Experimental Investigation on Magnetic Conditioning of Diesel to enhance the Performance and Emissions of DI Diesel engine

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Abstract. The aim of the current research presents an experimental work for the insertion of Neodymium N52 grade permanent magnets with various Gauss intensity (6000, 8000, 10,000 and 12,000), fixed on fuel line before the fuel injector of single cylinder 4-stroke diesel engine to find its performance, and emissions. By the insertion of permanent magnets, the diesel atomizes into tiny droplets due to de-clustering the hydrocarbon molecules. Which makes the fuel actively, mixes with the oxygen, cause complete combustion inside the engine cylinder. The experimental results showed that with the application of magnets on fuel lines an improvement in performance, combustion and exhaust emissions. The experimental results with magnetic fuel conditioning shown that brake thermal efficiency increases 7.2%, where as the brake specific fuel consumption decreases between (9.6 - 19.3) %, the higher value of 19.3% reduction rate was found in 12,000 Gauss field intensity. The emissions of Carbon monoxide and Hydrocarbons were reduced by 13.33%, 15% respectively. The overall engine performance, combustion and emissions with the magnetic fuel conditioning were improved.

1. Introduction

The conventional hydrocarbon fuel releases natural carbon particles which clog the fuel injector, resulting lower efficiency and wastage of fuel. Majority of internal combustion engines are working with liquid fuels, they do not participate in chemical reaction until they are vaporized and mixes with the air. The exhaust emissions of all IC engines contains of CO, CO₂, UBHC and nitrogen oxides. These harmful gases react with atmosphere air and forms smog. All the conventional fuels are compounds of hydrocarbon molecules. With installation of magnets on fuel lines the hydrocarbon molecules are ionized and realigned [1, 2]. One of the consistent strategies, which tend to increase the performance, combustion and decrease the emissions is magnetization method [3, 4]. Most of the fuels for Internal Combustion Engines are liquid fuel, these liquid fuel when undergo the vaporization and mixes thoroughly with air will participate in the combustion and heat energy releases in the combustion chamber [5, 6].
Diesel is a combination of hydrogen and carbon molecules. They form pseudo compounds due to various attractive forces which can combine into groups [7]. The molecular structure is comparatively constant throughout; in air-fuel blending method oxygen is not mixed properly which leads to improper combustion of diesel and results in creation of carbon emissions pumped into atmosphere [8]. It was established that diesel is ionized when subjected to magnetic field. The magnetic conditioning allows fast mixing with the oxygen and leads to complete combustion fuel [9, 10]. In addition, the magnetic treatment permits the tough bonding with the oxidizing medium that suggest further complete and best potential combustion of the hydrocarbons [11, 12]. The effect of magnetic conditioning diesel promotes better burning of fuel as a result improved brake power and decreased consumption of fuel. Further effect is improved combustion and decreased exhaust emissions of carbon particulate, CO and UBHC [13].

The improper oxidization of carbon molecules forms HC and Carbon monoxide are deposited on the walls of the engine cylinder as black carbon residue [14][15]. Deshmukh [16] investigated the magnetic fuel treatment to increase the performance and exhaust emission, and observed that the permanent magnet field intensity on the fuel line increases the properties of fuel. Chaware [17] broadly examined the ionization effect and reported the influence of magnetic conditioning on fuel properties. Rashid [18], observed the influence of magnetic conditioning on unleaded gasoline, reported that the result of magnetic field on Carbon monoxide was the mainly significant at majority of engine's loads. In the present study, focus is on magnetic treatment method that results the improvement in performance, and emission reduction in diesel engine application.

2. Magnetic devices
In the present investigation four permanent Neodymium (N52) magnets with various gauss intensities are (6000, 8000, 10,000, 12,000) used. Figure 1 represents the location of the magnetic device on the engine and Figure 2 shows experimental set up. The magnets are simply fixed on the fuel pipe in between fuel pump and fuel injection system. In fact, arrangement of the magnets over a metal pipe permits all the magnetic intensity penetrates through the metal as a result it gives improved performance and combustion. Further, the complete arrangement was made by wrapping with rope completely around the magnets that creates enough magnetic fields to have an effect on flowing-by diesel.

![Figure 1](image1.png)
**Figure 1.** Location of Magnet over fuel supply Setup line in the engine.

![Figure 2](image2.png)
**Figure 2.** Experimental
2.1 Experimental setup and procedure
Four stroke, single cylinder Kirloskar TV1 DI diesel engine with eddy current dynamometer was used for performance, combustion & emissions testing. The engine specifications are presented in Table 1.

| Model and Make | Engine Test Rig setup Apex |
|----------------|-----------------------------|
| Engine Type    | Kirloskar TV1 Engine        |
| Cylinders      | Single                      |
| Type of Cooling| Water cooled,               |
| Capacity of the Engine | 5.2 KW @ 1500 rpm,         |
| Cylinder Diameter | 87.5 mm                    |
| Stroke Length  | 110 mm                      |
| Compression ratio | 17.5                      |
| Variation of Fuel Injection | 0- 25 ° BTDC               |
| Type of Dynamometer | Eddy current Dynamometer   |
| Range of Piezo sensor | 5000 PSI                   |
| Device for Data acquisition | NI USB-6210, 16-bit, 250kS/s |
| Sensor used for Crank angle | TDC pulse with 1500 r.p.m |
| Type of Temperature sensor | K type thermocouple, |

An eddy current dynamometer was attached with the engine output shaft for generating loads. In-cylinder pressure variations were recorded by pressure transducer fixed on the piston head and charge encoder for every crank angle degree (C.A.D). From Lab View software the experimental data will obtain directly. Analog data from Resistance temperature detector (RTD) thermocouple was measured by NI-USB Data acquisition. The diesel flow rate was recorded by using glass burette and the necessary air flow was measured by using orifice air flow meter. The engine exhaust gas was analyzed by using infrared five gas analyzer and smoke meter. The exhaust gases were sent to the gas analyzer directly from the exhaust pipe. Figure 2 shows the experimental layout.

The experiments were conducted at a constant speed of 1500 rpm with 17.5 compression ratio. Initial load condition begins with no load and an increment of 3kg with a maximum load of 14 kg. The magnetic fuel device was fixed in between the fuel pump and fuel injector. The diesel passed through the fuel line oriented at 90° with the magnet assembly. The procedure was repeated for various loads and performance graphs were obtained for conventional and ionized diesel. Meanwhile, pressure transducers displayed the reading of Indicated Mean Effective Pressure with a change in crank angle which was shown and plotted on Lab View. The engine exhaust gas was flown from constant volume gas calorimeter with temperature transducers and variation in the temperature of the magnetized diesel was recorded. Exhaust gas samples of normal diesel and ionized diesel were then passed through exhaust gas analyzer and the readings of NOX, CO, CO2, UBHC were examined.

3. Result and discussion
3.1 Effect of magnetic intensity on brake thermal efficiency: Figures 3 illustrate the variation of brake thermal efficiency with brake power at various magnetic intensities. As per the graph, brake thermal efficiency changes with change in brake power. It was noticed that magnetized fuel reports slightly more thermal efficiency when compared with normal diesel. The 12,000 Gauss magnetic field intensities reports 7.2 % higher brake thermal efficiency than the diesel. The magnetic conditioning of fuel influenced the combustion quality hence the improvement in brake thermal efficiency is observed.

3.2 Effect of magnetic intensity on Brake Specific Fuel Consumption: Figure 4 represents the comparison of brake specific fuel consumption (BSFC) with the brake power. All magnetic field intensities and diesel experimented, BSFC decreased with increase in brake power. The
magnetized diesel found lower BSFC than normal diesel. The magnetic intensity of 12,000 Gauss has least value BSFC at 3/4th full load, which is 19.67% in comparison with normal diesel.

3.3 **Effect of magnetic field on in-cylinder pressure:** The experimental result reported that by the magnetic treatment of diesel at inlet, cylinder pressure and temperature are reduced compared to diesel as shown in the Figure 5 & Figure 6. The reasons for these changes of pressure and temperature are hydrogen reacts with oxygen and forms water vapor. The magnetic treated diesel splits the hydrocarbon structure, causes reduction in its surface tension and density; therefore, tiny molecules are injected into the combustion chamber. The improved properties produce better integration of diesel with air in the engine cylinder and improve the oxidation.

3.4 **Effect of magnetic field on Mass fraction:** The variation of percentages of mass fraction burn with crank angle of various magnetic intensities and without magnetic treatment is shown in the Figure 7. Mass Fraction Burn increases with the increase of crank angle all the magnetic intensities follow the same trend. For the 10000 Gauss intensity the mass fraction percentage is less when compared to normal diesel engine.

3.5 **Effect of magnetic field on Cumulative Heat Release:** The variation of heat release rate for different magnetic intensities under varying brake power is shown in Figure 8. The heat release rate generally relay up on ignition delay and injection timings. At 3/4th load condition, the heat release rate is higher for 12,000 Gauss magnetic intensity than for the diesel without magnetic treatment. This is due to the complete combustion of magnetic conditioned diesel which creates micro explosions, due to which the ignition delay is reduced and higher heat is released.

3.6 **Effect of magnetic field on Unburned Hydrocarbons:** Hydrocarbon emissions of the various magnetic conditioned fuels are less than the conventional fuel due to the improved chemical reactions. It is noticed that with improvement in magnetic field intensities the hydrocarbon emissions are reduced accordingly. Figure 9 shows that the magnetic field intensity 12,000 Gauss has 15.73 % lower hydrocarbon emissions than the normal diesel engine.

3.7 **Effect of magnetic field on Carbone Mon oxide:** The main reason for production of CO is due to the lack of adequate oxygen. Figure 10 presents the comparison of CO with the change in brake power. It is noticed that carbon monoxide enhance with enhance with engine load, due to increase in high rate of dissociation reaction. From the results it is noticed that 12,000 Gauss intensity projects 19.8% less CO production than diesel.

3.8 **Effect of magnetic field on Nitrogen Oxides:** Figure 11 represents the comparison of NOx emissions at various brake power. The engine releases the oxides to atmosphere are the mixture of oxides and dioxides of nitrogen. Nitrogen reacts with oxygen at high temperature and produces the NOx. Hence high temperature and adequate oxygen are the main factors for creation of NOx. It is observed that 12,000 Gauss magnetic intensity produces 12.4 % higher than normal diesel engine.

3.9 **Effect of magnetic field on Smoke Opacity:** Figure 12 presents the comparison of smoke density with various brake power. The quantity of soot produced relay upon the fuel type and quality of combustion. By adopting magnetic treatment of fuel the combustion is effective and produces lower smoke to the environment which is visible. It is observed from the figure that smoke opacity is 8.23% lower for the 12,000 Gauss magnetic intensity when compared with the normal diesel engine.
Figure 3. Comparison of brake thermal efficiency with various magnetic intensities

Figure 4. Comparison of bsfc with various magnetic intensities

Figure 5. Comparison of Cylinder pressure with various magnetic intensities
Figure 6. Comparison of Mean gas temperature with various magnetic intensities

Figure 7. Comparison mass fraction burned (%) with various magnetic intensities

Figure 8. Comparison of with cumulative heat release (KJ) various magnetic intensities
Figure 9. Comparison of Net heat release (J/deg) with various magnetic intensities

Figure 10. Comparison of Carbon monoxide with various magnetic intensities

Figure 11. Comparison of Nitrogen Oxides with various magnetic intensities
4. Conclusions
Experiments for performance, combustion and exhaust emissions are performed on diesel engine with a compression ratio of 17.5. The conclusions are drawn based on the experiments conducted by using permanent Neodymium N52 magnet with field intensities 6000, 8,000, 10,000 and 12,000 Gauss that is fixed on fuel line before the fuel injector. The results are compared with diesel without magnetic conditioning at ¾ load. There was nearly about 9.67% -19.3% decreases in BSFC and with about 7.2% improvement in brake thermal efficiency. The peak pressure was reduced about 8.69 % and mean gas temperatures were decreased. There was an increase of12.4% in Nitrogen Oxides and 15.07% of carbon dioxide with both carbon monoxide and Un-burnt Hydrocarbon lowering about 13.33% and 15.73% respectively. Ultimately, it is understood that there is a decrease in engine emissions exclude for Nitrogen Oxide and observed that BTE increases and BSFC decreases. The advantages of magnetic treated fuel are noteworthy since the results show that replacement of the diesel fuel with magnetic conditioned can be able with slight or no harmful effect. In addition, it is service free and one-time insertions which will improve the brake thermal efficiency of the engine as well as saves harmful exhaust gases.

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