Investigation on the combustion and emission characteristics of an Air swirl DI Diesel engine fueled with diesel-ethanol with Ethyl acetate blends

Vamsidhar V[#1], Srinivasa Reddy K[2], Pandurangadu V[3]
[#1]Research Scholar, Mechanical Engineering, Jawaharlal Nehru Technological University Anatapur, Anatapuramu.
[2]Mechanical Engineering, GVIC, Madanapalle.
[3]Mechanical Engineering, Jawaharlal Nehru Technological University Anatapur, Anatapuramu.

Abstract : This study investigated the influence on the combustion and emission characteristics of a DI Diesel engine fueled with DEE (Diesel-Ethanol-Ethyl acetate) blended fuels with dimpled inlet valve. The effects on the combustion phenomena of brake thermal efficiency and specific fuel consumption when Diesel-Ethanol is blended with 0%, 5%, 10%, 15%, 20% and 25% ethanol were tested in a 4-cylinder naturally-aspirated dimpled inlet valve direct-injection diesel engine at a steady speed of 1500 rev/min under five engine loads. Overall, compared with HSD (High Speed Diesel), DEE blends can effectively reduce specific fuel consumption and maintain a good trade-off relationship among hydrocarbon (HC), NOx, Carbon monoxide (CO) and Carbon dioxide (CO_2). Compared with HSD, the blended fuels with dimpled inlet valve perform better in suppressing specific fuel consumption and leading to a reduction in the pollute emissions.

***IndexTerms* - Air swirl, Diesel-Ethanol-Ethyl acetate, DI Diesel engine, emission characteristics, Specific fuel consumption.**

I. INTRODUCTION

Diesel engines are widely used in commercial applications because of the benefits in fuel economy and high power out. However, there is serious concern on their resource availability and emissions, in particular the nitrogen oxides (NOx), PM (particulate matters), Hydrocarbons (HC) and carbon monoxide (CO). In the last few decades, the significant global warming problems caused by CO have been magnified by the continued and increasing use of petroleum in diesel engines. Reducing CO, HC and NOx emission have become an explicit goal of policy measures to support the use of biofuels. Ethanol is a sustainable and oxygenated biofuel and could be potential elective fuel for vehicles, which can be mixed with diesel in the tank, or infused into the barrel specifically and consumed with diesel keeping in mind the end goal to diminish the depleted pollutants [1– 4]. The trouble of dissolving ethanol in diesel and the steadiness of mixes is affected by the temperature and water content, particularly high rates of ethanol are utilized and ambient temperatures below 10°C exist. The use of additives improves the solubility of ethanol in diesel. It was found that the solubility of ethanol in diesel was affected by aromatic hydrocarbons, the temperature of middle distillates and the paraffin content of diesel [5,6]. Some research results have proven that the additives can improve not only the stability of ethanol–diesel blends, but their performance on vehicle tests. The blends can reduce the NOx emission by 10% and smoke emission by 15%, but at the cost of a power decrease of 3–5% [7–9]. Lapuerta et al. [10] reported that water content, low temperature and high ethanol contents favoured the phase separation and that the additives can help blends formation. Furthermore, the stability of blends was more sensitive to water content and additives than the temperature [10].

Swirl is an organized rotational motion of air around the cylinder axis. Swirl is generated during the intake stroke due to specific intake manifold geometry and during the compression stroke because of the geometry of the piston and cylinder [11-13]. Curve blades on the neck of the poppet valve are preferred over the conventional shrouded poppet valve since; it will provide lesser blockage to the incoming charge and hence, will result in higher volumetric efficiency than the shrouded poppet valve [14-15].

Albeit numerous analysts have considered the security of ethanol– diesel mixes and their consequences for the execution of diesel engines, the emulsifiers or co-solvents are not generally used due to their surprising expense and incredible added substance content. In this paper, Ethyl acetate as emulsifier for ethanol– diesel mix was produced and the impacts of mixes on execution and outflows of diesel engine with dimpled inlet valve geometry were examined.

II. ENGINE SPECIFICATION AND EXPERIMENTAL SETUP

An experimental setup is developed to conduct tests on a four-stroke single cylinder DI Diesel engine with necessary instruments and utilized to evaluate the performance, emission and combustion characterizes of the engine at different operating conditions. A single cylinder water cooled, four stroke Direct Injection (DI) Diesel engine with a compression ratio of 17.5:1 is used for the experiment. The overall view of the experimental setup is shown in Figure 2.1. The piston has a hemispherical bowl. In order to carry the above list of performance tests the following Diesel engine test rig is being employed. The detailed specifications are listed in table 2.1.

Fig. 2.1 Experimental setup of the Diesel engine

Dimple is the process of removing a small amount of metal on the poppet valve head without altering any position and seating of the inlet valve. A small blind hole like impression are provided on the poppet valve head which are called as dimples shown in figure 2.2. Based on our earlier research and review of literature 10 dimples, have been provided on the poppet valve and experiments are conducted. The Diesel engine test is start with V0 i.e. valve without dimples, and compared with V10 i.e. valve having 10 dimples. Diesel and ethanol blends are made by a constant amount of 3% by volume of Ethyl acetate is used as surfactant in Ethanol-Diesel blends. Five blends of Ethanol-Diesel are prepared. They are E5, E10, E15, E20 and E25. For example, E5 stands for 5% by volume of ethanol, 3% by volume of ethyl acetate and the rest 92% by volume of Diesel. Likewise, ethanol percentages in the blends are 10% by volume for E10, 15% by volume for E15, 20% by volume for E20 and 25% by volume for E25. From this experiment, optimum fuel blend will be identified based on the performance measure and emission characteristic. The noted output data from the various experiments is being used to calculate the further performance output parameters such as brake power, Brake Thermal efficiency and Specific Fuel Consumption. The above steps are repeated by varying the load incrementally and analysed through comparative graphs.

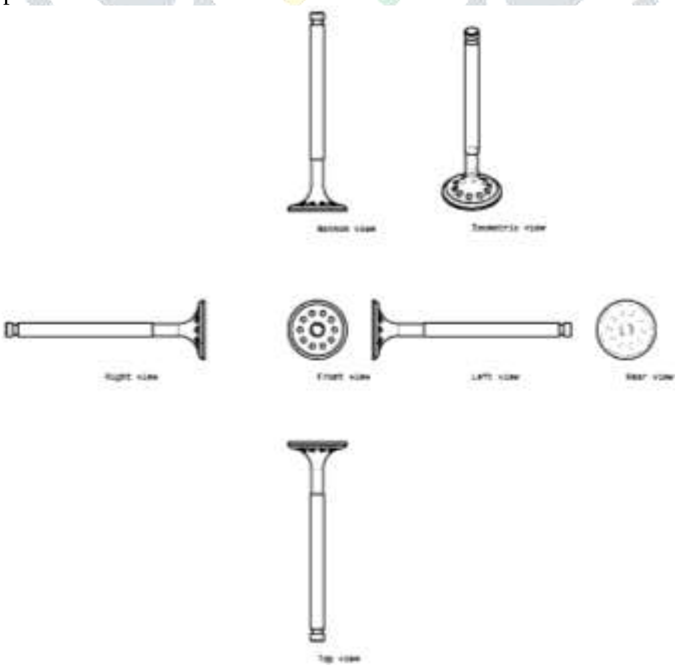

Figure 2.2 Dimpled inlet valve geometry with 10 dimples

Table:2.1 Diesel engine specifications

S. NO.	ITEMS	SPECIFICATIONS
1	Make	KIRLOSKAR
2	General Details	Single Cylinder, Four Stroke, C.I. Engine, Constant Speed, Vertical, Water Cooled
3	Method of starting	Cranking
4	Type, no. of cylinders	Vertical – 4 stroke, Single Cylinder
5	Bore x stroke(mm)	80 x 110
6	Displaced Volume (cc)	553
7	Compression Ratio	16.5
8	Maximum power	3.7 kW / 5 hp
9	Rated speed	1500 rpm
10	Cooling system	Water-cooled
11	Lube oil	SAE 70
12	Injection Nozzle	MICO-BOSCH 3 Hole Nozzle
13	Diesel Injection Pressure	210 bar
14	Injection Timing	270 BTDC (Static)
15	Combustion Chamber	Hemispherical, Open Combustion Chamber
16	Fuel	Diesel

III. RESULTS AND DISCUSSION

Experiments are conducted for various portions of ethanol–Diesel blends with 3% of Ethyl acetate as per the experimental procedure. All the experiments have been conducted at the fuel injection pressure of 210 bar. Performance tests are conducted on the swirl engine which is modified Diesel engine test rig with inlet valve geometry of V10. The experimental data has been collected for various fuel blends like E5, E10, E15, E20 and E25. The performance parameters are calculated and emissions are measured and graphically compared with standard Diesel engine.

3.1 *Brake Thermal Efficiency*

The variations of brake thermal efficiency with brake power for different ethanol-Diesel blends are drawn and shown in figure 2, it is evident that the brake thermal efficiencies are increasing with increase in brake power for all proportions of fuel blends up to 3/4th of the maximum brake power then starts decreases. It can be observed that thermal efficiency is decreasing with increasing percentage of ethanol due to the low calorific value, less cetane number and ignition delay the fuel blends with E20 and E25 gave thermal efficiencies of 27.41% and 26.98% respectively at 3/4 of rated load whilst standard diesel engine has 27.18%. The modified V10 valve geometry and E20 blend fuel has higher thermal efficiency compared to standard diesel engine. It is also observed that there is 1% of thermal efficiency improvement or sustained for V10 valve geometry with E20 when compared with engine with the standard diesel engine. This thermal efficiency is dropped when Ethanol proportions is increased whereas, due to the air swirl in the combustion chamber and addition of Ethyl acetate alters the fuel blends properties especially shorten the ignition delay hence thermal efficiency is increased by 1%.

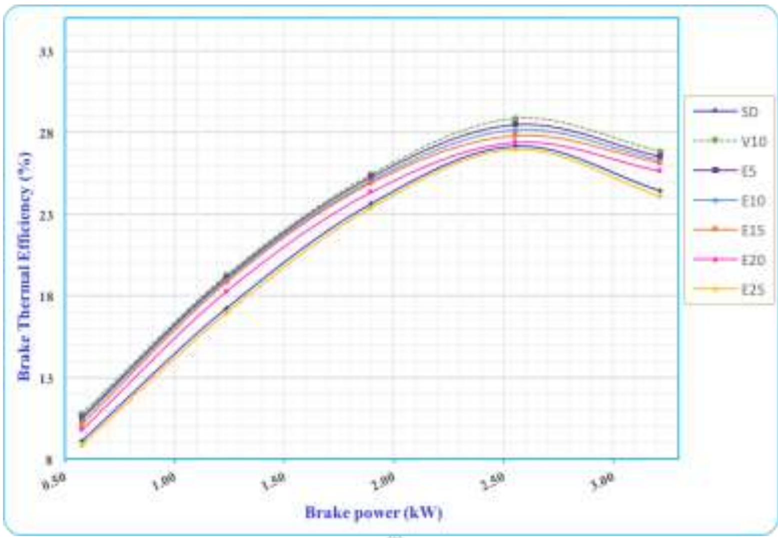

Figure 3.1 Comparison of brake thermal efficiency with different ethanol-Diesel blends with 3% Ethyl acetate.

3.2 Brake Specific Fuel Consumption

The variations of specific fuel consumption with brake power for different proportions of ethanol-Diesel blends with 3% ethyl acetate are drawn and shown in Figure 3. Specific fuel consumption for the fuel blends E20 and E25 are 0.319kg/kW-hr and 0.331 kg/kW-hr respectively, at 3/4 of rated load. The specific fuel consumption for the modified engine with V10 at 3/4 of rated load is 0.277 kg/kW-hr. Figure 4.3, illustrate that BSFC is decreasing with an increase in brake power for all proportions of the fuel blends, which are under consideration. It is also observed that the ethanol-Diesel blends E5, E10, E15, E20 and E25 have increasing trends in specific fuel consumption when compared with engine with V10 under various loading conditions. The specific fuel consumption has increased by 15.16% for E20 when compared with V10 engine at 3/4 of rated load. This increase in specific fuel consumption is due to the lower calorific value and lower viscosity of ethanol.

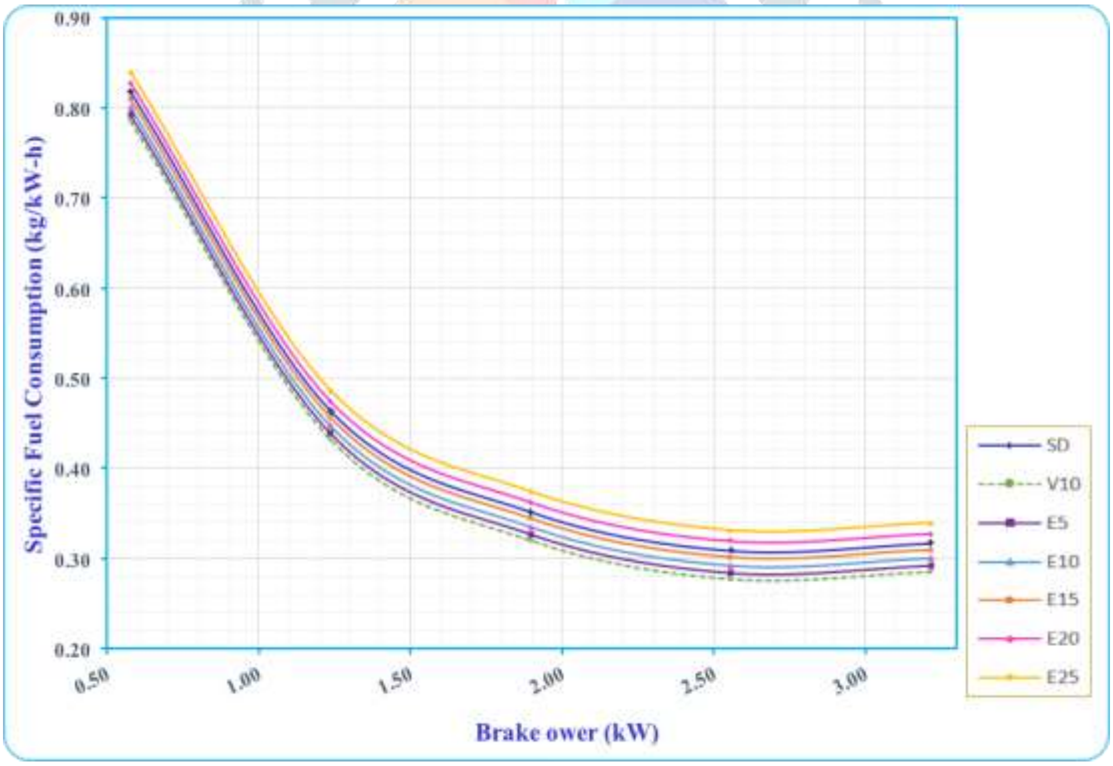

Figure 3.2 Comparison of specific fuel consumption with different ethanol-Diesel blends with 3% ethyl acetate.

The influence of ethanol blends on the emission parameters like Nitrogen oxides (NO_x), Hydrocarbons (HC), Carbon monoxide

3.3 Nitrogen Oxide (NOx) Emissions

The comparison of NOx emission with brake power for different proportions of ethanol-Diesel blends with 3% ethyl acetate are drawn and shown in Figure 4.4. It can be perceived from the figure 4.9 that NOx emission increases with increase in brake power. Also it can be noted that NOx emissions are decreasing with increasing volume of ethanol which is due to air swirl in the cylinder with oxygenation. The NOx emissions for E20 and E25 are 458 ppm and 462 ppm respectively, whereas it is 525 ppm for V10 configuration. The NOx emissions are lower of 12.76 % for E20 when compared to V10 at 3/4 of rated load. In combustion theory, there are three NOx formation mechanisms. They are (i) Thermal NOx formation (Zeldovich mechanism), (ii) Prompt NOx formation (Fennimore mechanism) and (iii) NOx formation due to nitrogen in the fuel. CO) and Carbon dioxide (CO2) is discussed below. Thermal NOx formation and Prompt NOx formation occur when there is an increase in ethanol blends. Increase in ethanol blend with ethyl acetate causes lower heat release rate, which decreases the adiabatic flame temperature. Thus, the NOx formation is decreased.

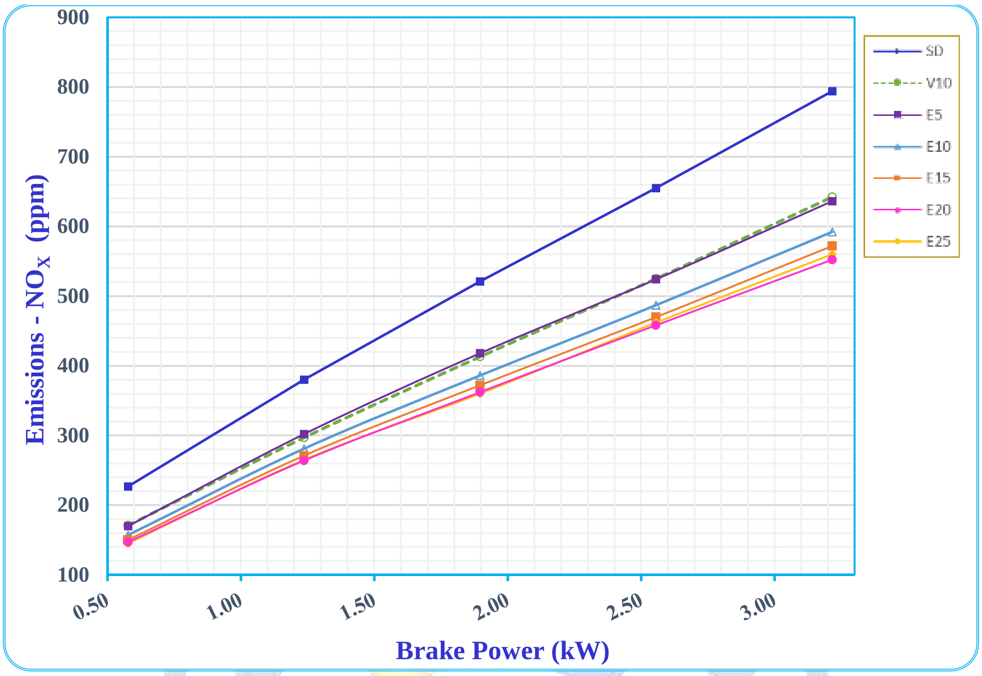

Figure 3.3 Variation of NO_x for various ethanol-Diesel blends with 3% ethyl acetate.

3.4 Hydrocarbon(HC) Emissions

The variation of hydrocarbon emissions of ethanol-Diesel blends with 3% of ethyl acetate (for E0, E10, E15, E20 and E25) against the brake power are shown in the Figure 4.5. There are different mechanisms that can affect hydrocarbon emissions in the combustion process and chamber design. HC emission generally increases compared to neat Diesel fuel due to high latent heat of vaporization of ethanol leaving unburnt ethanol in the exhaust. This makes the flame propagation faster and shortening the combustion process thereby increasing the HC emissions. The HC emissions for E20 and E25 are 155 ppm and 158 ppm respectively, whereas for V10 configured valve with Diesel produces 143 ppm. The HC emissions are higher of 8.39% for E20 fuel blend compared with V10 at 3/4 of rated load.

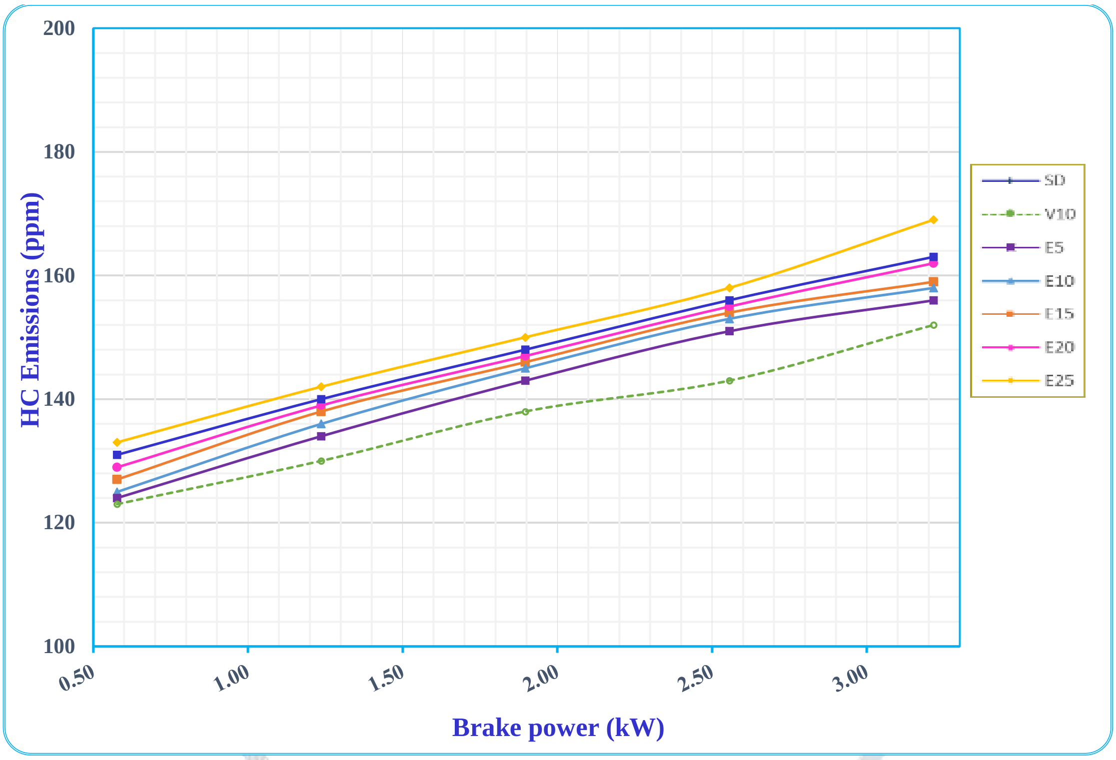

Figure 3.4 Variation of HC emission for various ethanol-Diesel blends with 3% ethyl acetate.

3.5 Carbon Monoxide(CO) Emissions

The variation of CO emissions of ethanol-Diesel blends with 3% of ethyl acetate, for E0, E10, E15, E20 and E25 with the brake power are shown in the Figure 4.6. The CO emissions for E20 and E25 are 0.383% and 0.387% volume respectively, whereas it is 0.401% volume for V10 with Diesel at 3/4 of rated load. The CO emissions are lower of 4.5% for E20 fuel blend when compared to V10 configuration at 3/4 of rated load. Higher percentage of ethanol blends result in higher emission of CO at part load due to lower combustion temperature caused by high latent heat of vaporization of ethanol. Also at lower load, the sufficient oxygen in the mixture would be very less due to lower temperature, which weakens the oxidation reaction at partial load. At high load, temperatures generally increase the speed of the chemical kinetics, so reducing the amount of CO for all ethanol blends.

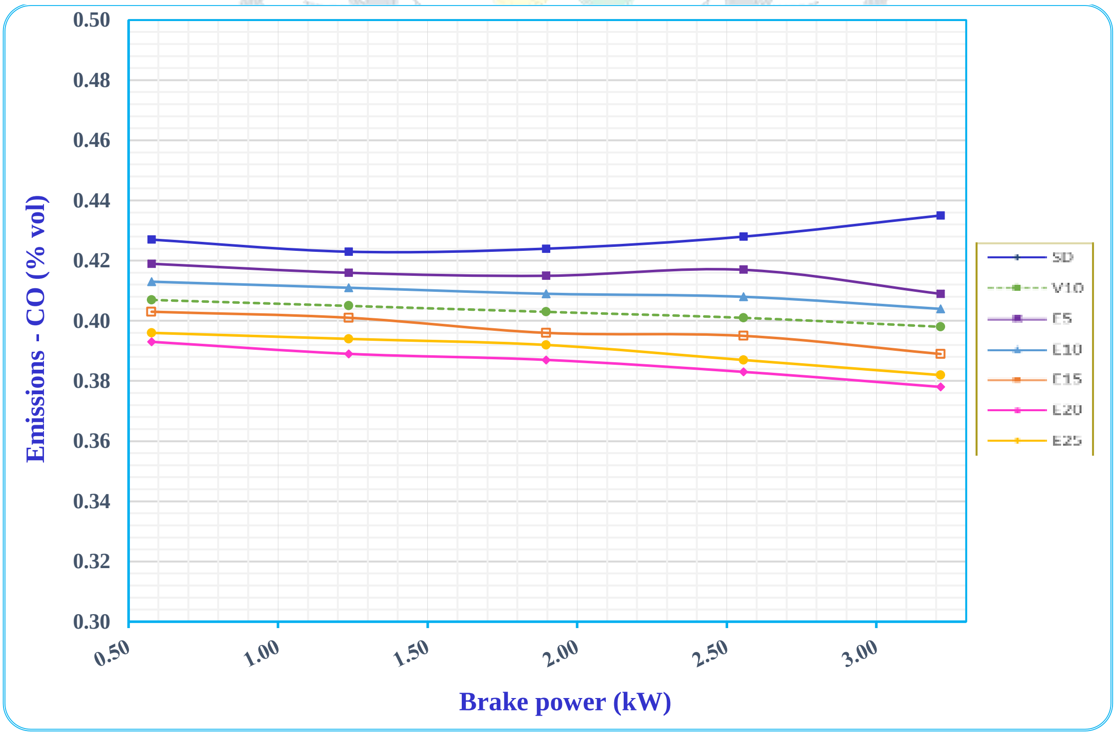

Figure 3.5 Variation of CO emission for various ethanol-Diesel blends with 3% ethyl acetate.

3.6 Carbon Dioxide (CO2) Emissions

The CO_2 emissions against brake power for ethanol-Diesel blends with 3% of ethyl acetate (for E0, E10, E15, E20 and E25) are shown in the Figure 4.7. The CO_2 emissions for E20 and E25 are 10.15% and 9.95% volume respectively, whereas V10 configured valve produces 8.91% at 3/4 of rated load. The CO_2 emissions are higher of 13.92% for E20 fuel blend when compared to V10 with Diesel at 3/4 of rated load. The oxygenated fuel like ethanol contains less CO_2 emissions at lower load with constant speed of 1500rpm. The CO_2 emission increases with increases in load, as expected. The higher percentage of ethanol-Diesel blends emits marginal amount of CO_2 in comparison with Diesel. E20 emits more amount of CO_2 emissions at higher loads due to air swirl and satisfying the combustion requirements.

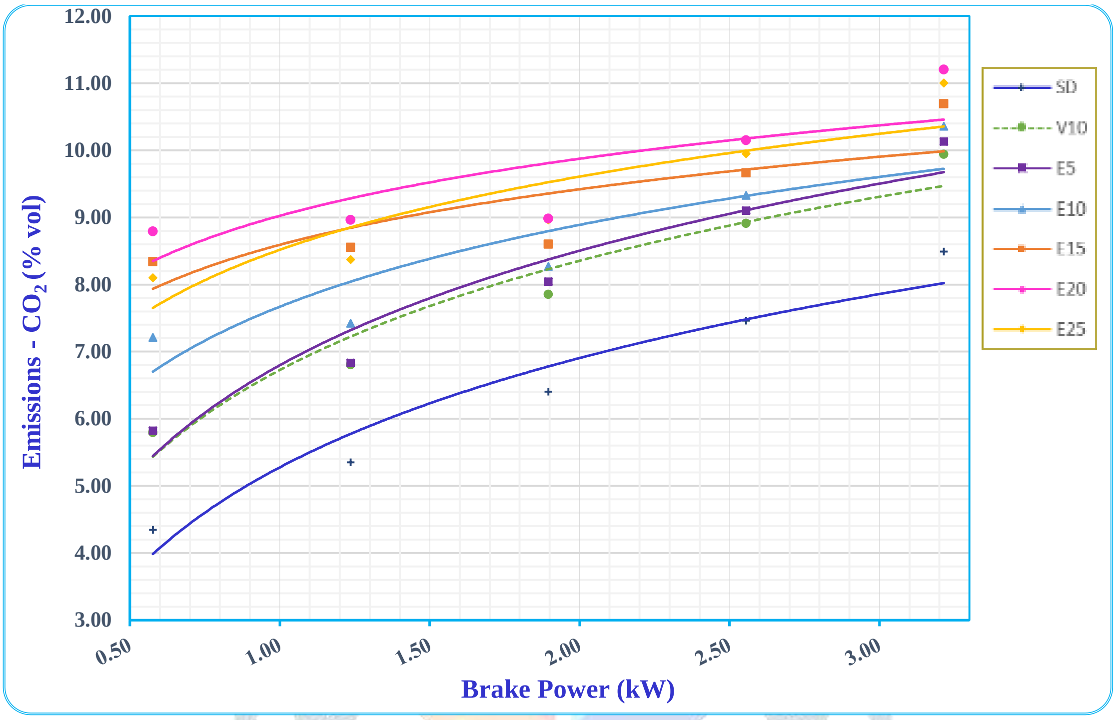

Figure 3.7 Variation of CO_2 emission for various ethanol-Diesel blends with 3% ethyl acetate.

IV. CONCLUSIONS

The following conclusions are drawn based on the quantity of ethanol-Diesel blends with 3% of ethyl acetate and the effect of inlet valve V10 air swirl in-cylinder:

- ✓ The brake thermal efficiency is increased by 1% for E20 blend when compared to standard diesel engine.
- ✓ The increase in brake specific fuel consumption with E20 fuel blends is 15.16% when compared with same V10 valve and diesel is used.
- ✓ The NOx emissions are lower of 12.76% for E20 when compared to V10 valve with Diesel at 3/4 of rated load.
- ✓ The HC emissions are higher of 8.39% for E20 fuel blend when compared to V10 valve geometry with Diesel at 3/4 of rated load.
- ✓ The CO emissions are lower of 4.5% for E20 fuel blend when compared to V10 valve geometry with Diesel at 3/4 of rated load.
- ✓ The CO2 emissions are higher of 13.92% for E20 fuel blend when compared to V10 valve geometry with Diesel at 3/4 of rated load.
- ✓ The thermal efficiency is similar to that of standard diesel fuel, while CO and HC emissions were higher at light load and at heavy loads HC and CO were reduced with a small increase in NOx emissions.

From this investigation, it is evident that E20 ethanol-Diesel blends with 3% ethyl acetate with V10 dimpled valve geometry produces the air swirl which gives better combustion and emission characteristics.

V. ACKNOWLEDGMENT

The authors wish to thank for all the support provided by the Department of Mechanical Engineering, Madanapalle Institute of Technology and Science, Angallu, Madanapalle.

REFERENCES

[1] Demirbas A., 2007. Progress and recent trends in biofuels. Prog Energy Combust Sci, 2007;33:1–18.

[2] Demirbas A. 2008. Biofuels sources biofuel policy biofuel economy and global biofuel projections. Energy Convers Manage 2008; 49:2106–16.

[3] Shen LZ, Yan WS, Bi YH, Lei JL, 2007 Performance comparison of ethanol/diesel blends mixed in different methods of diesel engine. J Combust Sci Technology, 13:389–92.

[4] Shi X, Yu Y, He H, Shuai S, Wang J, Li RL, 2005. Emission characteristics using methyl soyate–ethanol–diesel fuel blends on a diesel engine. Fuel 2005;84:1543–9.

[5] Rakopoulos CD, Antonopoulos KA, Rakopoulos DC, 2008. Multi-zone modeling of combustion and emissions formation in DI diesel engine operating on ethanol– diesel fuel blends. Energy Convers Manage 2008;49:625–43.

[6] Hansen AC, Zhang Q, Lyne PWL, 1996. Ethanol–diesel fuel blends – a review. Bioresour Technol 2005;96:277–85.

[7] Noguchi N, Terao H, Sakata C.,1996. Performance improvement by control of flow rates and diesel injection timing on dual-fuel engine with ethanol. Bioresour Technol 1996;56:35–9.

[8] Menezes E, Silva R, Cataluña R., 2006. Effect of ethers and ether/ethanol additives on the physicochemical properties of diesel fuel and on engine tests. Fuel 2006;85:815–22.

[9] Rakopoulos DC, Ralcopoulos CD, Kalcaras EC, Giakoumis EG., 2008. Effects of ethanol– diesel fuel blends on the performance and exhaust emissions of heavy duty DI diesel engine. Energy Convers Manage, 49:3155–62.

[10] Lapuerta M, Armas O, GarcÍa-Contreras R., 2007. Stability of diesel–bioethanol blends for use in diesel engines. Fuel, 86:1351-s57.

[11] Abhilash M Bharadwaj, K Madhu, Seemanthini J, Vismay K G, Anand M Shivapuji & Aravind T, 2013. Study of Swirl and Tumble Motion using CFD, International Journal on Theoretical and Applied Research in Mechanical Engineering, ISSN : 2319 – 3182, Vol-2, Issue-1,pp.36-39.

[12] Hiregoudar Y, Shivaprasad D, 2014. Effect of inlet air swirl on four stroke single cylinder Diesel engine's performance, Journal of Mechanical and Civil Engineering, p-ISSN: 2320-334X, Volume 11, Issue 4 Ver. IV, pp.59-68.

[13] Abdul Rahim Ismail, Rosli Abu Bakar, Semin, 2008. An Investigation of Valve Lift Effect on Air Flow and Coefficient of Discharge of Four Stroke Engines Based on Experiment, American Journal of Applied Sciences 5 (8): pp.963-971.

[14] Khan, I., Wang, C., and Langridge, B., 1972. Effect of Air Swirl on Smoke and Gaseous Emissions from Direct-Injection Diesel Engines, SAE Technical Paper 720102.

[15] Udayakumar, R., Valan Arasu, P., and Sriram, S.,2003. Experimental Investigation on Emission Control in C.I.Engines Using Shrouded Inlet Valve," SAE Technical Paper 2003-01-0350, 2003