to suspend small droplets of ethanol within the diesel fuel and it usually requires heating and blending steps to generate the final blend. introduce a more challenging dataset containing over 1800 annotated human images with a large range of pose variations and backgrounds.

tolerance in ethanol–diesel blends. The phase separation can be prevented by adding an emulsifier or co-solvent. Here by adding an emulsifier that acts to suspend small droplets of ethanol within the diesel fuel and it usually requires heating and blending steps to generate the final blend. The properties of Diesel and Ethanol are shown in Table 1. In this study we are using DEB15 (15% Ethanol and 85% Diesel)

Property	Diesel	Ethanol
Chemical formulae	$C_{12.35}H_{21.76}$	C_2H_5OH
Composition in %		
C	87.13	52.14
H	12.88	13.13
O	0	34.73
Density	820	786
Viscosity, Pa s	2.8	1.20
Latent heat, kJ/kg	375	840
Cetane number	48	6
Lower heating value, MJ/kg	42.90	27.47

Table 1: Fuel Properties

2.0 CFD Modelling

The combustion chamber is modelled and the analysis is carried out in detail using a CFD tool package ANSYS FLUENT. A three dimensional periodic, in-cylinder, transient system for a direct injection diesel engine is modelled by solving a set of governing equations from the conservation of mass, momentum, energy and species theories. The Figure 1 shows the meshed geometry of the cylinder.

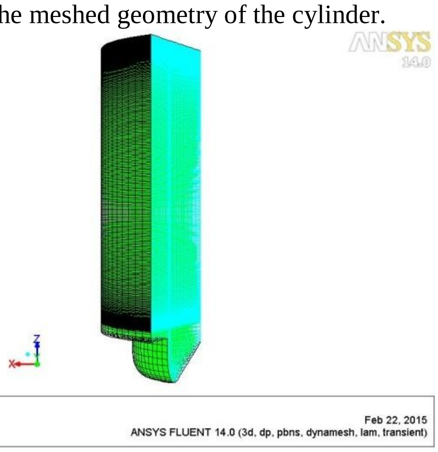

Figure 1: Meshed Cylinder Geometry

The in-cylinder parameters are

- Connecting rod length: 140 mm
- Bore: 80 mm
- Crank radius: 55 mm
- Crank shaft speed: 1500 rpm

In this present study the turbulent model selected is standard k- ε. This model of turbulence are of two-equation model in which the solution of two separate transport equations allows the turbulent velocity and length scales to be independently determined. It is a semi-empirical model, and the derivation of the model equations relies on phenomenological
considerations and empiricism. The turbulent (or eddy) viscosity, μ_t, is computed by combining k and ε as follows:

$$\mu_t = \rho\, c_\mu \frac{k^2}{\varepsilon}$$

The combustion model used is species transport with volumetric reactions. The inlet diffusion and diffusion energy source is turned on. Eddy dissipation is used for turbulent chemistry interaction. This approach is based on the solution of transport equations for species mass fractions, with the chemical reaction mechanism defined by user. DPM fuel injection model is also used in this study.

3.0 Experimental Setup

The engine setup shown in Figure 1 used for experimental investigation is a single cylinder, Four Stroke, Water cooled, PC based VCR Engine. It is connected to a eddy current type dynamometer for loading.

The compression ratio can be changed without stopping the engine. The setup is provided with necessary instrument for combustion pressure and crank angle measurement. These signals are interfaced to computer through engine indicator for Pθ-PV diagrams. Provision is also made for interfacing air flow, fuel flow, temperature and torque measurement. The setup has stand-alone panel box consisting of air box, two fuel tanks for dual fuel test, fuel and air measuring unit

Figure 2: Experimental Setup

4.0 Result and Discussion

This work is carried out in two stages the numerical CFD analysis and the experimental validation. Each parameters are studied both numerically and experimentally with DEB15.

4.1 Combustion Peak Pressure

The peak pressure obtained by CFD analysis is 61 bar and experimentally the peak pressure is 58 bar. This change in 3bar is almost negligible. The figure 3 shows the CFD result and figure 4 shows the experimental result in VCR Engine.

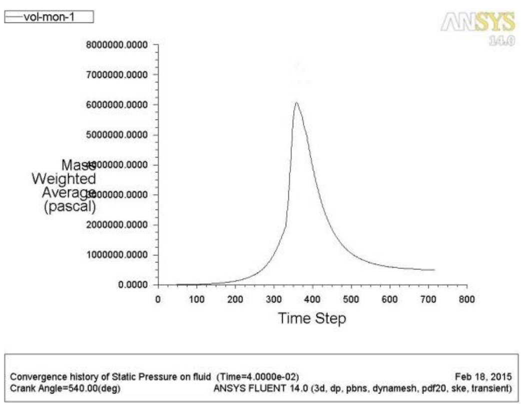

Figure 3: P-θ CFD Result

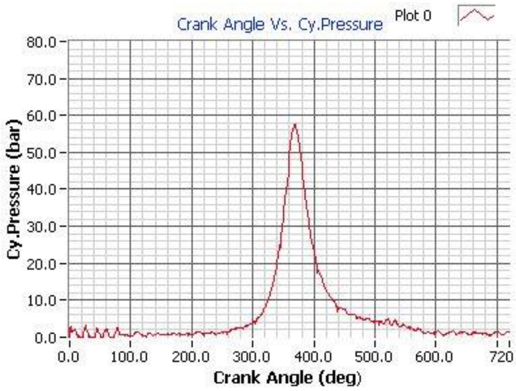

Figure 4: P-θ Experimental Result

4.2 Performance Characteristics

The performance characteristics of a single cylinder four stroke engine with DEB15 as fuel are discussed below.

The figure 5 shows the variation of volumetric, brake thermal, indicated thermal and mechanical efficiencies with brake power. The volumetric efficiency remains almost constant. The mechanical efficiency is increasing with the increase in break power. The brake thermal efficiency is also increasing, but at higher load there is a slight decrease can be noted. The indicated thermal efficiency shows an irregular variation with increasing load. All these performance characteristics with DBE15 as fuel lies closer to that of diesel alone operation.

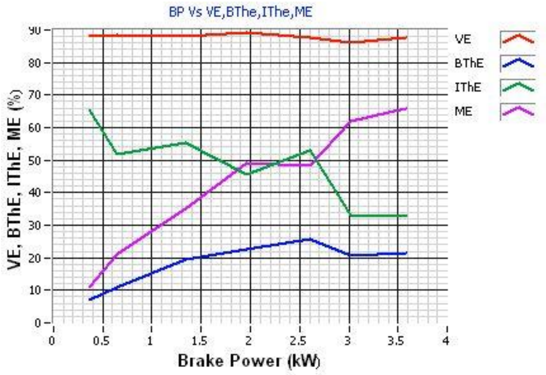

Figure 5: Efficiencies vs Brake Power

4.3 Exhaust Gas Analysis

The exhaust gas analysis is done with ANSYS FLUENT. The figure 6 shows the NO_x emission. The mass fraction on NO_x is $4.03e^{-05}$.

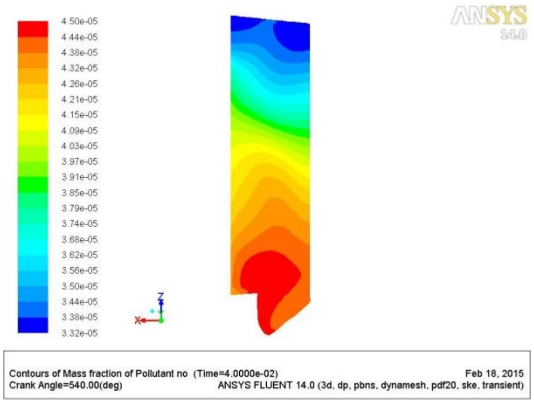

Figure 6: NO_x Emission

We can see the variation in the concentration of NO_x from he above diagram. The concentration is more athe the piston head and goes on decreasing upto the cylinder head.The mass fraction of soot is $6.43e^{-05}$ and CO emission is 0.129. The figure 7 & 8 shows the soot and CO concentration inside the chamber.

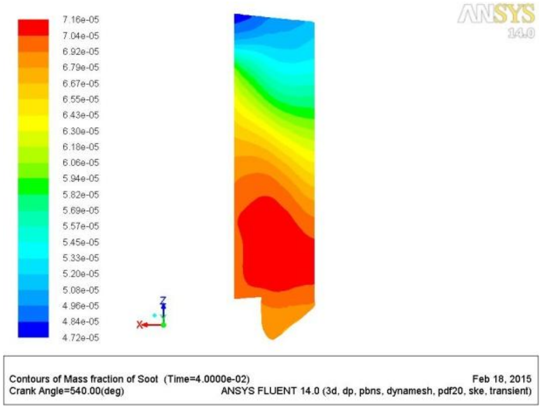

Figure 7: Soot Concentration

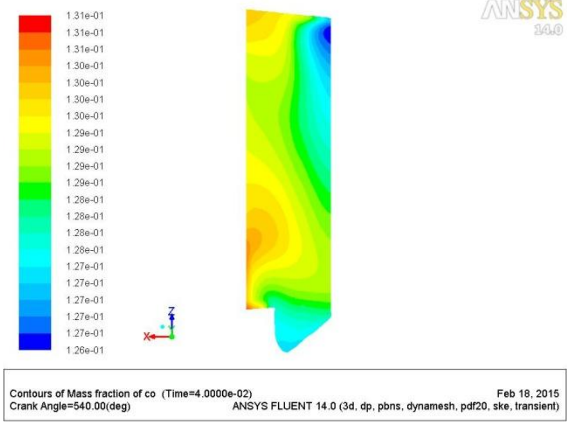

Figure 8: CO Emission

The mass fraction of unburnt oxygen is noted as $2.52e^{-13}$. This shows that almost complete combustion is taking place and the injected fuel is fully utilized by the air inside the combustion chamber.

5.0 Conclusion

The numerical CFD analysis using ANSYS FLUENT and the experimental study with DBE15 is done. The results are comparable which are obtained both numerically and experimentally. The peak pressure obtained shows only a change in 3 bar pressure. And it is also seen that the ethanol diesel blend can be used in normal CI engine without any engine modification. Thus the CFD tool ANSYS FLUENT is very reliable to predict the combustion and emission characteristics.

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