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Study on Effects of Magnetization of Fuel on Diesel Engine

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Abstract
Of an internal combustion engine. Many advancements have been made on the conventional internal combustion engine to reduce emission and increase the performance. Fuel magnetization is one of the new technologies used in internal combustion engines for reducing emission and improving performance. In this experimental study, the effect of strength and location of magnetization is compared by using an electromagnet as the fuel magnetizer. Density, kinematic viscosity, dynamic viscosity, flash and fire point of both normal and magnetized fuel have been measured and compared. Significant change in all these measured quantities was visible.
Experiments have been conducted for finding the thermal efficiency and smoke emission of vertical single cylinder diesel engine by changing the location (10cm, 20cm and 30cm away from injector) and strength (0.3T, 0.6T and 0.9T) of electromagnet. The magnetized fuel shows better results than normal diesel.

Keywords: Electromagnetic fuel magnetizer, Diesel Engine, Smoke emission

Introduction
Internal combustion engines have a major role in the power production. The usage of internal combustion engines ranges from small engines used for hand tools to very large engines used in marine transportation. The most common fuels used in internal combustion engines are gasoline and diesel. Both of these fuels are hydrocarbon fuels and are refined and separated by distillation of crude oil.
Internal combustion engines such as spark ignition and compression ignition engines are a major source of air pollution. The internal combustion engine exhaust gases include carbon monoxide (CO), oxides of nitrogen (nitric oxide - NO and small amount of nitrogendioxide – NO_2. together known as NO_x), unburned hydrocarbons (HC) and particulate matter (PM).Out of those particulate matter (PM), oxides of nitrogen (NO_x) and unburned hydrocarbon (HC) are of main importance in compression ignition engine. Carbon monoxide (CO) is not of high relevance in compression ignition engine exhaust emissions, because of the lean fuel-air mixture operation of diesel engine[1].

The combustion of hydrocarbon fuel causes the problems such as incomplete combustion, high carbon deposition and high emission level. Internal combustion engine fuels are compounds of molecules. Everymolecules contains a large number of protons, neutrons and electrons. Magnetic property (Ortho and Para) already exist in these molecules, thus it already have positive and negative electrical charges. However these molecules are in a cluster state called associations. The Internal combustion engine fuel is not completely reacted with oxygen in the course of combustion, due to the cluster state of the hydrocarbon molecules. The fuel particles or hydrocarbon clusters must be de-clustered and aligned in order to give better combustion. The alignment can be achieved by the application of magnetic field in the fuel line. This will also help in reducing the carbon settlement in carburetor, manifolds, combustion chamber and fuel injector, thus the engine can be kept clean.
Hydrocarbons are the principal constituents of the diesel fuel. In these hydrocarbons, hydrogen will be contributing only small quantity of molecular weight. Even though the energy produced by hydrogen during combustion is more than that produced by carbon. Hydrogen exists in two different forms-Ortho and Para.Para-hydrogen molecule occur in even rotation levels. The rotation of one particle in respect to another is in inverse course, thus it displays diamagnetic behavior. Ortho-hydrogen molecule occur in odd rotation levels. The rotation of one particle with respect to another is in same course, thus it displays paramagnetic behavior. Paramagnetic behavior of hydrogen atom catalyst many reactions, that is ortho-hydrogen is more reactive than para-hydrogen.
When hydrocarbon fuel is combusted, firstly oxidation of hydrogen atoms will takes place. Then carbon atoms are burned. Since the time taken for the oxidization of hydrogen atoms in the combustion process of internal combustion engine is less than that of carbon particle oxidization, in typical conditions a portion of the carbon will be just incompletely oxidized, this is a reason for the incomplete combustion of fuel. Oxygen bonds with hydrogen faster and is more energetic than oxygen bonds. When internal combustion engine fuel flows through a strong magnetic field with sufficient flux density, hydrocarbon molecules change their alignment from its para-hydrogen form to the more active, more unstableortho-hydrogen form. Thus helps in better

atomization of the fuel and draws additional oxygen fuel bonding. Physical properties of the fuel such as viscosity, density and conductivity may also change. This will result in better reaction of fuel particle with oxygen, making the combustion process more complete. This results in higher fuel efficiency, and reduced engine emissions.

Now a days many ways are established to reduce internal combustion engine emissions. One of the recent studies being conducted on the topic of reduction of exhaust emission and improvement of combustion in internal combustion engines by using magnetized fuel. Fuel magnetizer changes the internal energy of the fuel to undergo changes to the molecular structure which helps in easier combustion. This will result in better reaction of fuel particle with oxygen, making the combustion process more complete, thus it attainsmore engine output, higher fuel efficiency, increased power&reduction in the quantity of CO, HC, NO_x in the exhaust & therefore control the emission at low cost[2]. Usage of fuel magnetizer made with permanent magnet shows eye catching results in the reduction of HC emission in petrol engines. Usage of permanent magnet with different intensity gives different trend in HC and CO emissions [3]. By the application of magnetic field, the viscosity of hydrocarbon fluid diminishes if the fluid is flowing. Breakage of cluster hydrocarbon molecules in the fuel wasdetectedcausing better atomization of the fuel, better intercourse of the fuel with air, reduced quantity of unburned fuel and thus improving the thermal efficiency of the internal combustion engine[4]. With the implementation of a magnetizer along with a catalytic convertor all the emissions (CO, HC and NO_x) can be reduced to a large extend when used in a diesel engine [5]. An experiment conducted to improve the combustion efficiency of internal combustion engines by adopting a magnetic fuel ionization method, by which the fuel is ionized with a magnetic field produced by a high power magnet revealed that the thermal efficiency of the internal combustion engine is increased by2% and the emission levels reduced by5% due to better atomization and complete combustion [6]. Another study has conducted on the effect of fuel magnetizer in internal combustion engines and compared it with the effect and other parameters (life, economy, vehicle power and light off temperature) of the catalytic converter. The result was, by the implementation of fuel magnetizer in internal combustion engine the engine provides highest energy per litre of fuel and least toxic engine exhaust emissions. Thus fuel consumption and exhaust emission decreases [7].

All the above studies shows that with the usage of fuel magnetizer gives better fuel efficiency and reduced emission. Fuel can be magnetized by using either an electromagnet or a permanent magnet. Much effort were not taken to study the effect of position and strength of the fuel magnetizer in the internal combustion engine. So it is necessary to study the effect of position and strength of the magnetizer in the internal combustion engines. This work is the study on the performance and smoke emission of a single cylinder diesel engine by changing the position and strength of the electromagnet which act as a fuel magnetizer.

Methods of Magnetization

Fuel magnetization can be done by different methods. Position, strength, and type of the magnet(permanent magnet or an electromagnet) can be varied.

A permanent magnet is an object which creates magnetic field on its own. Permanent magnet is vulnerable to lose its magnetic abilities, if it is exposed to a very high temperature.Its magnetic properties can be only recovered by re-magnetizing. The main benefit of a permanent magnet above an electromagnet is that a permanent magnet does not need a constantsource of electrical energy to keep its magnetic field. Thus no power consumption during the operation.An electromagnet is an object which creates a magnetic field, when an electric current is allowed to pass through it. Usually an electromagnet is coveredround a core of ferromagnetic substancesimilar to steel, which improves the magnetic field formed by the coil. An electromagnet exhibits magnetic behavior only when an electric current is allowed to pass through it. The magnetic field strength of an electromagnet can be varied by varying the amplitude of electric current permitted to flow through the coil. This means, same electromagnet can be adjusted for different magnetic field strength levels. An electromagnet loses its magnetic propertywhen electric current is detached and becomes magnetic once again when the electric field is introduced. Magnetic field strength of the electromagnet can be rapidly controlled over a wide range by regulating the amplitude of electric current applied to the coil.

In this study for magnetizing the fuel, electromagnet is been used. Because it has the advantage of varying magnetic field strength by changing the current applied. The factors affecting the magnetic field strength of an electromagnet are coil length (L), number of turns in the coil (N), current passing through the coil (I) and magnetic permeability of the core material (μ_r).

Methodology and Experimental setup

In order to magnetize the diesel, a powerful magnet is needed. The options available for a magnet is to use a permanent magnet or to create an electromagnet. The advantage of electromagnet over permanent magnet is the ability to change the magnetic field strength by varying the current. In the current work, it is necessary to study the effect on diesel engine by varying the fuel magnetizer strength. Thus the permanent magnet is no longer an available option and the only choice left is to create an electromagnet. U- Shaped core is used for the electromagnet. Laminated silicon steel sheet is used to create the U- shaped core, because the eddy current losses in the laminated core will be low. At the both pole ends of the core a groove is made in the size of the fuel line. Thus the core can be perfectly fixed on the fuel line. By fixing the electromagnetic core with a groove to the fuel line will reduce the dielectric medium (air) between the fuel line and the core. Thus more magnetic field lines will pass through the fuel line.

Specification of electromagnet are given below

Length of the coil, L = 0.05m

Magnetic permeability of steel core, $\mu = 1.26 \times 10^{-4}$ H/m

No: of turns in the coil, N = 1000

Resistance of the coil, R = 50.5 Ω

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Magnetic field strength, B $= \mu \frac{NI}{L}$ in Tesla (T).

Table .1. Applied voltage and change in magnetic field strength

Voltage	Current	Magnetic field strength
V	A	T
6	0.12	0.3
12	0.24	0.6
18	0.36	0.9

In order to verify the change in diesel properties, those has to be measured. Thus properties like density, viscosity, flash and fire point of both normal diesel and magnetized diesel has been measured and compared (Table II)

For measurement of density of the fuel an electronic weight balance was used. The resolution of the electronic weight balance is 0.1g. A 200ml measuring flask is used for the collection of fuel. Mass of the measuring flask is noted. Then total mass of the flask with 200ml fuel is noted. The mass is taken for both magnetized and normal diesel. Net mass of the fuel can be found by subtracting mass of flask from total mass. Experiment is conducted three times for checking repeatability.

Redwood viscometer is used to measure the viscosity. Kinematic viscosity and dynamic viscosity of both normal diesel and magnetized diesel has been measured and compared. A redwood viscometer is illustrated in figure 1.Water bath in the redwood viscometer is used for varying the temperature of the measuring fluid and compare the viscosity of the same fluid at different temperature. Here the test is conducted to compare the viscosity of different fluids. So the temperature is kept constant. Thus no water is filled in the water bed and the temperature of the fluid is ambient temperature (28^{0}C) itself.

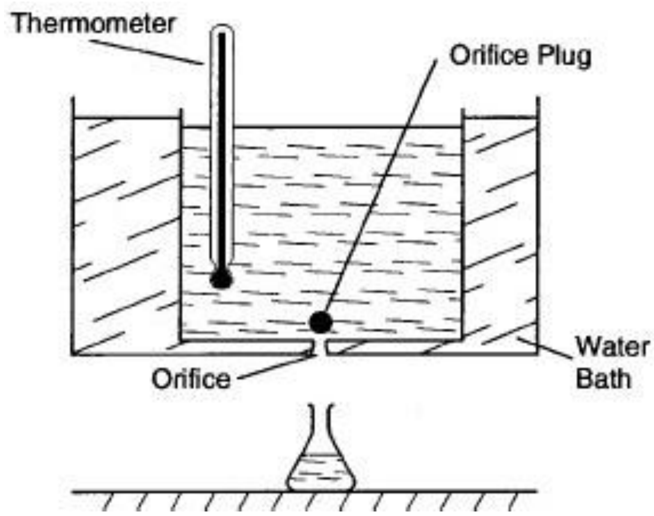

Fig. 1. Redwood Viscometer

For the measurement of viscosity measuring fluid is filled in the viscometer upto the marked level, with the orifice closed with the orifice plug. The fluid level has to be ensured, because the discharge through the orifice is dependent on the head of the fluid in the viscometer. The orifice plug was then removed and the fluid is collected in the 50ml measuring flask. Time taken for the flow of 50ml of fluid is measured. Experiment is repeated three times for checking repeatability. Then kinematic and dynamic viscosity has been found out.

Measurement of flash point and fire point is also done for the verification of the change in properties of magnetized diesel. Experiment is done in flash and fire point measuring apparatus. The temperature of the fuel is controlled by a heating coil and a thermostat. The thermostat cut off the heating coil when a certain temprature (adjustable knob determines the cut off temprature) is reached. Temperature of the fuel rises even after the cut off due to the heat radiation of the heating coil. An alcohol thermometer was used for the measurement of the fuel temprature. Fuel is filled in the fuel container upto the marked level. Heating coil is used for increasing the temperature. Temperature of the fuel is monitored throughout the procedure with the alcohol thermometer. After the temperature rises above 45^{0}C, a flame is introduced to the top level of the fuel container for a few times. This was repeated for rise in temprature of each 1^{0}C. Flash point is the temperature by which a small flash is occurred when the flame is introduced. Fire point is the teperature at which the fuel start burning when flame is introduced and continue to burn even after the removal of flame. This test was conducted for both normal diesel and magnetized diesel. The experiment was conducted several times for repeatability.

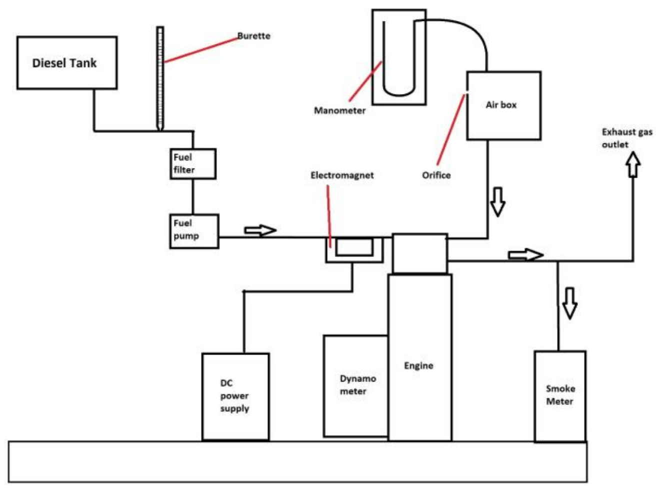

Fig. 2. Experimental setup

A single cylinder diesel engine in a test rig is used for conducting the experiment. The engine test rig is used for conducing performance test in the engine. The specification of engine and test rig is shown below.

Engine

- Make : Field Marshal
- Model : FM IV Supra
- Configuration : Vertical single cylinder diesel engine
- Displacement : 1433 cc
- Max power : 10 hp or 7.35 kW
- Rated speed : 1000 rpm

Dynamometer

- Type : Prony brake dynamometer
- Drum diameter : 32 cm
- Belt thickness : 5 mm
- Effective radius, r: 0.165 m

Smoke meter

- Make : AVL
- Model : 437c
- Resolution : 0.1%

The electric power needed for the electromagnet is given by a DC power supply, which can provide a voltage of 6V,12V, or 18V. The electromagnet is placed with proper seating with fuel line and groove in the core. Then it is attached to the fuel line with rope ties. Electric connections are properly made with electromagnet and the DC power supply.
The performance and emission test on the diesel engine with varying strength (0.3T,0.6T,0.9T) and position (10cm, 20cm,30cm away from injector) of the electromagnet has been conducted.

Results and Discussion

Experiment was conducted to find the effect of magnetization on diesel properties and the results are shown in table II. These results confirmed that the properties of the fuel changes with magnetization.
Performance and smoke emission test has been conducted on single cylinder diesel engine by varying strength and position of the electromagnet. Test was conducted with three different magnetic field strength(0.3T, 0.6T, 0.9T) and at different locations (10cm, 20cm and 30cm away from the injector).
A plot of smoke against brake power is shown in fig 3. From the graph it is clear that the diesel magnetization has an effect on the smoke emission. The blue line in the graph represents normal diesel and other lines represents magnetized diesel with magnets of different strength and position of the magnet. The reduction in smoke emission for magnetized fuel is due to the conversion of para- hydrogen molecule to the more reactive ortho- hydrogen molecule. This results in the combustion of cluster hydrocarbons and thus gives reduced smoke emissions. 0.6T magnetic field strength at 10cm away from the injector gives the least smoke emission throughout the experiment, which indicates 21% reduction in smoke than normal diesel at 50% maximum load of the engine.

Table .2. Change in magnetized diesel properties

	Density	Kinematic viscosity	Dynamic Viscosity	Flash point	Fire point
	ρ	ν	μ		
	kg/m³	m²/s	Pa.s	^{0}C	^{0}C
Normal Diesel	814.5	$3.1\text{x}10^{-6}$	$2.52\text{x}10^{-2}$	55.4	59.6
Magnetized diesel	798.7	$2.7\text{x}10^{-6}$	$2.2\text{x}10^{-2}$	54.4	59.4
Change in magnetized fuel	1.94% reduction	11.29% reduction	13.02% reduction	1^0C fall	0.2^0 C fall

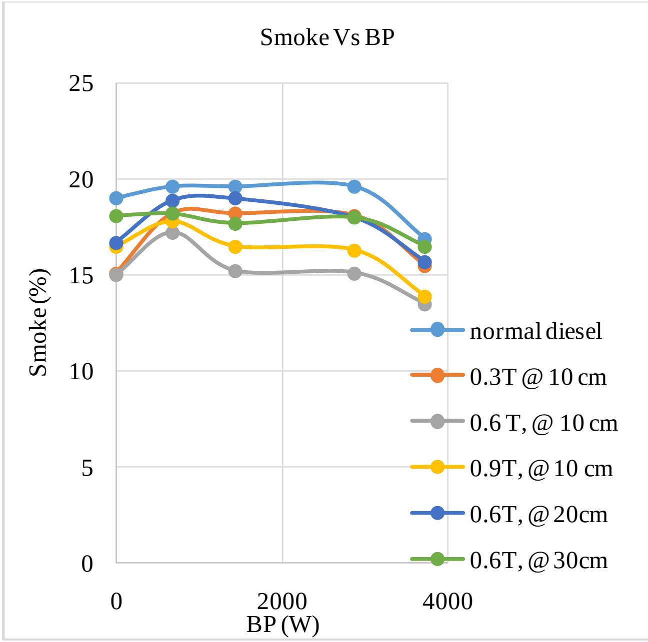

Fig.3. Smoke Vs Brake power

A plot of specific fuel consumption against brake power is given in fig 4. In this graph also it is clear that magnetization of diesel has an effect on specific fuel consumption. Normal diesel shows the highest specific fuel consumption. In other words it can be said that, magnetized fuel can produce more power than normal diesel. 0.6T magnetic field strength at 10cm away from the injector gives the least specific fuel consumption throughout the experiment, which is about 10% lower than the normal diesel at 50% maximum load of the engine.

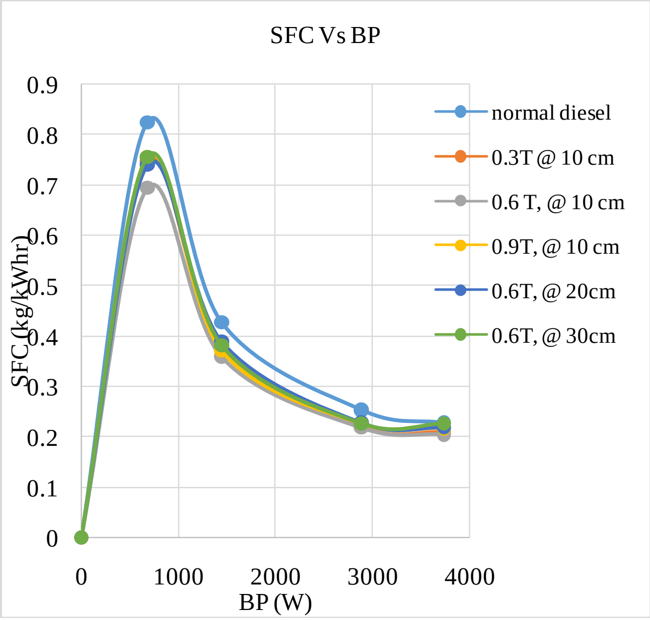

Fig.4. Specific Fuel consumption Vs Brake power

Fig 5 is a plot of thermal efficiency against brake power. In this data it is clearly visible that magnetized diesel gives better thermal efficiency that the normal diesel. The reason for this higher thermal efficiency for the magnetized diesel is the better combustion of magnetized diesel. Unburned cluster hydrocarbon in the magnetized diesel is less than that of normal diesel after combustion, this result in the higher thermal efficiency of the magnetized diesel. Magnetic field strength of 0.6T at 10cm away from the injector gives the highest thermal efficiency, which is12% higher than the normal diesel at 50% maximum load of the engine.

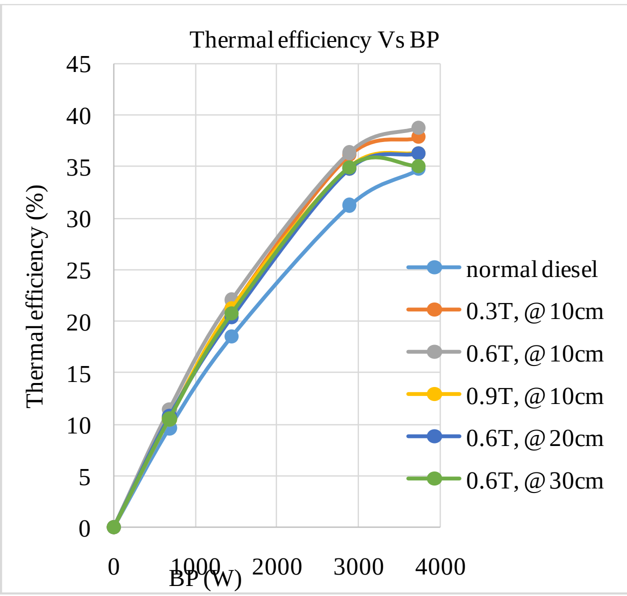

Fig.5. Thermal efficiency Vs Brake power

Conclusion

Experiments were conducted to study the effect of magnetization of fuel on diesel engine. An electromagnet is used for the magnetization of fuel. Experiments were conducted with 0.3T, 0.6T and 0.9T magnetic field strength. Positions of the magnet for conducting the experiments were 10cm, 20cm and 30cm away from the injector. 0.6T at 10cm away from the injector showed best results, which means it showed least smoke emission, least specific fuel consumption and highest thermal efficiency. These good effects are caused due to conversion of para-hydrogen molecule to ortho-hydrogen molecule which leads to less number of cluster hydrocarbons and results in better combustion.

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