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Effect of Ethanoland Fecl$_3$ Addition on the Performance and Combustion Characteristics of a Compression Ignition Engine.

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***Abstract*:**

Performance and combustion analysis of a single cylinder four stroke diesel engine has been done by using ethanol and ferric chloride ($FeCl_3$) as additives with diesel. The engine is supplied with neat diesel, ED10 (10% ethanol+90% diesel), ED20 (20% ethanol+80% diesel), ED10+0.2$FeCl_3$ (10% ethanol+90% diesel+0.2 gm/L $FeCl_3$) and ED20+0.2$FeCl_3$ (20% ethanol+80% diesel+0.2 gm/L $FeCl_3$) at various engine loads (0 to 12 kg) by maintaining constant engine speed of 1500 rpm. The results obtained that BSFC has been reduced by 5% when the engine is fueled with ED20+0.2$FeCl_3$compared to the neat diesel operation. BTE is found to be enhanced by 4% by adding ethanol and $FeCl_3$ with diesel. Exhaust gas temperature is also found to be reduced to 316.72^{0}C from 398.9^{0}C by using ED20+0.2$FeCl_3$and neat diesel respectively. Combustion analysis reveals that in cylinder temperature and pressure is almost identical in all the fuel blends compared to the neat diesel operation. Moreover the combination of ethanol-diesel-$FeCl_3$ in the diesel engine shows very promising results while considering thepower output andin-cylinder parameters.

Keywords: Performance; Combustion; Ferric chloride; Ethanol; Diesel engine

1. Introduction

The global warming and intense environmental pollution due to exhaust emission from the conventional engine urge the researchers to look for analternative fuel for the engine in order to mitigate the above-said problems. It is a well-known fact that the addition of some additives in diesel leads to enhanced performance and reducedemission of pollutants from the exhaust of diesel engines.In order to reduce the pollutant level, many researchers used oxygenated fuels such as ethanol, Di-ethyl ether (DEE), alcohol, etc. along with diesel in various proportions.V. Gnanamoorthi et al. [1] carried out the experiment by taking different blends of ethanol with different compression ratios. The thermal efficiency is observed to be increased at high load with more ethanol blend. As the compression ratio increases combustion as well as the performance ofthe engine improves. A decrease in emission like Hydrocarbon,

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Carbon monoxide and smoke were also observed by the work. Fu et al. [2] observed lowerNOx, smoke and CO_2 emissions by usine ethanol with diesel at high loading conditions. E.A.Ajav et al. [3] identified an increase in brake specific fuel consumption with higher ethanol percentage by taking ethanol diesel blend in different proportions like 5%, 10%, 15% and 20% in the diesel engine. The emission like carbon monoxide and nitrogen oxide decreases with the experimentation on diesel-ethanol blends as compared to only diesel. A similar trend of decrease in NO_X and PM emissions was reported by [4]. Su Han Park[5] observed unstable ignition characteristics using ethanol-blended fuel, injected around the top dead center (TDC) because of longer ignition delay caused by the higher the ethanol blending ratio in diesel. Huseyin Aydin [6] researched by taking 20% and 80% of ethanol and biodiesel blendand concluded thatthe performance of the CI engine is improved with the use of BE20(biodiesel and ethanol) as compare to B20 (biodiesel). It has been observed that exhaust emissions like carbon monoxide and sulphur dioxide were decreased by using the blended fuel compared to only diesel fuel. Performance of the engine has been evaluated by Yahuza I et al. [7] in which thay have usedethanol diesel blends varing compositions from 5 to 20% ethanol with diesel. The result indicated an improvement in thermal efficiency of the engine by using ED20 (20% ethanol with 80% diesel) at higher loading conditions. A similar kind of experimentation was performed by Santosh Kumar Kurre et al. [8], in which higher HC and reduced smoke emission were observed as the Compression ratio increases. NO_X emission decrease with a lower blend of fuel in allthe compression ratios. Brake thermal efficiency increases with reduced fuel consumption at higher compression ratio for all fuel. AhamadTaghizadeshAlisaraeiet al.[9] added ethanol to diesel in different proportions of 2, 4, 6, 8, 10 and 12% at various engine speeds.The maximum enhancment in power output and torque was found to be 3.8% by using 6% ethanol supplemented diesel as the fuel. Further a significant increase in ignition delay leading to poor perfprmance can be witnessed beyond 8% ethanol supplementation.HiregoudarYerrennagoudar uet al.[10] found the bio-fuel oil [90% Jatropa oil + 10%ethanol] to be a better alternative to diesel with identical performance and enhance emission properties compared to the diesel fuel.Giacomo Belgiornoet al.[11] observed an increase in THC and CO at all loading conditionsby taking diesel, gasoline and ethanol in the ratio of 68:17:15 and 58:14:30. Paul et. al. [12] used diesel-DEE and diesel-DEE-ethanol blends to evaluate the performance as well asthe emission characteristics of single cylinder diesel engine.Thermal efficiency of the engine was found to be increased with 5% DEE blend compared to higher blend of fuel. Emission parameters were found to be decresed at all blends of diesel during the experiment.

The present work enlight the effect of ethanol and ferric chloride ($FeCl_3$) on the performance and combustion characteristics of a CI enginewhich is used as the additive with diesel in various proportions.

2. Materials and methods

2.1. Preparation of fuel blends

Ethanol and diesel blend can be used as fuel in compression ignition engine without any modification. It is added to diesel at the proportion of 100ml ethanol with 900 ml diesel (ED10) and 200ml ethanol with 800 ml diesel (ED20). $FeCl_3$ is added to diesel-ethanol blend with different proportion (ED10 and ED20) of 0.2gm per litre of diesel. All the blends are stirred for 3 hours using a stirrer and exhibited excellent miscibility properties with no residue at the bottom of the container (Figure 1) even after 24 hours of blending. These blends are thus, selected as fuelsto run the engine.

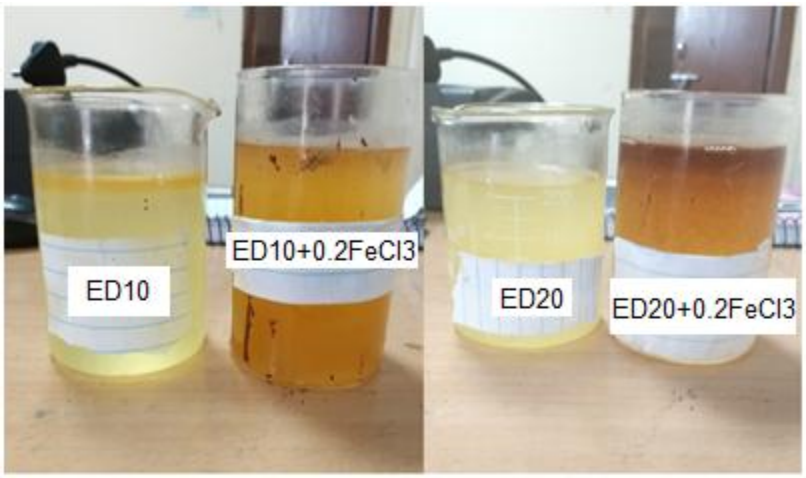

Figure 1. Solution of Ferric chloride and ethanol-diesel(ED20) blend.

2.2. Engine setup

A Kirloskar made, 661cc capacity, naturally aspired, four stroke, and single cylinder developing a utmost power of 5.20kW at 1500rpm is used to perform the investigation. The engine is connected to an eddy current dynamometer. The engine could be gradually loaded by activate a knob on the dynamometer. A load indicator indicates the engine load.Panel box housing, a manometer, air tank measuring unit, devices for measurement of fuel flow and air fuel including the engine load indicator is used for recording the experimental results. Fuel is supplied from a 15lt capacity fuel tank mounted on the top of the panel box with appropriate connections for fuel flow. The cylinder pressure is used by the help of a piezo sensor which has a range to measure the pressure upto 5000 psi. Engine rpm is measured by a Kubler make digital rotary encoder with a range of 1 to 10000 rpm.The compression ratio of the engine is 18. Table 1 provides the detailed engine specification used for the experiment.

Table 1. Specification of the Engine

Make	Kirloskar
Detail of the engine	Laboratory testing type, 4- stroke, single cylinder water cooling system, compression ignition type(CI)
Power ratings	5.20Kw at a constant 1500 rpm speed of rotation
Speed particulars	1500 rpm
Compression ratio	18:1
Bore	87.5 mm
Stroke	110 mm

The test rig (engine) contains the following components; a loading unit, an air flow unit, calorimeter, pressure sensors etc. Software package "Engine SoftLV" version 8.51 is used to record the details of the measured experimental parameters related with the experiment.The details of engine layout and engine setup are shown in Figure 2 and Figure 3.

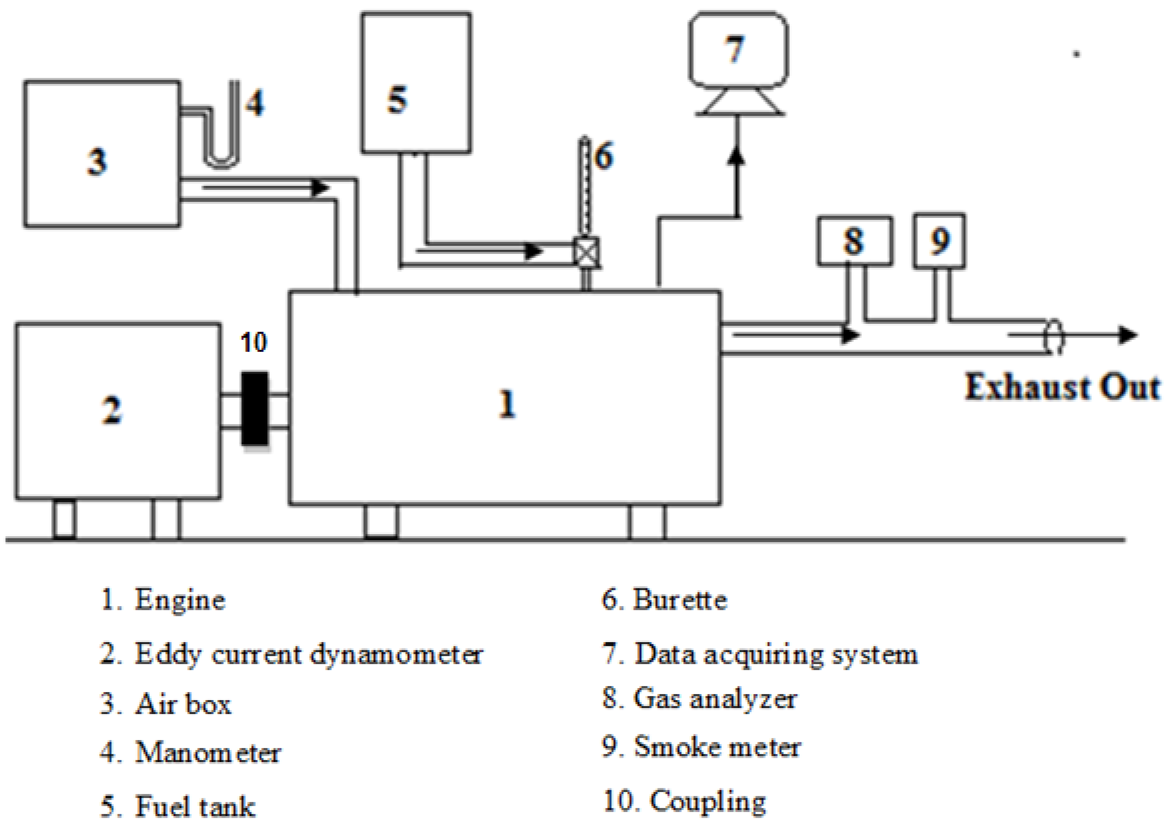

Figure 2. Layout of experimental setup.

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Figure 3. Actual experimental setup.

2.3. Experimental Methods

During experiment, the load is being varied from no load condition to full load by maintaining compression ratio of 18. The engine is run with neat diesel and ethanol-diesel mixed with Ferric chloride (0.2gm/litre) blend to find its effect. The tests are carried out at constant speed of 1500 rpm. The consumption fuel is measured using a measuring burette in the data acquisition system. Performance and combustion parameters are measured at different loads and a constant compression ratio of 18 separately with neat diesel and diesel-ethanol with Ferric chloride combination.

2.4. Error Interpretation

The uncertainties and error involved during the experiment are consequences of a faulty instrument, faulty calibration, working conditions, environmental conditions, faulty observation methods and modes of test. Uncertainties reflect measures of the accuracy of the experiment. Uncertainties associated isdetermined by using root mean square method. Table 3.3 houses the percentage of uncertainties associated with the measurement of various parameters.

Table 2. Uncertainty associated with the experiments

Measured Quality	Uncertainty
CO	±0.03
CO_2	±0.06
HC	±0.42
O_2	±0.01
NO	±0.45

3. Result and Discussion

3.1. Influence of Engine load on BSFC for neat diesel and Ethanol-diesel with FeCl3 blend

Variation of brake specific fuel consumption (BSFC) for the engine is presented in Figure 4. As evident from the figure BSFC is lowered with the enhancement of engine load. Maximum reduction of about 5% in the BSFC with $FeCl_3$ additions to diesel-ethanol as compared to only diesel mode is achieved. This is in the line findings of Kannan et al. [13], that $FeCl_3$ as a catalyst enhances the combustion process there by reducing the BSFC at standard optimized operating conditions. The diagram reveals the BSFC of the engine is reduced to a value of 0.30kg/kWh with 20% ethanol-diesel-Ferric chloride combination as compared to the value of 0.35kg/kWh when the engine runs with neat diesel. This may be considered as positive effect of FeCl3 addition seems the BTE of the engine is expected to improve with the lowered BSFC.

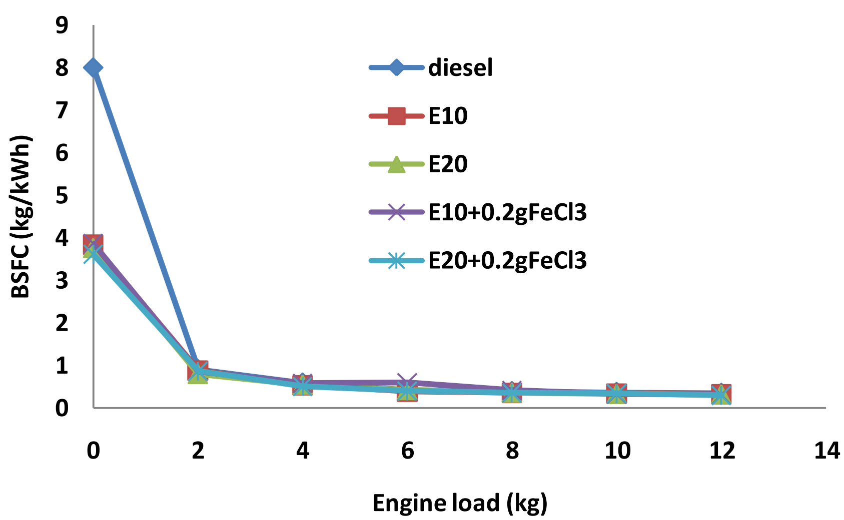

Figure 4.BSFC at different engine load.

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3.2. Influence of Engine load on BTE for neat diesel and Ethanol-diesel with FeCl3 blend

The variation of BTE with engine load for neat diesel and ethanol-diesel-Ferric chloride blend are presented in Figure 5. The diagram shows an improvement in the BTE values when the engine is fuelled with both neat diesel and ethanol-diesel-Ferric chloride combinations with different proportions (10% and 20%). The analysis of the BTE values shows that the fuel additive Ethanol and $FeCl_3$to diesel enhances the BTE values by about 4% as compared to without $FeCl_3$ additives. Literature revealed that iron-oxo species are formed with $FeCl_3$ additions that combine with oxygen (air) in the combustion chamber, thus enabling $FeCl_3$ to act as a catalyst for the process of combustion. This action of $FeCl_3$ on the combustion processes improves the oxidation processes concerning the hydrocarbons. It is estimated from the observation that at full load the engine fuelled by diesel-ethanol-ferric chloride mix results in a BTE of about 29.52% of the total fuel energy as compared to 25% BTE when engine is fuelled by neat diesel.

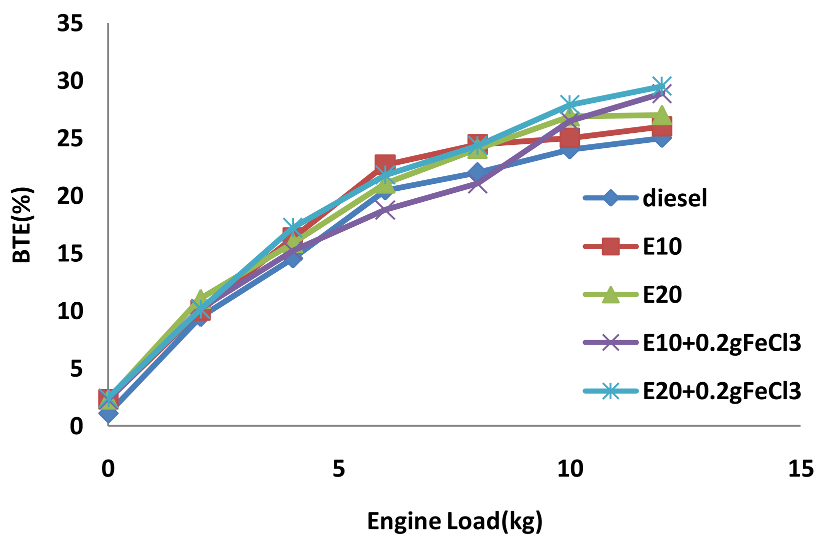

Figure 5.BTE at different engine load

3.3. Influence of Engine load on Exhaust gas temperature (EGT) for neat diesel and Ethanol-diesel with FeCl3 blend

The variation in temperature of exhaust gas from an engine running with neat diesel and ethanol-diesel-$FeCl_3$ mix with proportion of about (10 and 20%) at different engine loads is shown in Figure 6. The exhaust temperature is observed to be high at higher loads by using ethanol-diesel-Ferric chloride blend. The exhaust gas temperature is found to be 316.72°C at full load with ethanol-diesel-ferric chloride blend at 20% proportion. The same is found to be 398.9°C when engine is fuelled withneat diesel. This may be due to the enhancement of burning processes produced by the catalytic action of $FeCl_3$which is responsible for the drop in exhaust gas temperature.

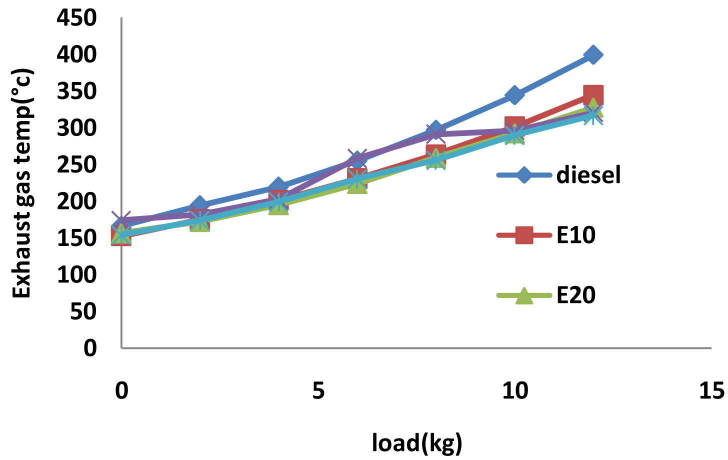

Figure 6. Variationof Exhaust gas temperature with load

3.4. Mean gas temperature at different crank angles as influenced by the engine load for diesel and diesel-ethanol-Ferric chloride

Figure 7 exhibit the experimental results with regard to the relationship between mean combustion of the gas temperature at different crank angles as influence by the engine load for neat diesel and ethanol-diesel-ferric chloride blend at full engine loads respectively. The mean combustion of gas temperature decreases when the load is increased. This decreases in the maximum gas temperature may be due to the reduction in the temperature inside the cylinder on the account of the heat of evaporation of ethanol which is absorbs from the total heat available in the cylinder.

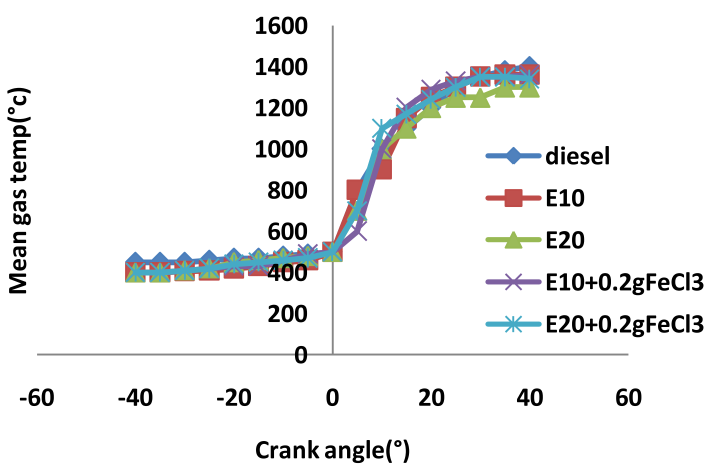

Figure 7. Variation of mean combustion of the gas temperature with reference to crank angle

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3.5. Cylinder pressure at different crank angles as influenced by the engine load for diesel and diesel-ethanol-Ferric chloride blend

The variation of in-cylinder pressure with crank angle at different engine loads when the engine is fuelled with only diesel and ethanol-diesel-ferric chloride blend with different proportion (10% and 20%) combination presented in the Figure 8. There is no significant change observed in the cylinder pressure of compression ignition engine by adding ferric chloride in the blend of ethanol diesel fuel.

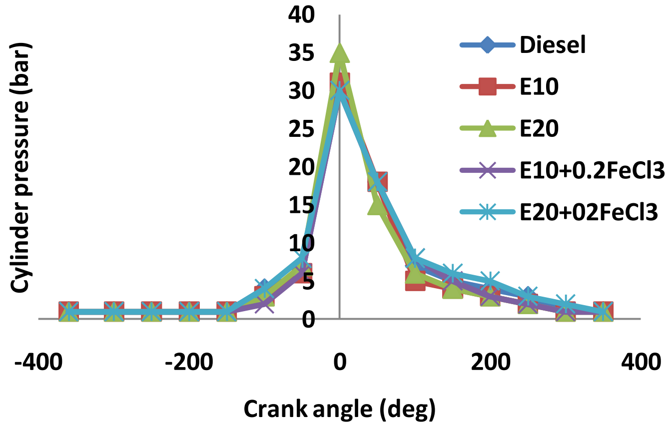

Figure 8. Cylinder Pressure variation with crank angle

4. Conclusion

The engine has been tested with the blended fuel and diesel separately and the conclusions drawn from the experiment are as follows:-

- $FeCl_3$-ethanol-diesel blend as a fuel in the compression ignition engine resulted higher brake thermal efficiency by 7% with lower brake specific fuel consumption up to 8% compared to only diesel mode of operation.
- Additions of $FeCl_3$ to ethanol-diesel blend results an improvement of in-cylinder peak pressure and temperature.

It can be concluded from the work that Ethanol-diesel-$FeCl_3$blend as a fuel in the diesel engine produces very inspiring results concedering the engine performance and combustion.

5. Scope for future work

The present investigation serves as gateway for the broad area of research towards the use of ethanol and ferric chloride as fuel additive in diesel engines by varing the compression ratio, injection timming, engine speed and so on. Future research will be done to optimize the emission parameters by using the above additives with diesel that can be helpful for a clean and green environment.

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