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Performance & Emission (CFD Analysis) Studies On A Single Cylinder Di Diesel Engine Fueled With Diesel & Cotton Seed Oil Blends At Injection Pressure 200 Kg/Cm^2

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Abstract

The search for alternate fuels for diesel engines has been intensified from the last few decades as substitute to fossil fuels. This is due to the faster rate of depletion of fossil fuels and worsening environmental pollution related to its use. The atmospheric pollution in major cities due to automobiles has already reached to alarming levels in developing countries. The pressure to import non-renewable petroleum crude products to keep the vehicles moving has become a herculean task. The impact of the twin problems such as exhaust emissions and depletion of precious foreign exchange reserves has become an accepted fact. Among many different types of alternate fuels available, vegetable oils and their esters has come across the world as good choices.

Reviews of the research revealed that with the usage of vegetable oil based fuels, the harmful exhaust emissions, particularly sulphur related compounds and carbon monoxide are considerably reduced when compared to diesel operation. Intensive research is being conducted in developing the fuels and lubricants for diesel engine based on vegetable oils. Vegetable oils need to be heated to a temperature that is high enough to give a low viscosity similar to diesel. In the present experimental investigation the performance of vegetable oils like cottonseed oil inside a single cylinder four stroke direct injection diesel engine are studied. The blends of vegetable oil with diesel are prepared in the ratios of 25/75, 50/50 and 100% by volume.

Brake thermal efficiency, brake specific fuel consumption and volumetric efficiency are computed at injection pressure of 200 kg/cm^2. The performance parameters for cotton seed oil are compared. The best engine performance is obtained with cotton seed oil at injection pressure of 200 kg/cm^2 in comparison with neat diesel.

The results obtained from the tests are further validated with a modelled CFD tool for emission contours using FLUENT. The use of various parameters like formation of oxides of nitrogen, carbon monoxide and unburned hydrocarbons are studied for the blend 25C75D at injection pressure of 200 kg/cm^2.

The performance of blends have much similarities with the diesel both from experimental as well as CFD results at injection pressure of 200 kg/cm^2

Keywords:* *cottonseed oil, blends, performance & emission, CFD emission analysis.

1. Introduction

Diesel engines are the major source of transportation, power- generation, marine applications etc. But due to gradual depletion of world petroleum reserves and the impact of environmental pollution there is an urgent need for suitable alternate fuels for use in diesel engines. In view of this, vegetable oil like cottonseed oil as alternate fuels to diesel.

From the research and studies carried out in the past, it is evident that there are various problems associated with the use of vegetable oils as fuel in compression ignition engines, predominantly caused by their high viscosity and poor volatility. The high viscosity is due to the large molecular mass and complex chemical structure of vegetable oils that in turn leads to problems related to pumping, combustion and atomization in the injector system of a diesel engine. Patni Neha [4] was investigated CSO methyl ester is slightly greater in comparison with jatropha biodiesel and petroleum diesel. It is also observed that indicated thermal efficiency (η ith) with use of CSO methyl ester is considerably greater (i.e. 20.70%) in comparision with jatropha biodiesel and petroleum diesel. Due to the high viscosity, the long term operation of the engine with vegetable oils normally introduce the development of gumming, the formation of injector deposits, ring sticking and problems related to the lubricating oils .Therefore, the reduction of viscosity of vegetable oils is of prime importance to make it a suitable alternative fuel for diesel engines. The problem of high viscosity of vegetable oils can be reduced in several ways, such as transesterification [1,3,6,8], micro emulsification , preheating the oils and blending with other fuels such as diesel , oxygenated organic compounds , and methanol .

Emission levels of the blends of diesel and vegetable oils were found to be reduced [2, 9].Therefore, a reduction in viscosity is of prime importance to make vegetable oils a suitable alternative fuel for diesel engines. The exhaust emission characteristics of Diesel engines operated with vegetable oils have been studied by many researchers [5,7,10]. However, a review of the research revealed that with the use of vegetable oil based fuels, the harmful exhaust emissions, particularly sulphur related compounds and carbon monoxide are considerably reduced when compared to Diesel fuel.

The objectives of this study is to examine the performance of DI diesel engine with blends of cottonseed oil with diesel at various load conditions, to find which blends will be best suitable for DI diesel engines and exhaust gas analysis to determine the good performance and less pollutant. The results obtained from the tests are further validated with a modelled CFD tool for emission contours using FLUENT. The use of various parameters like formation of oxides of nitrogen, carbon monoxide, unburned hydrocarbons and soot are studied for the blend 25C75D at injection pressure of 200 kg/cm^2.

The performance of blends have much similarities with the diesel both from experimental as well as CFD (emission) results at injection pressure of 200 kg/cm^2

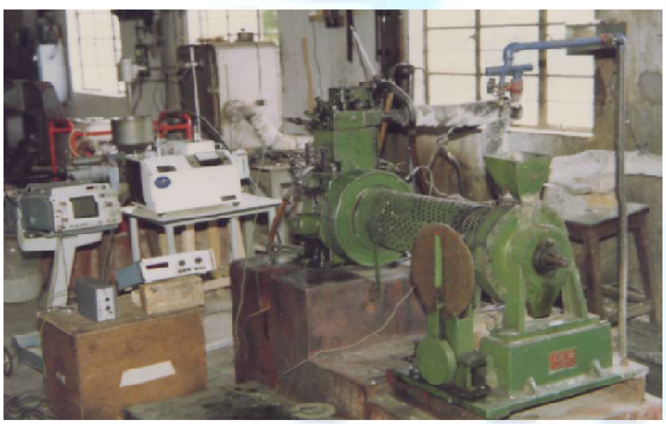


Fig.1 Experimental set up

Table 1 Engine specification (Input Values)

Bore	8.75 cm
Stroke	11.0 cm
Connecting rod length	23.2 cm
Piston bowl configuration	Hemispherical bowl
Engine speed	1500 rpm
Initial swirl ratio	2
Initial charge temperature	363^{0}k
Fuel	Diesel, cotton seed oil
Density of fuel	815 kg/m^3
Critical temperature of fuel droplets	619^{0}k
Injector	Single hole
Type of spray	Droplet particles
Mean injection velocity	80m/sec
Start of injection	28^0 bTDC
End of injection	4.5^0 bTDC

.Table: 2: Properties of diesel and cotton seed oil

Properties/ oils	Diesel	Cottonseed oil
Density(Kg/m^3)	815	951
Viscosity, CSt	4.8	35.2
Calorific Value(MJ/Kg)	45.52	39.47

2. Results& discussions

The properties of vegetable oil are almost same as that of diesel and hence it is used in diesel engines with little or no modification. The viscosity of the vegetable oils is higher and preheating the oil to the temperature minimizes the problems arising due to this. A series of exhaustive tests are carried out on a test engine using diesel and vegetable oil blends of three different kinds of oil separately as fuels at 1500 rpm. While conducting the experiment injector pressure is maintained at 200 kg/cm^2

The variation of fuel consumption at different loads at an injection pressure of 200 kg/cm² is shown in fig. 2.1. It is seen that the fuel consumption for blends of cottonseed oil and diesel are higher when compared to neat diesel fuel. The better atomization of fuel to attain fine droplets of fuel is possible with lower viscosity. As the viscosities of the fuels considered are higher, the mean effective diameter for the better combustion is also higher. Hence the fuel consumption for the fuels considered is higher as compared to diesel.

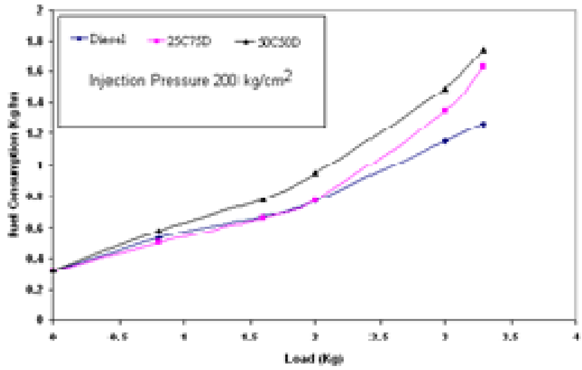


Figure 2.1: Comparison of Fuel Consumption Vs Load

The variation of brake specific fuel consumption with brake power at an injection pressure of 200 kg/cm^{2}is shown in fig. 2.2. It is observed that brake specific fuel consumption for blends of cottonseed oil and diesel are higher when compared to neat diesel fuel. For effective burning of the fuel the calorific value of the fuel should be higher so that the evaporation of the fuel is also high. The calorific values of cottonseed oil, blends of cottonseed oil and diesel are lower when compared to diesel, hence the fuel evaporation is slower. Slower evaporation rates and higher injection rates lead to higher brake specific fuel consumption.

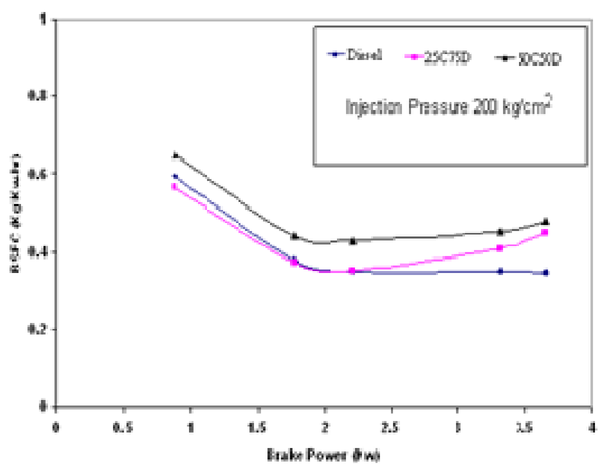


Figure 2.2: Comparison of Brake Specific Fuel Consumption Vs Brake Power

The variation of brake thermal efficiency with brake power at an injection pressure of 200 kg/cm^{2}is shown in fig. 2.3.It is learned that brake thermal efficiency for blends of cottonseed oil and diesel are lower when compared to neat diesel fuel. The thermal efficiency depends on higher calorific values and lower injection rates. Lower injection rates mean the lower mean effective diameter of the fuel. To achieve better combustion, fuel needs higher burning rates and good mixing of fuel evaporated with air so that all the fuel injected is completely burned. Having lower calorific values and higher injection rates for cottonseed oil, blends of cottonseed oil and diesel the complete combustion of fuel is not possible. Hence the incomplete combustion of fuels considered is the reason that is for lower brake thermal efficiency when compared to diesel.

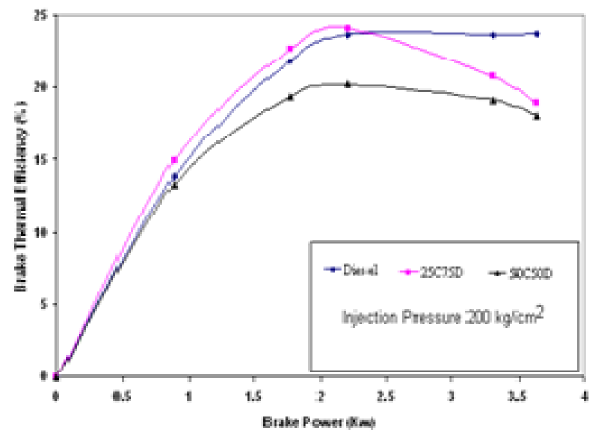


Figure 2.3: Comparison Brake thermal efficiency Vs Load

The variation of volumetric efficiency with load at an injection pressure of 200 kg/cm^{2}is shown in fig 2.4. It is observed that volumetric efficiency for all the fuels are decreasing as the load is increasing. The density of air decreases as the temperature increases, so at higher loads the inlet manifold temperatures are higher. Hence the air density decreases as the load increases. Also as the load increases the fuel consumption increases at a faster rate so that the mixtures become leaner. Ultimately the volumetric efficiency decreases as the load increases. The volumetric efficiency for blends of cottonseed oil and diesel when compared to diesel is lower. The reason, the vegetable oil has oxygen content inherent in it, so the air drawn into the engine cylinder is less. As the percentage of vegetable oil increases in the blend the air drawn into the engine cylinder is decreased and hence the volumetric efficiency decreases.

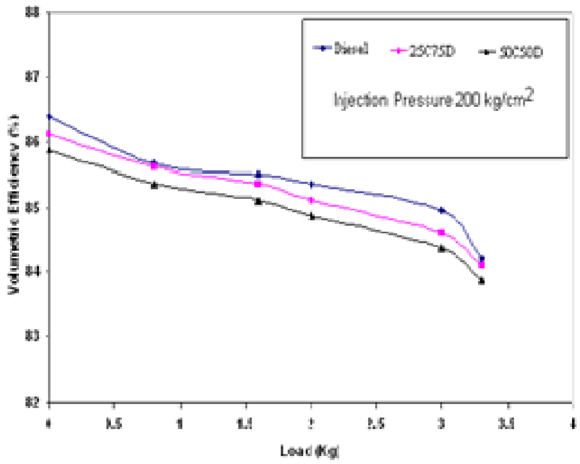


Figure 2.4: Comparison Volumetric efficiency Vs Load

The variation of exhaust gas temperature at different loads at an injection pressure of 200 kg/cm^{2}is shown in fig. 2.5. The exhaust gas temperature for blends of cottonseed oil and diesel is higher when compared to diesel. The reason that, the unburned fuel goes into the exhaust manifold and burns there so that the exhaust gas temperatures are higher when compared to diesel. The higher injection rates, higher fuel consumption and lower evaporation rates make the fuel go unburnt into the exhaust manifold.

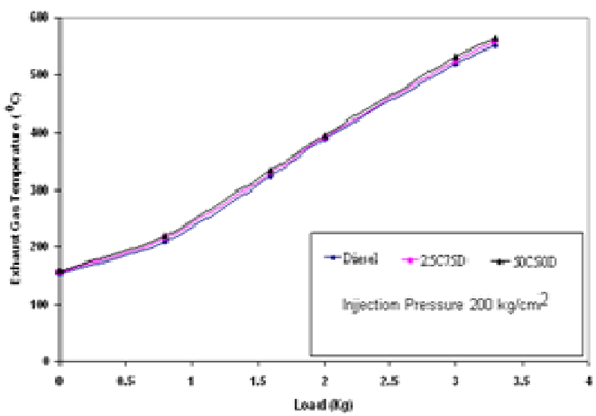


Figure 2.5: Comparison of Exhaust gas temperature vs. Load

Fig.2.6 shows the variation CO2 with brake power for Cottonseed oil and its blends with diesel in the test engine at an injection pressure of 200 kg/cm^2. CO2 emission of 50% blends having higher values compared with all other blends and diesel. The highest value of CO2 at 25% blend of cottonseed oil is 7.54% in respect to the value of 7.7% for diesel.

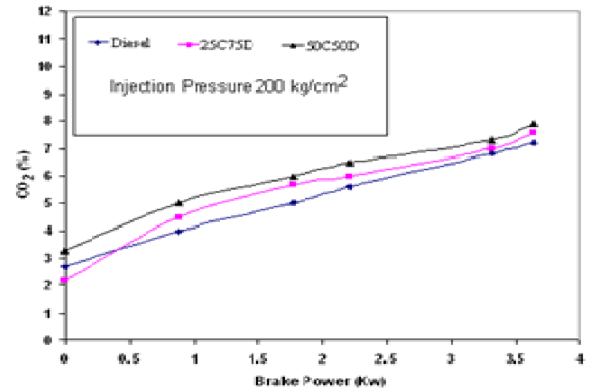


Figure 2.6: Comparison of CO_2 Emission Vs Brake Power

Fig.2.7 shows the variation of CO emission with brake power for cottonseed oil and its blends with diesel in the test engine at an injection pressure of 200 kg/cm^2. The CO of 50% blend of cottonseed oil has higher values compared with all other blends and is well comparable with diesel. The CO of all blends and diesel increases with increase of brake power.

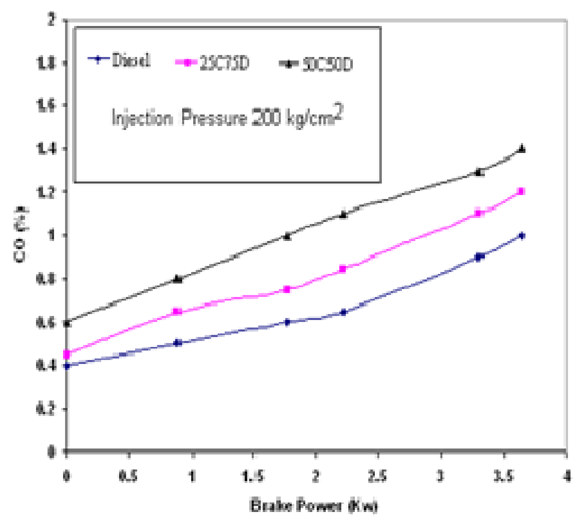


Figure 2.7: Comparison of CO Emission Vs Brake Power

Fig.2.8 shows the variation of hydrocarbon emission with brake power for cottonseed oil and its blends with diesel in the test engine at an injection pressure of 200 kg/cm^2. HC emission of 50% blend of cottonseed oil has higher emissions compared with all other blends. While, HC of

Diesel and 25% blend of Cottonseed oil are near to pure diesel.

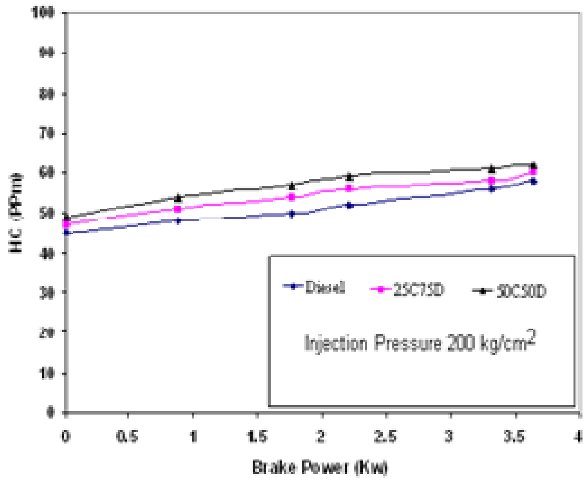


Figure 2.8: Comparison of HC Emission Vs Brake Power

Fig.2.9 shows the variation of NO_X emission with brake power for cottonseed oil and its blends with diesel in the test engine at an injection pressure of 200kg/cm^2. NO_X of 25% blend of cottonseed oil is slightly lower than that of diesel. 50% blend has less NO_X emission compared with all other blends throughout all brake power loads.

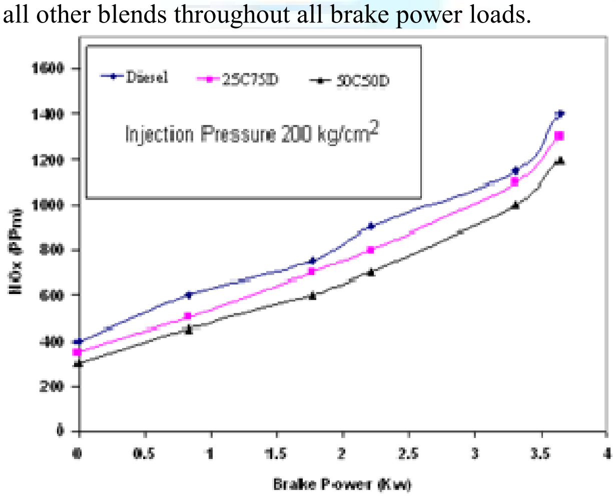


Figure 2.9: Comparison of NO_X Emission Vs Brake Power

Fig.2.10 shows the variation of smoke emission with brake power for cottonseed oil and its blends with diesel in the test engine at an injection pressure of 200kg/cm^2. Diesel has lower smoke emission compared with all other blends of cottonseed oil.

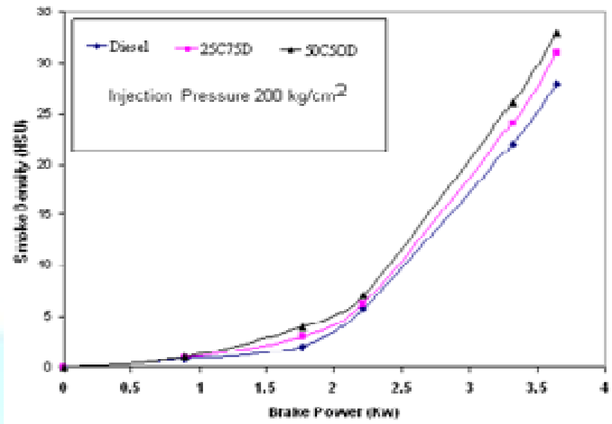
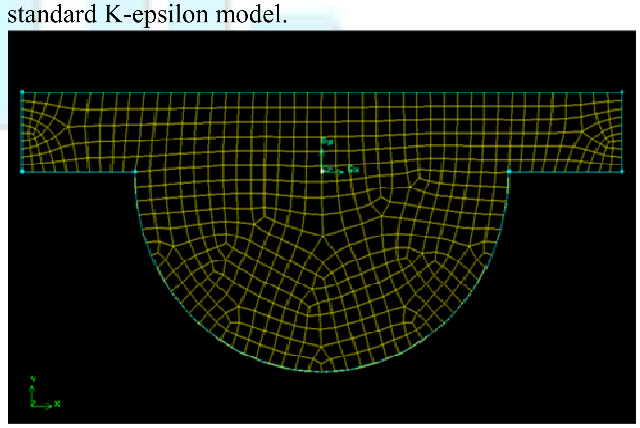


Figure 2.10: Comparison of Smoke Level Vs Brake Power

2.1 Emission Characteristics of blends by using CFD at injection pressure of 200 kg/cm^2 And Validation of results with CFD analysis.

The present work of predicting and analyzing the in-cylinder processes of a diesel engine is carried out to validate the results obtained a modelled CFD tool for emission contours using FLUENT. The use of various parameters like formation of oxides of nitrogen, carbon monoxide and unburned hydrocarbons are studied for the blend 25C75D at injection pressure of 200 kg/cm^2. A single cylinder diesel engine with hemi-spherical bowl shape in the piston is considered for the analysis, because the test engine for which the experimental results available has the same bowl configuration. The other engine details used in the analysis are also same as that of the test engine. The variations in the global parameters with Crank angle, during compression and expansion processes, are presented in x-y plots. The detailed analysis of spatial information, predicted using CFD code modified with standard K-epsilon model.

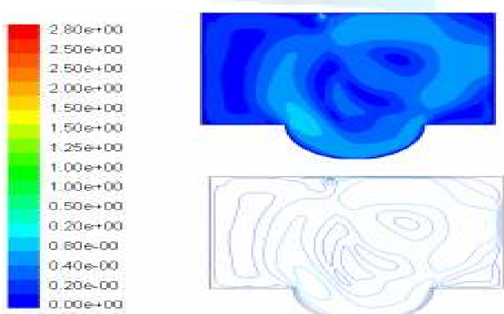


The temperature distributions plotted for 340^0 of cranks angle (CA) on a vertical plane. The influence of different parameters on the formation of oxides of nitrogen, carbon monoxide, unburned hydro carbons and soot. The local parameters (flow field, spray distribution and temperature contours) plotted for different blends at 200 kg/cm^2 injection pressure. The spray and flame reaches the edge of the piston bowl with in short period 7^0-10^0 CA. The concentration of oxygen in the high temperature zone is very high resulting in a high NO_X rate of formation.

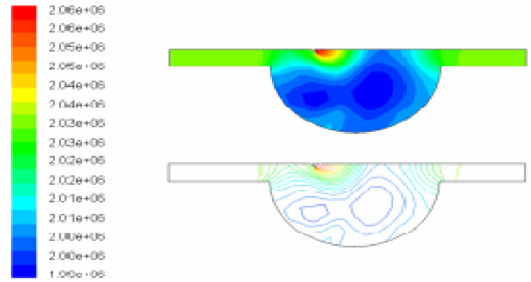
The NOx from emission test is 1100 ppm at 1500 rpm. The detailed time history of spray, fuel mass fraction and temperature distributions provided by the CFD simulation are valuable towards gaining a better understanding of the features of combustion for given engine configurations . NO_X formation is highly sensitive to temperature and also effected by species concentration. In-fact the flame in the hemi-spherical bowl is not sufficient to burn a complete combustion because of the bowl shape.

The deviations from experiment and simulation results of NO_X emission are around 3-5 %. It is found that the general agreement between prediction and engine test is good.

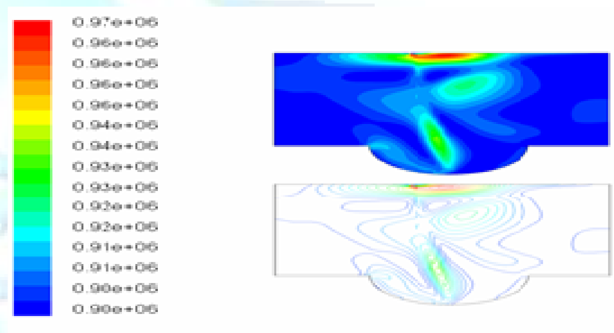
2.1.1 Emission contour for Cottonseed oil and Diesel blends (25C75D) at 340 ^{0} of cranks angle (CA)



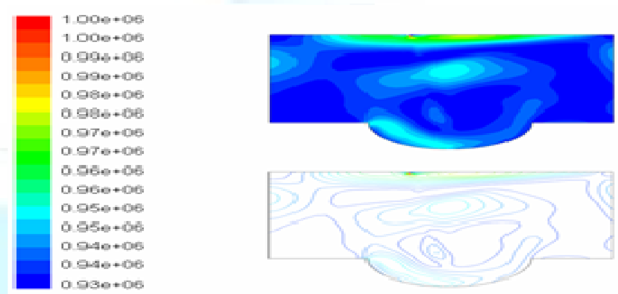
Contour of CO2 Emission



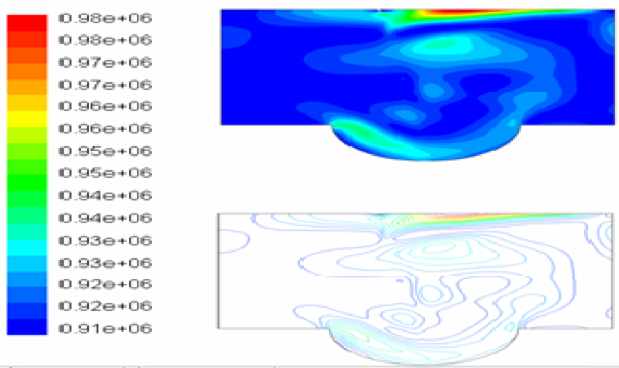
Contour of HC Emission



Contour of CO Emission



Contour of NOx Emission



Contour of Smoke Density

3. Conclusions

The present work is carried out on a single cylinder 4-stroke compression ignition engine fitted with a hemispherical bowl-in-piston with different ignition accelerating fuel additives. Systematic experimental work has been carried out to investigate the performance of diesel engine using blends of Cotton seed oil, with diesel at 200 kg/cm^2 fuel injection pressure. These results are taken into account to carry out with CFD analysis for emission contours.

The experimental study is conducted to evaluate and compare the blends of cottonseed oil and diesel: 25C75D, 50C50D. These are considered as partial supplements to conventional diesel fuel in a single cylinder direct injection naturally aspirated diesel engine.

The series of tests are conducted using each of the fuels blends in the engine working at a constant speed of 1500 rpm and at different loads for fuel consumption, brake specific fuel consumption, brake thermal efficiency, volumetric efficiency and exhaust emissions are compared.

- The brake specific fuel consumption value for Diesel at full load is 0.3473Kg/Kw-hr at injection pressure of 200 kg/cm^2
- The brake specific fuel consumption value for 25C75D at full load is 0.4473Kg/Kw-hr, injection pressure of 200 kg/cm^2
- The brake specific fuel consumption values for 50C50D at full load is 0.4777Kg/Kw-hr at injection pressure of 200 kg/cm^2,
- The brake thermal efficiency values for Diesel at full load are 23.76% corresponding at injection pressures of 200 kg/cm^2.
- The brake thermal efficiency values for 25C75D at full load are 18.88% at injection pressures of 200 kg/cm^2.
- The brake thermal efficiency values for 50C50D at full load are 18.9% at injection pressures of 200 kg/cm^2,
- The volumetric efficiency values for Diesel at full load are 84.22%, at injection pressures of 200 kg/cm^2.
- The volumetric efficiency values for 25C75D at full load are 84.12%, at injection pressures of 200 kg/cm^2.
- The volumetric efficiency values for 50C50D at full load are 83.88%, at injection pressures of 200 kg/cm^2.
- The exhaust gas temperature obtained for Diesel at full load are 550^{o}c, at injection pressures of 200 kg/cm^2.
- The exhaust gas temperature obtained for 25C75D at full load are 557^{o}c, to injection pressures of 200 kg/cm^2.
- The exhaust gas temperature obtained for 50C50D at full load is 563^{o}c, at injection pressure of 200 kg/cm^2.
- The CO_2 emission Values for Diesel at full load are 6.9%, at injection pressures of 200 kg/cm^2.
- The CO_2 emission Values for 25C75D at full load are 7.2%, at injection pressures of 200 kg/cm^2,
- The CO_2 emission Values for 50C50D at full load are 7.6%, at injection pressures of 200 kg/cm^2.
- The CO emission Values for Diesel at full load are 0.9%, at injection pressures of 200 kg/cm^2.
- The CO emission Values for 25C75D at full load are 1.16% , at injection pressures of 200 kg/cm^2,
- The CO emission Values for 50C50D at full load are 1.4%, at injection pressures of 200 kg/cm^2.
- The HC Emission Values for Diesel at full load are 54ppm, at injection pressures of 200 kg/cm^2.
- The HC emission Values for 25C75D at full load are 58ppm, at injection pressure of 200 kg/cm^2,
- The HC emission Values for 50C50D at full load are 60ppm, at injection pressure of 200 kg/cm^2.
- The NO_X emission Values for Diesel at full load are 1400ppm, at injection pressure of 200 kg/cm^2.
- The NO_X emission Values for 25C75D at full load are 1300ppm, to injection pressure of 200 kg/cm^2,
- The NO_X emission Values for 50C50D at full load are 1200ppm, to injection pressure of 200 kg/cm^2
- The smoke density values for Diesel at full load are 27HSU, at injection pressure of 200 kg/cm^2.
- The smoke density values for 25C75D at full load are 31HSU, to injection pressure of 200 kg/cm^2.

- The smoke density values for 50C50D at full load are 33HSU, at injection pressure of 200 kg/cm^2.

- The exhaust emission values of CO_2, CO, HC and smoke density values for 25C75D are near to diesel exhaust emission at injection pressure 200 kg/cm^2.
- The exhaust emission value of NO_X values for 25C75D is less compared to diesel at injection pressure 200 kg/cm^2.
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- Maximum temperature is observed at 200 kg /cm^2 pressures for the blend 25% diesel with 75% cotton seed oil, which is almost equal to diesel engine temperature.
- The emission characteristics curves and CFD emission counters for the blends 50C50D at 200 kg/cm^2 injection pressure is more emission compared to 25C75D the blends of cottonseed oil, it is also observed the blends of 25C75D emission values are near to that of pure diesel.
- From both experimental and CFD results that the blend of Cottonseed oil 25% and Diesel 75% has got good performance at 200 kg/cm^2 injection pressure without any modification in the existing diesel engine

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