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Miqdam T Chaichan
Energy and Renewable Energies Technology Center, University of Technology, Baghdad, Iraq

Adel M Salih
Mechanical Engineering Dept, University of Technology, Iraq

Khaleel I Abass
Mechanical Engineering Dept, University of Technology, Iraq

Correspondence:
Miqdam T Chaichan
Energy and Renewable Energies Technology Center, University of Technology, Baghdad, Iraq

Magnetic Field Effects on Methanol-Diesel Blends Fueled CIE: Part A- Engine Performance

Miqdam T Chaichan, Adel M Salih, Khaleel I Abass

Abstract
The impact of the magnetic field on the performance of (CI engine) is investigated experimentally in this study. Thermal efficiency, brake specific fuel consumption (bsfc) and exhaust emissions were measured for Iraqi diesel fuel and methanol blends. The fuel was subjected to a magnetic field of (2000 Gauss), respectively. The magnetic field was placed on fuel supply line to magnetize the fuel before injected into the combustion chamber. Four strokes and cylinders, direct injection engine was used in this study.
A reduction in fuel consumption up to (2.19%) and (5.488%), brake thermal efficiency rose by about (13.5%) and (4.7%), for 10% and 20% methanol added to diesel, respectively. The exhaust temperature increased up to (3.65%) and (1.7%) 10% and 20% methanol added to diesel, respectively.

Keywords: Magnetic field, magnet, brake power, thermal efficiency, fuel consumption.

1. Introduction

At present, there are many unresolved problems: climate change, global warming and air pollution, and these are not local problems but they are global [1]. All these problems are related to the production of energy for electricity and heating or for fueling cars and trucks [2]. The use of fossil fuels such as diesel and gasoline is outstanding and has excellent thermal value. To date, scientists and researchers have not been able to determine the optimal alternative fuel, despite millions of studies [3]. Studies and statistics have shown that crude oil will be depleted in 70 years while natural gas will last a little bit longer [4]. However, the shift to alternative fuel for the day did not happen, and the best and most optimistic hopes indicate that renewable energies will occupy at 2050 about 20% of the energy market, which means that 80% of this market will depend entirely on near-depleted fossil fuels [5]

The high calorific value of both gasoline and diesel with their liquid availability at low temperatures and high flash point makes them ideal fuels for spark ignition and compression ignition engines [6]. When looking at the alternative fuels for gasoline, for example, natural gas is characterized by its high octane number, which is a good feature in the ignition engines [7, 8]. However, it is also characterized by slow flame propagation and its low heating value compared to gasoline [9, 10]. In addition, it enters to the engine in the gas phase, which reduces the volumetric efficiency of the engine [11]. Liquefied petroleum gas (LPG) is also an approved alternative to gasoline [12]. It has a flame speed of about equal to that of gasoline and has a good heating value but less than gasoline [13-16]. The liquefied petroleum gas enters the engine in a gas manner, which reduces the volumetric efficiency of the engine as well as it interacts with the parts of the fuel system manufactured from plastic [17-20]

Hydrogen gas is the fuel of the future that burned to produce water vapor and it is extracted from the water and thus is considered renewable fuel [21, 22]. Many studiers prefer to call it an energy carrier instead of a fuel because it is constantly renewed [22, 23] Because of the cleanliness of this fuel, it is the first and most likely candidate to operate fuel cells with zero emissions [24]. This gas requires many safety requirements before using it in vehicles [25]. Hydrogen has a rapid flame propagation that is no other type of fuel like it, and it does not leave any hydrocarbon contaminants [26-28]. The disadvantage of this fuel is its low heating value based on volume basis and low volumetric efficiency of the engine working in it [29, 30].

It is difficult for these types of gaseous fuels to operate in diesel engines because of its high octane number, so it is tested in the engines of dual fuel [31, 32, 33]. In such engines it confirmed its activity and increased the engine performance [34-37]. Oxygenates such as ethanol, methanol, and biodiesel have been treated as alternatives to gasoline and diesel [38]. Ethanol has the potential to be derived from agricultural sources such as maize and sugarcane, so bioethanol can be considered a good alternative for use in spark ignition engines [39, 40]. This liquid fuel has a high octane number and it is found in the liquid phase, so it does not reduce the volumetric efficiency of the engine, but on the contrary increases it by having oxygen in its chemical composition, ranging from 9% to 11% [41]. Ethanol in diesel engines can only be used as second fuel because of its low cetane number [42, 43]. The heating value of ethanol is low compared to diesel and gasoline, so when used as fuel, the fuel consumption of the engine increases [44, 45].

Biodiesel can be considered an excellent alternative to diesel as it has a heating value close to diesel as well as its cetane number is good and can be improved with the addition of cetane number improvers [46, 47]. What distinguishes this fuel is that it contains oxygen in its chemical composition in varying proportions depending on the source of production from 9% up to 13% [48]. This fuel can be produced from several types of agricultural products, animal, and even residues of restaurants and homes [49]. Biodiesel causes more fuel consumption than diesel, but the exhaust emissions from combustion are lower [50].

Methanol is currently used in race cars that require high compression ratios and high octane fuel [51]. The octane of methanol is up to 140 while its cetane number is no more than 3%, so its use in diesel engines is in dual fuel engines. Methanol is characterized by a high proportion of oxygen in its chemical composition and the production of the process of reforming methane by water vapor is an easy and inexpensive process [52]. But, this fuel is toxic and burns without emitting a color or odor, making it very high safety requirements. All oxygenates, including methanol, have a high laminar burning velocity equal to or sometimes superior to diesel [53]. Since methanol has a lower thermal value than gasoline and diesel, its use alone or with either fuel will increase fuel consumption [54].

Cars and vehicles on the roads have increased worldwide, using diesel and gasoline [55, 56]. More than 60% of vehicles, trucks, heavy machinery and equipment are diesel powered [57]. This fuel emits large amounts of air pollutants from the exhaust of its engines [58]. In order to dispose of them, second fuel was used as mentioned above, whether gas or liquid [59]. The use of variable valve timing technology, use of alternative methods such as PCCI, HCCI, and RCCI were tested and promising results were achieved [60, 61, 62]. In addition, the exhaust gas was recycled in high proportions to the diesel engines to reduce the NOx pollutants emitted from [63, 64, 65]. However this action increased the PM levels and the work is still on reducing the two together using a water-diesel mixture or adding nanomaterials to this suspension [66, 67].

Methanol is usually added to diesel at a weight or volume ratio of 10% or 20%. The impact of this addition is examined on the performance of the diesel engine. In this study it will be added in the same ratios and will examine the performance of the engine, but with the use of magnets composite on the fuel line to evaluate its impact of the laboratory engine four-cylinder and if this easy addition to the engine will reduce the fuel consumption and improve performance to reach the performance of a normal diesel engine

2. Experimental Setup

2.1 Experimental rig and measuring devices

In this study, a direct injection, four-cylinders, four strokes, diesel engine was used. The motor used has the displacement size of three litres. The motor is connected to a hydraulic dynamometer used to measure torque. Figure 1 shows an image of the experimental engine used, and Table 1 lists the main technical specifications of the studied engine

Fig: 1 the experimental diesel engine rig

Engine brake torque is measured using the hydraulic dynamometer and water as the friction fluid. The rotational speed of the engine was measured using the analogue tachometer (VDO). In order to measure the fuel consumption of the engine, a glass tube with a fixed volume of fuel (100 ml) was used to measure fuel consumption.

The engine is equipped with an air-damping and an air pressure gauge. This box is equipped with an orifice plate and a pressure gauge to measure the difference in pressure between the atmosphere and the pressure inside the air box.

Figure 2 shows a photograph of the two magnets of 100 Gaussian each, used in this research. The first magnet is manufactured by the United States of America; the second is a manufactured in China. The fuel passes through lines under the forces of permanent magnet that have been installed on these lines near the fuel entrance. Magnets are installed so that the south pole of the magnetic field is adjacent to the fuel line, and the North Pole is away from the fuel line. The use of the magnetic field on the fuel feed line is to equip ionized fuel to the combustion chamber.

Table 1: The main technical specifications of the engine

Engine type	4cyl., 4-stroke
Engine model	TD 313 Diesel engine rig
Combustion type	DI, water cooled, natural aspirated
Displacement	3.666 L
Valve per cylinder	Two
Bore	100 mm
Stroke	110 mm
Compression ratio	17
Fuel injection pump	Unit pump

	26 mm diameter plunger
Fuel injection nozzle	Hole nozzle 10 nozzle holes Nozzle hole dia. (0.48mm) Spray angle= 160^{o} Nozzle opening pressure=40 Mpa

Fig: 2 the magnets used in the study

2.2 Calibration

Since the work depends on many measuring devices, the accuracy of all readings and data obtained from the measuring devices is done by accurate calibration of all measuring devices and determine the proportion of error by measurement if any.

1. **Tachometer**
   The linear method was used to calibrate the speed measuring instrument. A measured speed by a tachometer type (VDO) setup in the the experimental rig was compared by a diagrammatic speed that was obtained from another tachometer type (gas analyzer) which can also be used for measuring the engine speed by attaching an inductive clip-on pickup to a spark plug cable. The results were compared and plotted.
2. **Hydraulic Dynamometer**
   The measuring of brake power was conducted by using the hydraulic dynamometer, which was calibrated by using an electric generator dynamometer.
3 **Exhaust gas temperature**
   Exhaust gas temperature was measured by the means of thermocouples type K. The thermocouples were calibrated using a standard thermometer. The thermocouple and a standard thermometer are inserted in a vessel filled with distilled water. This vessel was heated using an electric heater with heat regulator to change the water temperature. The water temperature was read before heating with both thermometer and thermocouple and the two readings are compared for calibration.

The following relationships were used to calculate engine performance
Brake Power

$$Bp = \frac{2\pi * N * T_b}{60 * 1000} \text{ (kW)} \ldots\ldots(1)$$

Where:
T_b = Brake torque (N.m).
N = Engine speed (rpm)

Fuel consumption (L/h)

$$\text{Fuel consumption} = \frac{V_f}{\text{time}} \text{ (L/h)} \ldots\ldots (2)$$

V_f = volume of fuel consumption in (Liter)

Air Consumption ($\dot{m}_{a,act.}$)

$$\dot{m}_{a,act.} = \frac{5\sqrt{h_o}}{3600} \times \rho_{air} \text{ (kg/Sec} \ldots\ldots(3)$$

h_o = pressure differences between the atmosphere and pressure inside the air box.
ρ_{air} = 1.18 (Kg/m^3)

Fuel mass flow rate $\dot{m}_f$

$$\dot{m}_f = \frac{V_F}{\text{time}} \times \rho_F \text{ (kg/sec)} \ldots\ldots(4)$$

V_F = volume of fuel consumption

Brake specific fuel consumption Bsfc

$$Bsfc = \frac{\dot{m}_f}{Bp} \times 3600 \ \frac{kg}{kW.hr} \ldots\ldots (5)$$

Brake thermal efficiency

$$\eta_{bth.} = \frac{BP}{\dot{m}_f * L.C.V} \ldots\ldots (6)$$

2.3 Experimental procedure

The processing of the studied fuel mixtures and the preparation of the engine and measuring equipment for the implementation of this experimental work and according to the following steps:

1. The first step in this experimental work is the preparation of diesel-methanol blends used in the tests. 10% methanol added to 90% diesel fuel by volume (called M10) and 20% methanol was added to 80% diesel (called M20).
2. In the second step, during this stage the preparation the measuring instruments are prepared and calibrated to be ready to read the data for normal operation or in the case of adding magnetic field.
3. During engine operation, engine speed, operating torque, pressure difference between the atmosphere and pressure within the air box, and the time required to consume 100 mL of fuel are measured in cases with or without magnetic field.

3. Results and Discussion

Figure 3 represents the amount of fuel consumed (L/h) when the engine was run at speed varied from low (1250rpm) to high (3000 rpm). The measurement was taken when the engine was operated by diesel fuel without using magnets as the base line for comparison. In the second set of experiments the magnets were used with diesel fuel and both M10 and M20 blends. The engine fuel consumption increased by increasing the engine speed from low to high speeds. The figure's curves show that the fuel consumption reduced when the magnets were used compared with the case without using magnet. The diesel fuel consumption was reduced by 5.488% when the magnets were added to the fuel line. It is well known that adding methanol increases the fuel consumption due to its lower heating value compared to diesel, but adding magnets to the fuel line caused this consumption to decrease. The effect the magnetic field was clear, it affected the molecular grouping resulting in a reduction of fluid viscosity at the macroscopic levels, ionization and realignment of fuel molecule or hydrocarbon chain, the fuel is now actively interlocked with oxygen, hence proper mixing and combustion occurs in the engine resulting in a better fuel economy. The reduction in the fuel consumption was 3.12% and 0.83% for M10 and M20 respectively compared to diesel fuel without adding magnets

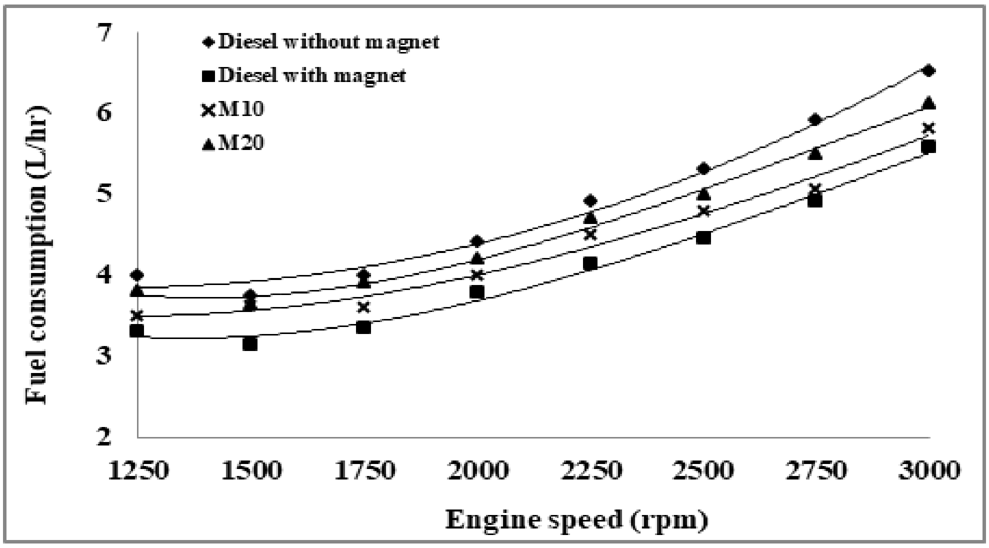

Fig: 3 the impact of magnets addition on the fuel consumption for variable engine speeds

Fig. 4 declares the impact of using magnets on the brake power produced from the engine for variable engine speeds. The figure shows an increase in the delivered brake power for diesel fuel when adding magnets to the fuel lines. In the same manner, the brake powers of the methanol-diesel blends were increased in a way that M10 produced higher brake power than diesel engine without magnet by about 2.08% while in the normal case without adding magnets to the fuel line the reduction in brake power was about 16.78% as Ref. [52] indicated. When M20 was used the engine brake power was less than diesel engine by about 3.41% while its reduction was 20.78% in Ref. [52] case.

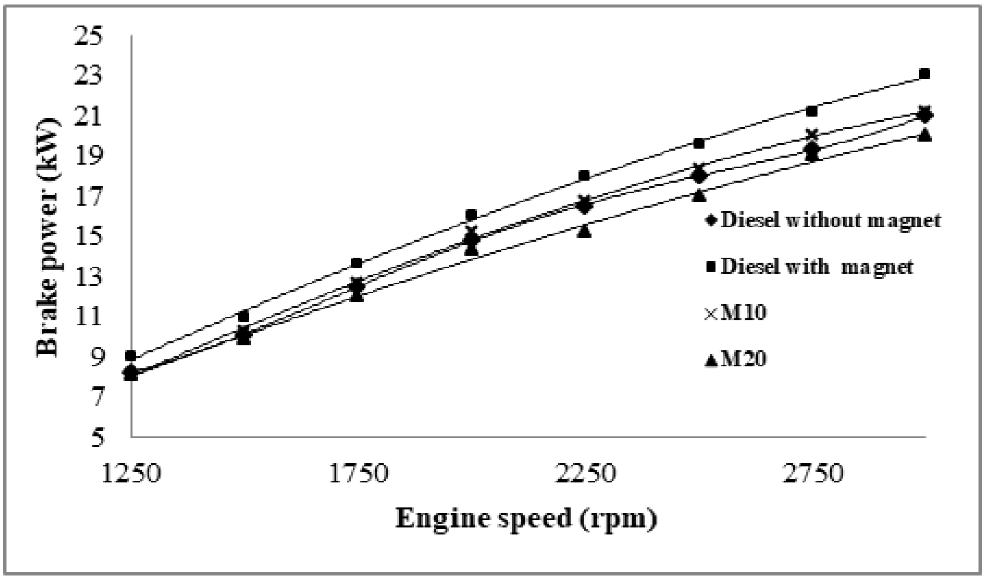

Fig: 4 the impact of magnets addition on the brake power for variable engine speeds

The brake thermal efficiency is defined as the ratio of the brake power to fuel consumption and lower heating value (LHV). The brake thermal efficiency indicates the ability of the combustion system to accept the fuel, and provides comparable means of assessing how efficiency of the energy in the fuel was converted to mechanical output. Figure 5 shows the effect of magnets addition on brake thermal efficiency for variable engine speed. Brake thermal efficiency increased for diesel fuel when magnetic field was applied with about 13.5% for the range of studied speeds. The effect of adding magnets on M10 blend was higher than M20 as the brake thermal efficiency of the engine fueled by M10 increased 4.7% compared to diesel engine without magnets. The increments in brake power with the decrements in brake specific fuel consumption are the reasons for the increment in the engine brake thermal efficiency.

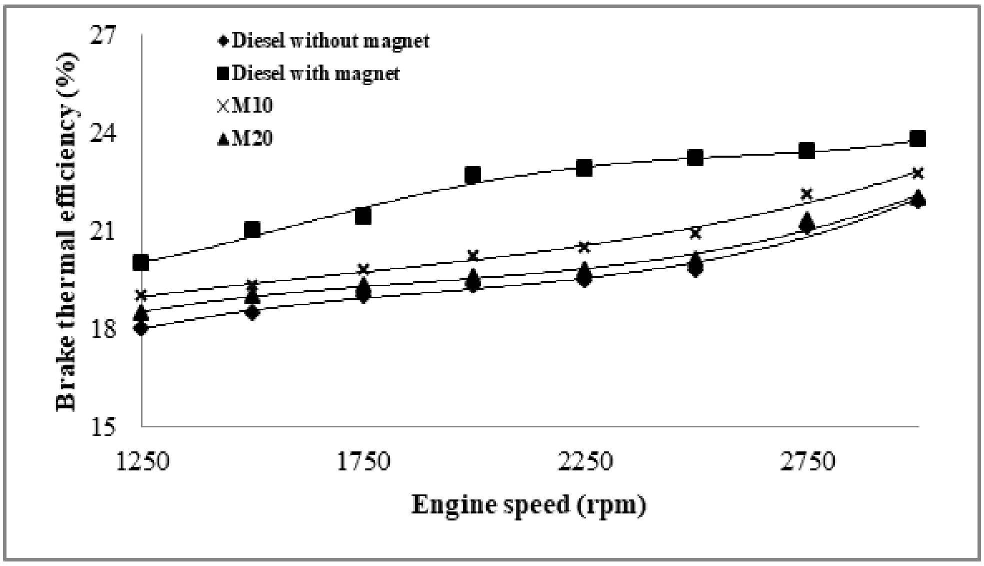

Fig: 5 the impact of magnets addition on the brake thermal efficiency for variable engine speeds

Figure 6 reveals that the exhaust temperature increased when the engine speed was increased, and when magnets were used. The increase in exhaust gas temperature was 5.7% when diesel engine was supplied with magnets. When the engine was fuelled by M10, the increasing rate was 3.65% compared with diesel engine run without magnets. The increments in the exhaust gas temperatures indicated that there was enhance in combustion within the combustion chamber. The usage of the magnetic field caused the exhaust temperature to be increased.

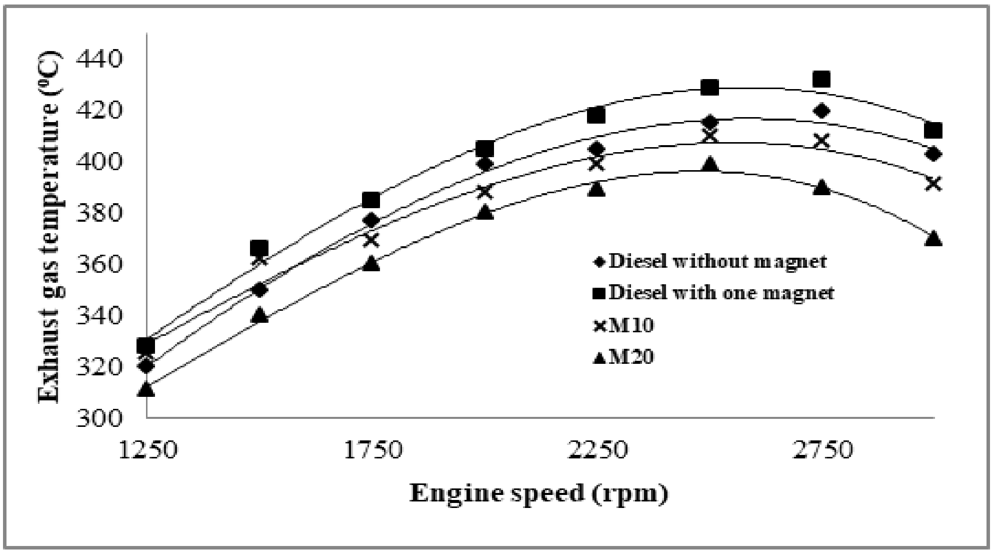

Fig: 6 the impact of magnets addition on the exhaust gas temperature for variable engine speeds

Conclusions

The impact of adding magnetic field to a CI engine on its performance was studied when it was fueled by diesel, M10, and M20. The results indicate that the engine's brake specific fuel consumption reduced with magnets addition. The magnetic field caused a significant reduction in the M10 and M20 fuel consumption. The diesel engine brake power increased using magnetic field as well as for methanol-diesel blends engines'. The engine brake thermal efficiency was improved with the adding magnets. Increasing the magnetic field enhanced this efficiency. The temperature of exhaust gas increased with the using of the magnetic field, this is an indication of increasing the temperature of the mixture inside the combustion chamber. The results show that the use of M10 as a fuel with the presence of magnets gave better results than the case of M20 because the effect of reduction in the total heating value of the blend was limited in the first case.

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