Influence on performance and emission characteristics of diesel engine by introducing medium strength magnetic field in fuel and air lines

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Abstract. Manufacturing In this work, the energy of electromagnet is used to treat the fuel and airline for reducing the fuel consumption and emissions in four-stroke diesel engine. The experiment comprises Internal Combustion (IC) Engine test rig and electromagnets with different intensities (4500, 6000, 8500 and 10000 gauss), are installed along the honeycomb structured mini channel fuel line and air suction line. Experiments are carried out in four-stroke diesel engine test rig for variable engine load by applying medium strength magnetic field on air and fuel supply line. The medium strength magnetic field is used to improve the atomization process effectively, due to that increment in the rate of disintegration of the droplets, as result the viscosity of the fuel decreases. Because of cohesive force between the fuel molecules are affected by the magnetic field and it leads to less surface tension force effect, thus helps to improve atomization process. It is observed that, the impact of magnetic field treatment considerably increased the brake thermal efficiency about 13% and maximum fuel reduction of 11% was obtained for field intensity 10000G and also found that the HC, CO, PM, and NOx emissions are decreased about 10.4%-14.2%, 24–25%, 13%–15%, and 8.4%-11% respectively, but CO2 is increased up to 12.2% because of association of oxygen molecules with CO which is critical point and it can be treated in the catalytic converter.

1. Introduction

As of late, there are such a significant number of endeavours pertaining of better performance and emission limit of engines per unit fuel supply. Bharath Stage (Indian Emission Standards) emission standards are more stringent towards emission norms that demands exhaust treatment and improved performance modification in all relevant aspects in engines. Generally, diesel engine is one of serious plant for generating the pollution over gasoline engine and diesel fuel has much energy density with complex molecular structure [1].

Magnetic field is introduced as external stimuli, which ionizes the fuel as per the theory of magnetic field mutual action. Complex hydrocarbon chain have different critical physical behaviour during atomization process because it has thickly stuffed structures called pseudo compounds, which can additionally compose into groups [2]. Stereochemistry is explained the isomerism of that normal structure para state of hydrogen and useful ortho state by magnetic strength. At the time of combustion para arrangement is not right orient to combine oxygen with hydrogen due to poor penetration of oxygen in air/fuel mixture. Magnetic field strength helps to polarize the hydrocarbons and it converts critical para state into ortho state of hydrogen, due to that favourable isomers was obtained, which
increase space between hydrogen in molecular chain and set platform for interlocking oxygen with hydrogen more[3]. Also it has been likewise noticed that when the fuel goes through a magnetic field, there atomization process improved by affecting surface tension of the fuel why because fluidity (1/µ) improved for mixture formation. Thus, it leads to complete combustion in engines [4].

Some of investigations have assessed the effect of magnetic field on diesel fuels, gasoline for reducing emissions as well as fuel consumption [5] and also trying to predict right optimized operating parameter at higher energy performance. Previous work [6] is reported 22%, 12% and 7% reduction in CO, HC and fuel consumption by pre combustion treatment (5000 gauss magnetic field is applied) and post treatment in gasoline engine. Impact on CO2 emission by introducing magnetic field in four stroke single cylinder engine was captured with catalytic converter which makes clear that after treatment is also needed [6]. Everyone focused on introduction of magnetic field in fuel line pre combustion treatment, however limited work was carried out on airline. Applying effective magnetic field on both fuel and airline are very critical and challenging, because it was seriously affected by air gap in interface.

The objectives of this work are to improve performance and reduce emissions using medium strength magnetic field in a diesel engine by introducing magnetic flux in fuel and air supply line.

2. Experimental setup

2.1. Magnetic Inducer

A magnetic field is introduced in fuel line which has honeycomb structure made by multi mini channel (dia>3mm). The challenge of introducing mini channels is to maintain pressure drop and it is helpful to disperse magnetic field in the fuel line. Airline also connected with magnetic coil which is faced to North Pole, due to that state of orientation is changed from Para state to Ortho state which open to adhere more oxygen with fuel hydrocarbon. So that proper combustion takes place, the surface tension force (cohesive of fuel bunch) also was affected by magnetic field and it leads to better atomization for attain air/fuel mixture. The coil is connected with controlled magnetic field system, for that required power is trapped from the battery and it was connected to regulator which controls the applied magnetic field as per need flux strength (4000–10000 Gauss) [9]. The specification of the diesel engine is shown in the below table 1.

| Specification                  | Details of specification          |
|-------------------------------|----------------------------------|
| Model                         | DAF8                             |
| Make                          | Kirloskar                        |
| Type                          | Four stroke, Water cooled, Diesel|
| No. of cylinder               | 1                                |
| Bore                          | 110 mm                           |
| Rated speed                   | 1800 rpm                         |
| Stroke length                 | 85 mm                            |
| Combustion principle          | Compression Ignition Engine       |
| Maximum Load                  | 11 kg                            |
| Compression ratio 3 port      | 18:1                             |
| Lubrication system            | Forced lubrication               |
2.2. Experimental Procedure

The test runs are conducted in mono cylinder, four stroke water cooled diesel engine arrangements shown in the figure 1 to find the performances and exhaust gas qualities. Engine is coupled with eddy current dynamometer to apply electrical load on engine effectively. pollutants from exhaust stream is measured by using five gas analyzer and results observed are CO, NOx in ppm scale but all others in percentage (%). The experiment loads are swinging between 25% ~100% at rated speed of the above said engine (1800 rpm). Before taking observation results, the engine is warmed up for 30 minutes that was continued with 4 minutes for further every sampling cycle test. At any time, three Particulate Matter (PM) and Polycyclic Aromatic Hydrocarbons (PAHs) tests were gathered during each and every run, it acquires significant result data. The samples are gathered from exhaust for PAH examinations by utilizing isokinetic samples and the values noted cautiously with appropriate trial techniques that are adhered with standard norms. The data acquisition system is collecting all the data’s from various locations in engine and also integrated with gas analyzer. It measures the presence of such gases like HC, CO, NOX and CO2, at every above said load with and without magnetic field.

Figure 1. Photographic view of experimental setup.

3. Results and discussion

The results were observed by normal condition as well as magnetic field applied condition that are interpreted by performance characteristics.

3.1. Influencing of magnetic field on engine performance

The performance of engine is denoted by two parameters i.e. Brake Specific Fuel Consumption (BSFC) and Brake Thermal Efficiency (BTE). The BSFC (g kW⁻¹ h⁻¹) is considered as the fuel burning up per unit mechanical energy generation. In general, when engine load increases BSFC decreases but its value remains same and there are no notable changes in the specific fuel consumption. The BSFC and BTE are calculated based on the equation (1) and equation (2), in which, V indicates the mass of the fuel used in each run (g), P is mechanical work generation in (kW), and t represents the time taken for volume fuel usage, and H indicates the calorific value (kJ g⁻¹) of the diesel fuel.

\[
BSFC = \frac{V}{Pt} \text{ (g kW}^{-1} \text{ h}^{-1})
\]

(1)

\[
BTE = \frac{Pt}{VH} \text{ (%)}
\]

(2)

Equation 3, is used to calculate the total fuel consumption, where Vr is the CC of fuel utilized to produce power, (L) and D is the distance travelled by the vehicle.
Total Fuel consumption = \( \frac{V_r}{D} \) (lt. \ km\(^{-1}\)) \hspace{1cm} (3)

Previous report [10] produced similar result for both BSFC and fuel consumption at 50% loading condition in their work. BSFC is decreased significantly by 11%, while put variation in engine load from 25% to 50%. In case of brake thermal efficiency at superior loads the combustion efficiency will be better in diesel engine due to rise in cylinder temperature, which improves the atomization and evaporation process. Likewise similar experiment study [11] towards BTE was obtained that says BTE increased due to ionization process while increasing the voltage applied on magnetic inducer. Applied magnetic intensity on the fuel and air line is influencing the engine performance and emission characteristics and it is proportional to the rate of atomization. From the figure 2, BTE is increased approximately 13%, when compared to the conditions without and with magnetic fields (8500G) respectively. Hence the mechanical efficiency increased by 14% under part load operation at magnetic strength 10000G.

![Figure 2. Brake thermal efficiency vs brake power for various magnetic intensity.](image)

3.2. Magnetic field impact on Mechanical efficiency
From the below figure 3, it is clear that the mechanical efficiency increases with increase in magnetic field (10000 gauss) applied to the fuel and air line by magnet inducer. In part load operation the mechanical efficiency increased by 6% to 8%, when compare with and without magnetic field, respectively. Previous work [11] reported similar result that mechanical efficiency increases with increase in applied magnetic field due to higher heat release rate by ionization of fuel, it was open to attain effective increase in mechanical efficiency of engine at part load as well as peak load operations, when the intensity of magnetic field is 10000 gauss.
Figure 3. Mechanical efficiency vs brake power for various magnetic intensity.

3.3. Magnetic field influence on Pollutants formation

The emission prediction have done at part load conditions for normal diesel and it was treated by four different magnetic fields of 4500G, 6000G, 8500G and 10000G, and these are tabulated in Table 2.

Table 2. Emission levels at 50% loading condition with different magnetic field.

| Magnetic field (Gauss) | CO (ppm) ±14 | HC (%) | CO₂ (%) | PM (mg Nm⁻³) | NOₓ (ppm) |
|-----------------------|--------------|--------|---------|--------------|-----------|
| 0                     | 2030         | 16.9   | 3.2     | 44           | 350       |
| 4500                  | 2019         | 16.7   | 3.4     | 42.4         | 342       |
| 6000                  | 2001         | 15.8   | 3.65    | 41.7         | 338       |
| 8500                  | 1859         | 14.5   | 3.8     | 39.9         | 335       |
| 10000                 | 1865         | 12.7   | 4.2     | 39           | 330       |

Thus it is clear (from the Table 2) that the effect of magnetic field in the fuel line is used to reduce emission, especially CO is more in engine exhaust due to incomplete combustion [11]. The medium magnetic strength is taking care of significant decrease in the pollutant formation, diesel was treated with 10000 gauss magnetic condition gives a better result in CO emission is 1865 ppm which is reduced by 25% (from the figure 4) at part load condition with respect to applied magnetic strength.

Figure 4. CO Vs. brake power for various magnetic intensity.
HC emission at part load condition is noted for diesel engine with and without magnetic field. It was emitted due to incomplete combustion of fuel and causes of line fault or storage tank, so minor escape through leak and evaporation [12]. At full load condition, the amount of HC emissions are found to be 16.7% for diesel under normal conditions, when magnetic field is introduced in fuel and air line corresponding HC values are approximately decreased by 10.4%–14.2% at 10000 gauss. The experiment clearly shows that the increase in magnetic field reduces the HC emission significantly when compared to normal operating condition.

![Figure 5. HC vs brake power for various magnetic intensity.](image)

The figure 6 shows the variation of CO$_2$ emission with respect to different engine power is critical which not affected by magnetic field. The CO$_2$ emissions are directly proportional to the quantity of fuel consumed by the engine and it is increased under all operating conditions [13]. At full load condition it was reached maximum 12.2% which is treated by post treatment process (by catalytic converter).

![Figure 6. CO$_2$ vs brake power for various magnetic intensity.](image)

The mechanism of NOx formation demands higher cylinder temperature, at no load and part loads condition, the NOx emission was less due to low consumption of fuel and slightly reduced in cylinder temperature [14-15]. From the figure 7, it is getting increased at peak loads due to higher combustion temperature, the amount of NOx emissions are 350 ppm, 330 ppm for diesel with and without magnetic field, respectively. NOx emission is reduced based on over period of running time are decreased by 8.4%, 11.6% for 8500 gauss and 10000 gauss respectively.
Particulate matters (PM) are formed due to incomplete combustion of fuel in combustion chamber and presents of impurities in both fuel and air, as result shoot formation takes place. It was noted in the below figure 8, that significant reduction in PM shows efficient combustion achieved in combustion chamber. PM reduction (13% ~ 15%) was found in medium strength magnetic field 8500 gauss and maximum reduction in 10000gauss strength.

4. Conclusions
Introducing a magnetic field in the fuel and airline brought about a decrease in BSFC by 11%, while the BTE is enhanced by approximately 13%. In view of emitted pollutant reduction in percentage, the HC, CO, PM, and NOx emissions are decreased about 10.4%-14.2%, 24–25%, 13%–15%, and 8.4%-11% respectively. CO2 emission is increased by 12.2% due to association of oxygen with CO and forms CO2. Particulate matters are encounter by filter and the presents were reduced by 15% at part load with the magnetic field inducer.

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