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Research paper



Emission of CI Engine Using $FeCl_3$ and Diethyl ether as Additives

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Abstract

Improving the performance of IC engine and reducing the toxic gases by applying the advance technology is the main key to safe guard the nation economy and health. The present investigation is to compare the emission of the single cylinder four-stroke diesel engine by adding proper additives ferric chloride (FeCl3) and diesel-diethyl ether (DEE) with diesel. The investigation defeats that Diesel-DEE15 combination has show the lowest HC and CO emissions except NO emission.

Keywords: diesel *engine; ferric chloride; diethyl ether; nitrogen oxide*

1. Introduction

Needless to say consumption of the fossil fuels to make energy available for utilization in different purposes, leading to the progress of the country, results in the depletion of the underground resources of fuels at a very high rate. It is possible that with the lapse of time, the fuel-stock below the crust of the earth may be lowered to such an extent that the conveyance, transport etc. will be jeopardized. This requires complete combustion of the fuel and effective utilization of the available energy including the generation of minimum quantities of toxic gasses.

2. Literature of Emission

The study involving the addition of ferric chloride ($FeCl_3$), on the DI diesel engine performance, emission and combustion characteristics was performed by Kannan et al. [1]. BSFC decreased and BTE increased. The NO extent in the exhaust was decreased slightly while the CO_2 emissions increased with the addition of the FBC. Jothithirumal et al. [2] stated that cerium oxide added in nano-particles in diesel engine, which gives increase of CO emission and decrease in NO_x. Barik et.al does the experiment to increase the BTE with decrease in BSFC by diethyl ether injection to CI engine [3]. The DEE as an additive lowered NO_x and smoke levels in the exhaust [4]. Cinar et al. do the experiment to study the mode of combustion in a DI diesel engine fuelled by premixed DEE and neat diesel separately. Interestingly 10% DEE premixed fuel, 20% premixed DEE fuel and 40% premixed DEE fuel were characterised by small cycle to cycle variations, distinct cycling variation and audible knocking combusting during engine operations. Therefore the tests were conducted up to 30% DEE ratio only. NO_x and soot emissions were decreased with an increase in the CO and HC emissions [5]. The diesel engine fuelled with diesel-DEE blends through 5%, 7.5% and 10% DEE additions in diesel were investigated in laboratory by Likhitha et al. [6]. It was observed that increased proportions of DEE increased the BTE and mechanical competence of the engine with a simultaneous decrease in the specific fuel consumption. Improvement of efficiency and diminish the emission level in a dual fuel mode, using DEE [7]. Ethanol blend reduced viscosity, surface tension of the fuel, reduced CO and smoke emission [8].

In the present experimental investigation has done by running diesel engine for one hr trial. The engine is fuel by diesel and diesel-catalyst ($FeCl_3$) mixed in order to study the various parameters under the influence of catalyst in the fuel. These parameters are compared with the diesel. The experiment is carried out with diesel and ferric chloride added to diesel (0.2gm/litre) and diesel with 15% DEE. It is found that the emission label decreases.

3. Experiment

3.1. Experimental setup

A Kirloskar made, 661cc capacity, naturally aspired, four stoke, and single cylinder diesel engine developing a maximum power of 3.5kW at 1500rpm is used to conduct the experiment. The engine is connected to an eddy current dynamometer. The engine could be gradually loaded by actuating a knob on the dynamometer. A load indicator indicates the engine load.

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 has been used to record the details of the measured experimental parameters related with the experiment. Pressure sensors attached to the data acquisition system used to collect the pressure data during the conduct of experiment. The extents of emissions in the exhaust gas have been measured using a multi-gas analyzer model AVL- 444 model. A smoke meter, AVL-437 model with a measuring range from 0 to 100% at a resolution 0.1% is used for measurement of the smoke opacity. A computerized data acquisition system was used to collect, store and analyze the data.

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3.2 Experimental procedure

After steady state condition the experiments were started. During the experiment, the engine started at zero load condition to full load condition at a constant compression ratio of 18. The experiment was carried with diesel and ferric chloride along with diesel (0.2gm/litre).
On the basis of its earlier stability, abilities to act as an oxidation catalyst and the associated lesser possibilities of creating the environmental hazards. $FeCl_3$ is often selected as a catalyst for engines run with diesel. $FeCl_3$ was mixed with diesel. $FeCl_3$ was added to diesel at a proportion of 0.2 g per liter of diesel. For proper mixing used stirrer. No precipitation was observed as shown in Fig. 1.

In addition to the experimental procedures already adopted for analysis the engine hazardous gas emissions, DEE additions to the fuel mix include an additional procedure for evaluating the effect of DEE addition to the fuel mix. DEE was blended with diesel at a proportion of 15% (DEE15) that is 150 ml of DEE mixed with 850 ml of diesel. Then used in engine.

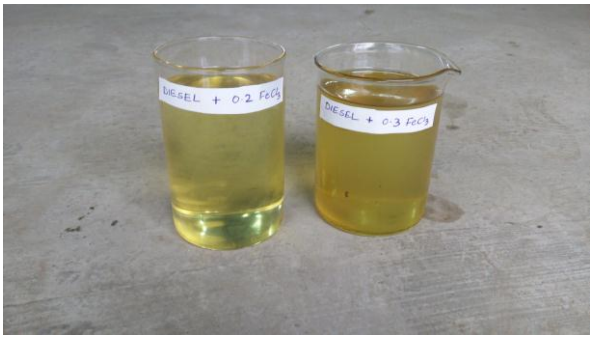


Fig. 1. Different proportions of Ferric chloride and diesel mixing.

3.3 Uncertainty analysis

The uncertainties in the experiment are consequences of a faulty instrument, faulty calibration, working conditions, environment, faulty observation methods and modes of the test [9, 10]. Uncertainties reflect measures of the accuracy of the experiment. Uncertainties associated with measuring various parameters have been determined by using root mean square method [11]. The percentage of uncertainty is given in Table 1.

Table 1: Measurement range, resolution and uncertainty of AVL 444 gas analyzer.

Emission parameters	Measuring Range	Resolution	Percentage of Uncertainty
CO	0…10% vol.	0.01% vol.	±0.04
CO_2	0…20% vol.	0.1% vol.	±0.07
HC	0…20000 ppm vol	1 - 10 ppm vol.	±0.47
O_2	0…22% vol.	0.01% vol.	±0.01
NO	0…5000 ppm vol.	1 ppm vol.	±0.48

4. Results and discussion

The engine is run separately using diesel and diesel+$FeCl_3$ blend at 0.2gm/lt. of diesel. This blend as indicated earlier ensures complete miscibility and DEE blend.

4.1. Emission parameters

4.1.1. Engine emission of Carbon monoxide emission (CO)

As seen in Figure 2 increase in the engine load, a CO emission decreases. This is an account of an increase in the cylinder liner temperature with the increase in the load. In diesel+ $FeCl_3$ combinations the CO emission is decreased by about 14% at 100% load as compared with diesel alone. This may be due to the improvement in the combustion process of $FeCl_3$ which enhance the conversion of carbon monoxide to carbon dioxide that reduces the total CO emissions in the exhaust gases [1].

Diesel+DEE15 give a severe reduction in CO emission about 62% lower than that of diesel at 100% load. Due to its low boiling point and viscosity this is recognized to addition of DEE, which results in a better combustion process. In addition, the molecular oxygen in DEE gives a complete oxidation of fuel air mix improving the combustion processes [12].

At 100% load, diesel+DEE15 show 13% reduction in CO emission as compared to diesel + $FeCl_3$.

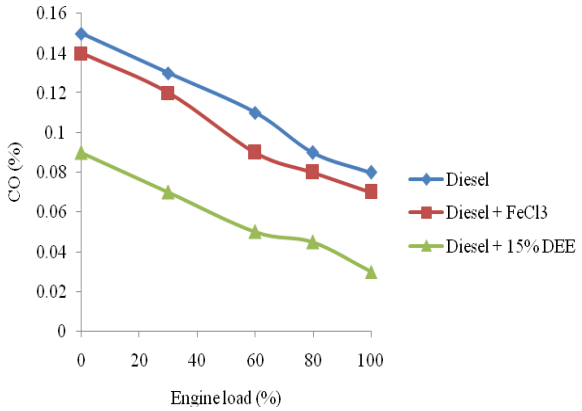


Figure2: Variation of CO emission with engine load.

4.1.2. Carbon dioxide emission (CO_2)

This CO_2 emission has been plotted against the engine load in Figure 3 with the engine being fuelled by diesel and diesel+$FeCl_3$ combinations separately. An increase in the CO_2 emissions has been witnessed when the engine load increases. This is because of a complete combustion of the fuel resulting from increased engine loads. The engine run by a combination of disesl+$FeCl_3$ shows an increase of about 8% CO_2 emissions as compared to diesel. This is because of an enhancement in the conversion of CO and CO_2 due to catalytic effect of $FeCl_3$.

Diesel+DEE15 combination, CO_2 emission was found to be higher about 0.3% than that of diesel at 100% load. Due to the presence of molecular oxygen in DEE gives higher CO_2.

As compared to diesel with ferric chloride, diesel+DEE15 show 5% reduction in CO_2 emission at 100% load.

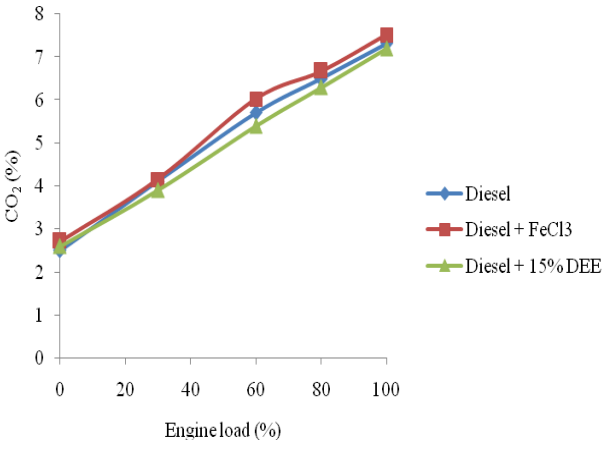


Figure3: Variation of CO_2 emission with engine load.

4.1.3. Hydrocarbon emission (HC)

As presented in Figure 4 the HC contents in the exhaust gasses is a function of the fuel composition. HC emissions are high for diesel and disesl+$FeCl_3$ combinations. At light engine loads posing serious environmental issues. However, with the increase of engine load, a decrease in the HC emissions is witnessed. This is attributed to the rise in the combustion temperature at high engine loads. When $FeCl_3$ + diesel the HC emission is decreased by about 38% at full load compared to diesel.

Diesel+DEE15 combination, HC emission was found to be lower about 42% than that of diesel at 100% load. DEE additions results in a reduction of HC emissions compared to all the tested combinations of fuel as observed from the recorded results. This is attributed to the low boiling point and high cetane number of DEE, which improves the combustion processes and improved oxidation of hydrogen fuel leading to a complete combustion and a consequent reduction in the HC emissions [13].

At full load, Diesel+DEE15 show 3.4% reduction in HC emission as compared to diesel + $FeCl_3$.

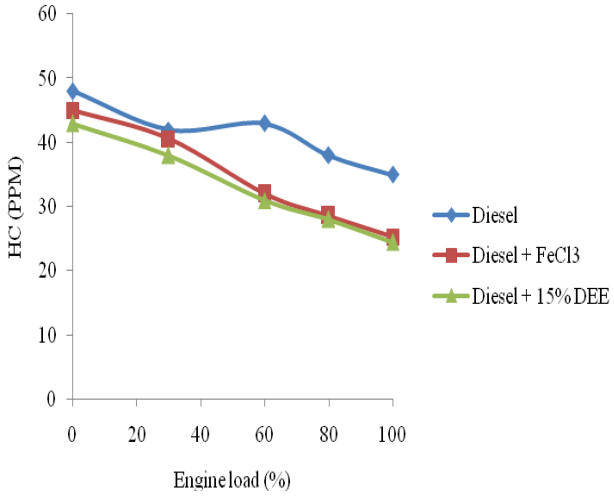


Figure 4: Variation of HC emission with engine load.

4.1.4. Nitrogen oxide emission (NO)

Figure 5 exhibited that the NO emissions increase with an enlarge in the engine loads. This is because of the rise in the in cylinder temperature at high engine loads and that a high temperature is responsible for formation of NO [14]. It is further seen from the figure that addition of $FeCl_3$ results in about 2% increase of NO in the exhaust gases as compared to the diesel. The improved combustion process started by $FeCl_3$ enhances the in-cylinder temperature, as well as the tendency of $FeCl_3$ (catalyst) for oxidizing N_2 into nitric oxides during the process of combustion. These two effects simultaneously increased the NO emission in the exhaust. It is further seen from the figure that addition of $FeCl_3$ results in about 2% increase of NO in the exhaust gases as compared to the diesel. The better combustion process started by $FeCl_3$ enhances the in-cylinder temperature, as well as the tendency of $FeCl_3$ (catalyst) for oxidizing N_2 into nitric oxides during the process of combustion. These two effects simultaneously increased the NO emission in the exhaust.

Diesel+DEE15 combination, NO emission was found to be higher about 35% than that of diesel at higher loads. This can be due to higher cetane number of DEE the combustion advances leading to increase in combustion during premixed stage of combustion [15].

Diesel+DEE15 show 17.82% increased in NO emission as compared to diesel with $FeCl_3$ at 100% load.

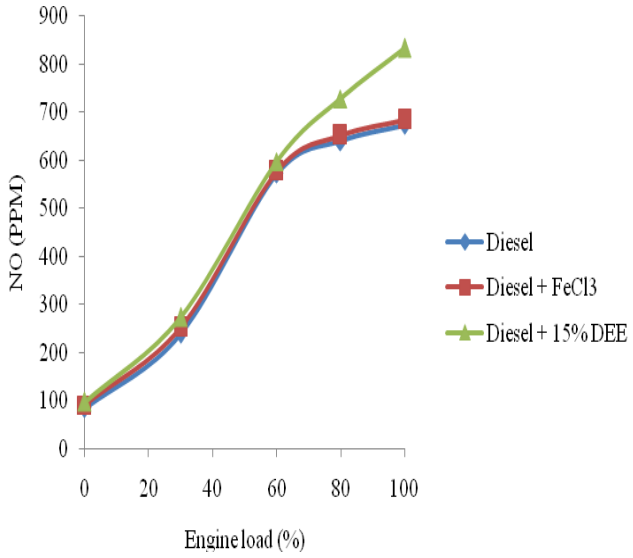


Figure 5: Variation of NO emission with engine load.

4.1.5. Smoke opacity

It may be observed from Figure 6 that an increase in the engine loads an increase the smoke opacity. Evidence from the figure when an oxidation catalyst likes $FeCl_3$ is added to diesel the process of oxidation of the carbon to CO_2 is accelerated and reduction of about 2% in the smoke opacity is observed.

Diesel+DEE15 combination, smoke opacity was found to be lower about 72% than that of diesel at higher engine loads. This may be due to the early start of combustion and high cetane number of DEE that allows more time for the oxidation of soot with available oxygen.

Diesel+DEE15 show 72% reduced in smoke opacity emission as compared to diesel with $FeCl_3$ at 100% load.

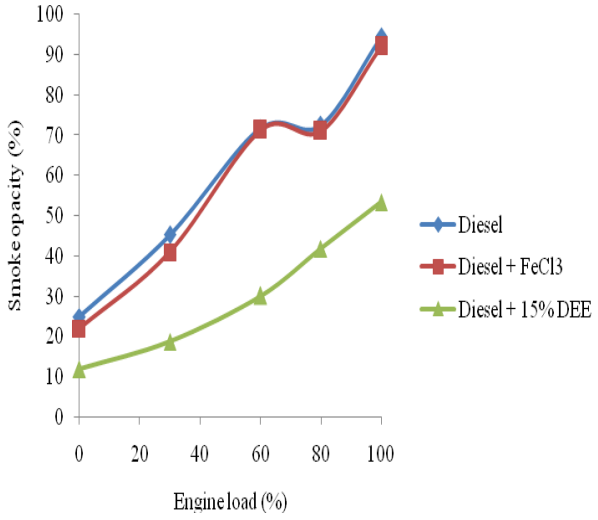


Figure 6: Variation of smoke opacity emission with engine load.

4.1.6. Oxygen emission (O_2)

The variation of oxygen concentration in the exhaust gasses with engine load for diesel and diesel+$FeCl_3$ mix is shown in Figure 3.18. Oxygen emission decreases with increase in engine load. About 5% reduction of oxygen concentration in the exhaust is observed with $FeCl_3$ additions to diesel as compared to the diesel. Oxygen concentration in the exhaust gasses reduces due to the

catalytic action of $FeCl_3$ [1].

Diesel+DEE15 combination, oxygen concentration was found to be lower about 7% than that of diesel at 80% engine load. This may be due to the more utilization of oxygen by the improved combustion with DEE blend.

Diesel+DEE15 show 2% increased in oxygen emission as compared to diesel with $FeCl_3$ at 100% load.

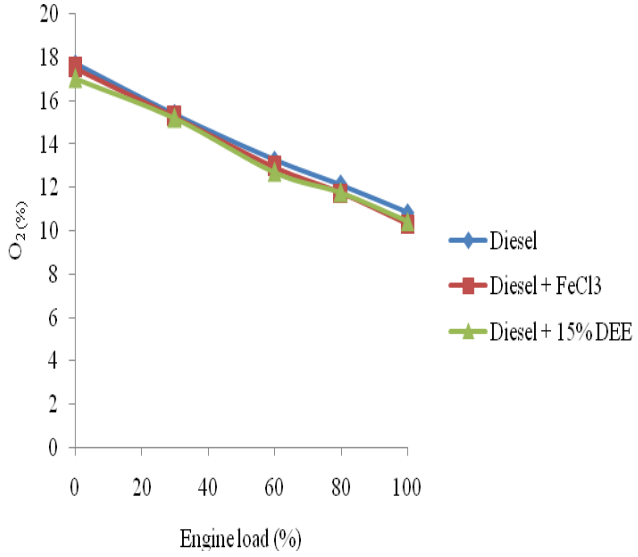


Figure 7: Variation of O_2 emission with engine load.

5. Conclusions

The following conclusions are drawn from the experimental results and their vivid analysis pertaining to the performance of CI engine and the emission characteristics. When the engine is fuelled with diesel and with diesel other additives ($FeCl_3$, and DEE) separately.

- The emissions pertaining to CO, HC, O_2 in exhaust gas decreased and the emissions pertaining to NO, CO_2 increased with diesel + $FeCl_3$.
- Diesel+DEE15 combination has shows the lowest HC and CO emissions compared to all the other combinations. Diesel+DEE15 combinations result in a 35% rise in the NO emissions at 80% engine load as compared to the diesel mode.
- Diesel +DEE15 combination gives very good results concerning reduction of various hazardous emissions from diesel engines.

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