Experimental Investigation of a Magnetic Fuel Ionization method in a DI Diesel Engine to Improve the Performance and Emissions

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Abstract: The increase in usage of the automobiles day by day releases a huge amount of exhaust emissions such as HC, CO, CO2 and NOx etc. All these pollutants in exhaust emissions mainly depend on combustion phenomena which occur in engine cylinder. The effect of incomplete combustion releases a large amount of exhaust emissions as well as low brake thermal efficiency. To address these problems a novel method of magnetic fuel ionization method is adopted to condition the fuel. In the present investigation the experiments were conducted by using permanent Neodymium N52 magnet with field intensity 12,000 Gauss (1.2 Tesla) of Mono pole and Dipole that are fixed on fuel intake manifold before the fuel injector. This magnet creates a powerful magnetic field thereby the hydrocarbons changes their orientation. Due to this the molecules interlocked with the oxygen during combustion process and produces better combustion in the engine cylinder. The enhanced combustion causes to increase in the Combustion and reduction in poisonous gases from the engine.

1. Introduction
The deficiency of conventional diesel fuel and huge exhaust emissions from diesel engines inspired the researchers and engine manufacturers to innovate various techniques to address the fuel utilization and can lower the engine emissions. One of these techniques is ionizing the hydrogen molecules in the fuel to create the homogenous mixture and fine spray of fuel in injection by adopting high intensity of magnetic field. Normally fuels for motor vehicles are compound molecules, such molecules are not properly aligned so the diesel molecules do not inter locked effectively with the oxygen atoms at the time reaction. Therefore, the hydrocarbons present in the fuel must be realigned through the magnetic ionization technique to improve the molecular excitement and turbulence.

The basic principle of magnetic ionization technique is creating high magnetic field intensity which interacts with the hydrocarbons present in the diesel with oxygen. All the fuels mainly consist of hydro-carbons. Due to the various attractive forces of organic chemical compounds these form closely packed structures known as pseudo hydrocarbon compounds. During the air/fuel mixing process these structures are relatively stable, so it is not possible to penetrate into the interior of oxygen atoms. The entry of suitable amounts of oxygen in to the core of these groups is therefore delayed [1]. This leads to improper combustion of diesel fuel and causes the formation of more exhaust emissions. Due to the high magnetic field, hydrocarbons which are present in the diesel de-cluster and attain more contact area, to react with oxygen [2]. According to Vander wall’s hypothesis weak molecular forces of hydrogen molecules cannot have a strong bond with oxygen. If the oxygen have a strong bond with hydrogen then the combustion rate can be enhanced due to this there is a reduction in consumption of fuel and improvement in brake thermal efficiency[3],[4].

The advantage of polarity is that it creates the dipoles of the magnet which influence under huge magnetic intensities. This leads in improved brake thermal efficiency as well as less consumption of fuel [5]. The status of free association, directional order of and perfectly aligned hydrocarbons in the fuel is noticed after the ionization. This type of hydrocarbon molecules reacts very rapidly with oxygen molecules causing better combustion [6][7]. The contact of oxygen in the correct quantity to
the inner groups of particles is hindered and this deficiency oxygen to the group that delays the complete combustion [8]. Hydrocarbon molecules conditioned with the magnetic ionization method lean to de-cluster, developing smaller molecules readily penetrated with oxygen which leading to improved combustion [9]. The performance and exhaust emissions of a single cylinder 4-stroke VCR petrol engine was examined under varying ignition timing between 5 degree and 30 degree before Top dead centre in steps of 5 degrees [10]. The engine performance and exhaust emissions of a single cylinder 4-stroke diesel engine were examined with NdFeB magnets of 6000G coated with Ni-Cu-Ni. Air fuel ratio was observed to change from 31.38 to 33.8 with a noticeable enhancement [11]. To study the influence of magnetic fuel conditioning on the performance of combustion engines, gasoline, diesel and natural gas were tested in two different engines with different configurations under the magnetic field. Their analysis ended that the highest effect of magnetisation was on gasoline fuel compared to the other two fuels [12]. The effect on diesel generator performance and emissions with magnetic tube installation on the fuel intake manifold was studied [13]. Khurji examined the effect on a single cylinder, 4-stroke diesel engine with permanent magnets fixed before the fuel pump. Brake specific fuel consumption was lowered due to decreased surface tension of diesel and also noticed the emissions decreased significantly [14].

2. Magnetic device
Three Neodymium N52 permanent magnets with field intensity 12,000 Gauss device is used in the present research work. These magnets were fixed on fuel intake manifolds; Figure 1 shows the arrangement of magnets. The major difference between monopole and dipole magnets arrangement is in the monopolar magnets there is no magnetic wave transmission from north to south but the magnetic intensity exists as field. In the dipole the field moves north to south visa-versa. The intensity place a role in agitating the molecules of any particle or flow kept across the field.

2.1 Experimental Test Rig.
The experimental test rig consists of 4-stroke single cylinder water cooled DI diesel engine with fixed compression ratio coupled to dynamometer with a bore of 87.5mm and stroke of 110mm was used for performance, combustion and emissions testing. Complete engine specifications of the DI diesel engine is given in Table 1.

| Model and Make               | Engine Test Rig setup Apex          |
|------------------------------|-------------------------------------|
| Engine Type                  | Kirloskar TV1 Engine                |
| Number of Cylinders          | Single cylinder, 4-Stroke           |
| Type of Cooling              | Water cooled,                       |
| Capacity of the Engine       | 5.2 KW @ 1500 rpm,                 |
| Diameter of Cylinder         | 87.5 mm                             |
| Length of Stroke             | 110 mm                              |
| Compression ratio            | 17.5                                |
| Variation of Fuel Injection  | 0- 25° BTDC                        |
An eddy current dynamometer was attached with the diesel engine output shaft for generating loads. In-cylinder pressure variations were recorded with piezoelectric pressure transducer fixed on the head of the piston and charge encoder for every crank angle degree (C.A.D). Lab View software obtained the in-cylinder pressure data as a direct measurement of crank angle and net heat release rate and indicated mean effective pressure (IMEP). 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 exhaust emissions were analyzed by five gas analyzer and smoke meter. The exhaust gases were sent to the gas analyzer directly from the exhaust pipe. The Figure.2 shows the schematic diagram of the experimental test rig. The experiments were conducted at a constant engine speed of 1500rpm with a compression ratio of 17.5. Initial load condition begins with no load and an increment of 3kg with a maximum load of 15 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 same procedure was repeated for different loads and performance graphs of brake specific fuel consumption, and brake thermal efficiency were obtained for conventional and ionized fuel. 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.

| Type of Dynamometer          | Eddy current Dynamometer |
|------------------------------|--------------------------|
| Range of Piezo sensor        | Range 5000 PSI, with low noise cable |
| Device for Data acquisition  | NI USB-6210, 16-bit, 250kS/s |
| Sensor used for Crank angle  | Resolution 1 Deg, Speed 5500 r.p.m with TDC pulse |
| Type of Temperature sensor   | RTD, PT100 and Thermocouple, Type K |

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 oxides of nitrogen, Carbon Monoxide, carbon dioxide, Un-burnt hydrocarbon were examined.
3. Results and discussion

3.1 Effect of Magnetic treatment on diesel consumption
The comparison of brake specific fuel consumption with the variation in brake power is shown in Figure 4. For magnetic field intensity 12,000 Gauss with mono pole as well as dipole and diesel was tested. It is observed from the graph that for the magnetic conditioned diesel fuel, the consumption of fuel values were lower than that of unconditioned diesel fuel at various brake powers. It is noticed that brake specific fuel consumption is 19.3% lower in dipole magnetic field intensity 12,000 Gauss (1.2 Tesla) when compared with unconditioned fuel and its value is 0.25 Kg/Kw.hr at 75% of load.

3.2 Effect of Magnetic treatment of diesel on brake thermal efficiency
The Figure 5 illustrates the comparison of brake thermal efficiency (BTE) with the variation in brake power. It is noticed that the brake thermal efficiency increases with an increase in brake power for all the cases. The magnetized diesel fuel shows higher brake thermal efficiency at all the brake powers when compared with the untreated diesel. The dipole magnetic field intensity with 12,000 Gauss (1.2 Tesla) has 7.2 % higher brake thermal efficiency at ¾ load, when compared with untreated diesel. The quality of combustion and the increase in net heat release influences the brake thermal efficiency which is achieved by conditioning of the fuel with magnets.

3.3 Effect of Magnetic ionization of diesel on in cylinder Pressure
The experimental test reports that by the magnetic treatment of fuel with 12,000 Gauss (1.2 Tesla) dipole on in-cylinder pressure and temperature was lowered than diesel without magnetic conditioning as shown in the Figure 6 & Figure 7. The reasons for these changes of pressure and temperature in a normal working diesel engine under the ideal combustion circumstances, hydrocarbon molecules would interact with oxygen to form water vapor and carbon dioxide. The magnetic treated diesel breaks the hydrocarbon chains, which effects in a lower it’s surface tension and density; therefore, tiny diesel droplets are injected during injection time within the combustion chamber. The above properties produce better air fuel mixing in the engine combustion chamber and improve the oxidation. With adopting these properties, the ignition delay period is lowered as a result of this, the fuel is completely burned and develops a smoother engine output results decrease in-cylinder pressure and temperature. These reports of the decreased pressure and temperature supports the results attained from literature [15].

3.4 Effect of magnetic ionization on Cumulative Heat Release
The comparison of cumulative heat release and net heat release under varying brake power is shown in Figure 8 and Figure 9. The heat release rate generally relay up on ignition delay and injection timings. Magnetic conditioned fuel breaks the hydrocarbon chains which effects the properties of diesel, hence produce better air fuel mixing in the engine combustion chamber, improve the oxidation and decreases the ignition delay period as a result of this the fuel completely burned and evolves more heat. At ¾th load condition, the heat release rate is higher for 12,000 Gauss magnetic intensity of dipole magnets 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 period is decreased and higher heat is released.

3.5 Effect of magnetic ionization on Unburned Hydrocarbons
The variation of hydrocarbon emissions with brake power is shown in the Figure 10. The hydrocarbon emissions are increasing with increase in brake power for all the cases. The hydrocarbon emissions mainly depend up the combustion process. It is observed that the magnetic field intensity 12,000 Gauss (1.2 Tesla) of dipole magnetic conditioned fuel has 15.73 % lower hydrocarbon emissions than the unconditioned fuel. This is due to the complete combustion of magnetized fuel.
3.6 Effect of magnetic field on Carbon monoxide
The main reason for carbon monoxide formation is due to the insufficient oxygen available at the time of combustion. Figure 11 shows the comparison of Carbon monoxide with the brake power. It is observed that carbon-monoxide increase with increase of engine load, due to high combustion temperature and the related improvement in the dissociation rate of chemical reaction. From the graph it is understood that 12,000 Gauss with dipole magnetic treatment of fuel has 13.3% lower Carbon monoxide emission than unconditioned diesel at ¾ load.

3.7 Influence of magnetic treatment on Nitrogen Oxides
The comparison of Nitrogen Oxides with brake power is shown in Figure 12. At high temperatures Nitrogen reacts with oxygen and forms oxides of Nitrogen. Magnetic conditioning of diesel fuel improves the combustion process. Due to the high temperatures and availability of oxygen there is high formation of NOx in the exhaust gases form the engine. It is observed that 12,000 Gauss magnetic intensity of dipole magnetic treated fuel produces 12.4 % higher nitrogen oxide than normal diesel engine.

3.8 Effect of magnetic field on Smoke Density
The comparison of smoke density with brake power is shown in the Figure 13. The soot formed in the exhaust emissions mainly depends upon percentage of fuel mixed with air and fuel type. If the formed soot is not burned completely in combustion cycle, it will pass through the exhaust gases. It is observed from the figure that smoke opacity is 8.2% lower for the 12,000 Gauss magnetic intensity of dipole conditioned fuel when compared with the normal diesel engine.
Figure 5: Comparison of brake thermal efficiency with brake power

Figure 6: Comparison of Peak pressure with various crank angles

Figure 7: Comparison of Mean gas temperature with various crank angles

Figure 8: Comparison of cumulative heat release (KJ) with crank angles
Figure 9: Comparison of Net heat release (J/deg) with crank angles

Figure 10: Comparison of Unburned Hydrocarbons with brake power

Figure 11: Comparison of Carbon monoxide with magnetic intensities
4. Conclusions
The following conclusions have been drawn based on the experiments conducted on 4-stroke single cylinder DI diesel engine by using permanent Neodymium N52 magnet with field intensity 12,000 Gauss (1.2 Tesla) of Mono pole and Dipole that are fixed on fuel intake manifold before the fuel injector. The experiments with magnetic treatment of the fuel lowers the in cylinder pressure and brake specific fuel consumption. Exhaust emissions of carbon monoxide, unburned hydrocarbons and smoke density with magnetic condition are decreased with up to 13.3, 15.73 and 8.2% where as brake thermal efficiency and Nitrogen oxides increased with up to 7.2 and 12.4% compared to normal diesel engine. During the magnetic conditioning the right combustion is achieved. Hence it is concluded that the magnetic conditioning of diesel improves the combustion and performance of CI engine by changing the hydrocarbon molecules orientation.
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