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AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF MAGNETIC FUEL TREATMENT ON SI ENGINE PERFORMANCE

Ahmed A. Abdel-Rehim*, Ramadan Abdel-Aziz*, Khairy H. El-Nagar*
Hamdy H. Maarouf**

** Shoubra Faculty of Engineering, Benha University, Cairo, Egypt*
*** PetroJet, Cairo, Egypt*

ABSTRACT

The pressure imposed on science and scientists to attack all possible (and may be impossible) methods to achieve higher fuel and engine efficiency is well known. Not only driven by the extremely dangerous environmental situation (global warming and pollution), but also by other factors like fluctuating oil prices and depletion of fossil fuel resources. Due to these factors, research is going everywhere at a tremendous level to better use of available resources.
In the present study, a series of experimental work is introduced to explore the impact of fuel magnetic treatment on engine performance. Two main types of magnetic treatments were tested; the first type is depending on a permanent magnet, while the second type is depending on an electromagnetic magnet.
Two different designs for the electromagnetic device were examined to explore the effect of number of coils, material, source of electricity and some other parameters on engine performance.
Two fuels were examined, gasoline as a liquid fuel and Natural gas as a gaseous fuel.Some attractive results showed that we can increase engine power by 20 % and reduce fuel consumption by the same percentage depending on engine operating conditions. Promising results were obtained for the reduction in engine main pollutants (CO, HC, and NO_x).

I. INTRODUCTION

There are many ideas for fuel conditioning have been tried based on different techniques such as filters, catalysts, additives, etc.

Many inventors propose fuel saving products depending on the idea that combustion can be improved by treating the fuel with a magnetic field. Many of these magnetic products or devices have been patented and produced in order to reduce fuel consumption and engine emissions [1-18].

Technologies have ranged from simple clamp-on magnets to a variety of electric and electronic devices. Many of these products have met with limited success because there are a number of factors to take into account and variables to accommodate. For example, a device that applies a constant magnetic field of a constant strength will have a limited effect because different fuels can be fed at different rates through pipes of different materials, thicknesses and bores. Therefore, a somewhat more sophisticated approach is required.

For these reasons, the US Environmental Protection Agency (EPA) has published their reports, after testing some of these devices, to conclude that vehicles equipped with these devices (permanent magnets) did not show any improvement in fuel economy or in emissions reduction [19-23].

There are many different magnetic treatment methods used to treat engine fuels. A permanent magnet is a device which consists of multi-magnetic strips organized in an enclosure and produces a high frequency magnetic field on the fuel which passes through the device. Electromagnetic coils depend on generating the magnetic field from electricity using different circuit designs. In this case full control on the magnetic field strength is applicable depending on the operating conditions.

In the present study, a series of experimental work is introduced to explore the impact of fuel magnetic treatment on engine performance. Two main types of magnetic treatments were tested; the first type is depending on a permanent magnet, while the second type is depending on an electromagnetic magnet.

Two different designs for the electromagnetic device were examined to explore the effect of number of coils, material, source of electricity and some other parameters on engine performance.

Two fuels were examined, gasoline (92 Octane Number) as a liquid fuel and Natural gas (NG) as a gaseous fuel. Results were compared at the same conditions using the following indications:

1- When the engine is running without any modifications e.g. without applying any magnetic field the following expression is used (WITHOUT MAG).
2- When a permanent magnet is used, the following indication is used (PERMANENT MAG).
3- When the iron coil is used alone, it is indicated by (IRON COIL).
4- When the fiber coil is used alone, it is indicated by (FIBER COIL).

5- When the two coils are used together, the iron and the fiber ones, it is indicated by (DOUBLE COIL).

According to the source of the electricity, an alternative current is indicated by (AC), while a direct current is indicated by (DC).

II. EXPERIMENTAL SETUP

The experiments were conducted on a single-cylinder Honda model (GX390K1) 13 HP engine with a cylinder bore of 88 mm and a stroke of 64 mm. The compression ratio of the engine is 8.

Three different magnetic coils were used. The first coil is a permanent magnetic device which is used commercially in the market. The other two electromagnetic coils were custom made with the specifications shown in table (1). Appendix (A) shows a schematic diagram of the experimental setup

	Iron Coil	**Fiber Coil**
Core Material	Iron	Fiber
Wire length (L)	55 m	
Number of wire turns (N)	500	
Magnetic flux intensity (B)	5.56xI mTesla Where I is the current	
Current (I)	0.18 – 6.66 Amp.	

Table (1) Electromagnetic coils specifications

III. EFFECT OF MAGNETIC FLUX INTENSITY AND COIL MATERIAL

One important part to explore is the effectiveness of controlling magnetic flux intensity on engine performance and comparing the results with the permanent device.

Three different values for the magnetic flux intensity have been chosen to indicate the low, medium and high values as shown in table (2). These values were chosen as an average depending on the specifications indicated in table (1), the circuit design and temperature limitations.

No.	**Description**	**Magnetic Flux Intensity (mT)**
1	Low Flux	6.97
2	Medium Flux	13.95
3	High Flux	26.16

Table (2) Magnetic flux intensity used in the experiments.

Limited effect is shown in figure (1) for the iron and fiber coils when low flux was used compared to the permanent device. Not only limited effect from the low flux, but also the permanent magnetic flux seems to be more effective in this case. This can be explained by two effective properties for the permanent coil:

1- Design factor which results in magnetic flux migration between the different sets of north poles and south poles where the fuel passes in this case through a swirling magnetic movement between the north and south poles.
2- The length of the permanent magnetic coil, which reflects the whole fuel traveling distance, is relatively longer than the other two coils. This means that there is a longer contact path in the case of permanent magnet.

When a high flux was tested as shown in figures (2, 3 and 4) the magnetic effect started to be observed where table (3) summarizes the results.

Device type	**Average increase in the output power (%)**
Fiber coil –AC	7.5
Fiber coil –DC	7.9
Iron coil –AC	12
Iron coil –DC	13
Double coil –AC	12.3
Double coil –DC	14.4
Permanent coil	3.63

Table (3): Average increase in the output power (%) at the same engine speed for different types of magnetic coils.

As clearly seen in table (3), the following points can be stated:

1- The average increase in the engine power is 3.63% for the permanent coil over the range of speed and power in the present investigation.
2- Using high flux over the fiber coil doubled this effect.
3- Using iron coil at the same conditions increases the engine power compared to the fiber coil and this can be explained by the ability of iron to collect and concentrate the electromagnetic waves which means that the coil material is one important factor affecting the results.
4- In spite of this improvement in the coil effect on engine power when the iron coil was used, there is a side effect to increase the magnetic flux which is increasing the coil temperature. Increasing the coil temperature can burn the coil out. Accordingly we have limitations in using iron coil with variable or controllable flux.
5- Using the two coils in series (double coil) produced the maximum effect as shown in table (3). The reason behind this is the properties of the magnetic waves produced where the double coil has two properties: The first one is the nature of magnetic flux which is affected by the two coil specifications. The second is the total length of the two coils together.

IV. EFFECT OF CURRENT SOURCE AC OR DC.

Another important parameter to explore is the effect of the origin of the current used. AC current from the outlet lab source was used accompanied by a suitable circuit, while the engine battery was used to generate the DC current using another suitable circuit.

When fiber coil was tested with AC and DC, figure (2), no difference between the two sources was observed except the last point at high power and high speed.

The experiment was repeated for the iron coil, and double coils where the same trend is clearly seen in figure (3) and figure (4) respectively.

Accordingly from these observations, there is no difference between AC and DC current on the engine power, except the stability in the behavior of the data recorded by the DC current, which can be explained by the nature of the AC current which behaves as a sine wave compared to constant behavior of the DC current. Regardless of the initial observation of no difference between AC and DC, both types will be under investigation in most of the study.

V. IMPACT OF MAGNETIC TREATMENT ON LIQUID FUEL (GASOLINE)

V.1 Fuel Consumption

Figures (5.a) and (5.b) represent a relationship between engine power and the corresponding fuel consumption for AC & DC current sources. The engine speed was maintained constant for the same compared power value while the throttling position was adjusted to obtain the same speed and power.

The figures show reductions in fuel consumption by using magnetic fuel treatment.

As clearly seen, using double coil with high flux results in better effect on the fuel consumption where a reduction of 20% can be achieved compared to 9 % for the permanent coil.

A direct comparison between AC current and DC current is illustrated in figure (5.c). The previous observations still applied on this figure.

Figure (6.a) shows the effect of magnetic field when allowing engine speed to be varied and maintaining the same throttling position for the engine power.

The same trend was obtained as discussed earlier where the double coil is still producing the best effect over the other coils with an average reduction of 20 %.

The whole experiment was repeated using DC current as shown in figure (6.b) and both current sources were compared in figure (6.c) where no effective variation between both currents is recorded.

V.2 Effect of Magnetic Treatment on Brake Specific Fuel Consumption (BSFC)

The effect of magnetic treatment on engine BSFC is shown in figure (7.a) for the coils under investigation. In this experiment AC current was used.

As clearly seen in the figure the three coils (iron, fiber and double coil) are very close in their effect.

But at the same time, the figure shows a noticeable reduction in BSFC when the magnetic effect is considered even for permanent magnet.

The same treatment is obtained when the experiment is repeated using DC source as shown in figure (7.b).

Figure (7.c) shows a comparison between the two current sources where no significant change is observed.

Figures (8.a) and (8.b) show the effect of magnetic treatment when maintaining the same throttle position at the same power value. In this case, as mentioned earlier, it was allowed to the engine speed to change according to the output power. In this case the maximum reduction in engine BSFC of 26 % was obtained for the double coil using AC current, while the maximum reduction of 28.5 % in engine BSFC was obtained for the double coil using DC current.

Figure (8.c) shows a direct comparison between AC and DC current. In this figure limited enhancement is observed and the difference between the two sources varied from 1 % to 6.2 %.

V.3 Effect of Magnetic field Treatment on Engine Exhaust Emissions

In this section, the impact of using magnetic field on engine emissions was investigated. In this case, measurements of unburned hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x) were plotted for the three coils using DC current source. Three different output powers, 1500W, 3000W, 4500W were chosen to illustrate this effect.

Figures (9, 10, and 11) represent the effect of magnetic flux intensity generated from DC current source on CO, HC, and NO_x emissions for the three coils at three different output powers. The following points can be observed from the figures:

a) A fairly linear relationship between the magnetic flux intensity and engine emissions for the three coils.

b) The double coil represents the best choice due to its effect on CO, HC, and NO_x emissions which recorded to reach 61.5, 53, and 50 % respectively at the maximum flux compared to the initial point (where no magnetic effect).

c) Variable magnetic fluxes produce better effect on engine CO emissions compared to the permanent coil.

d) There is no significant reduction in NO_x emissions with increasing flux intensity compared to CO and HC. This can be explained by the dependence of

NO_x formation on operating temperatures which are affected by the engine power.

VI. EFFECT OF MAGNETIC TREATMENT ON GASEOUS FUEL (NATURAL GAS)

It was reported in the previous sections that magnetic fuel treatment has an impact on the engine performance; especially the rate of fuel consumption and it was discussed that double coil has the best effect compared to the other two coils. Also, it was reported that DC current produces more stable output data compared to AC current.

In the present section, the effect of magnetic field on gaseous fuels (specifically NG) is presented. Most parameters related to engine performance are discussed again for natural gas but in this case the investigation is limited to the double coil which proved to treat the fuel better than the others.

VI.1 Effect of Magnetic Treatment on Fuel Consumption, Brake Power and BSFC for NG

Figure (12) shows a comparison between the rate of fuel consumption without magnetic treatment and with magnetic treatment using double coil and AC source. The results show an increase in the range of 2.5-7% in engine's power at the same fuel flow rate or a reduction of about 4-10% in fuel consumption at the same power. At the same conditions, a reduction of 6.5-13.8% in BSFC can be obtained using magnetic treatment as shown in figure (13).

VI.2 Effect of Magnetic Treatment on Exhaust Emission for NG

The effect of magnetic treatment on HC, CO and NO_x emissions using NG as a fuel is indicated in figure (14). The maximum reductions in CO, HC, and NO_x emissions for the three tested loads are summarized in table (4).

Figure (15) represents a comparison between the effect of magnetic treatment on gasoline and NG for CO, HC, and NO_x emissions at 1500 watt. Table (5) summarizes this comparison. The comparison shows that the magnetic treatment is more effective on gasoline fuel than NG fuel which can be explained by the tendency of liquid fuel molecules to change their random organization to a more simple structure which simplifies the combustion reactions. On the other hand, it is not easy to force the gaseous molecules to keep their new positions for a long period of time. Accordingly, losing the magnetic effect on gaseous fuels is faster than liquid fuels due to the effect of their density. Another important reason that natural gas does not contains additives which increase the fuel tendency to the magnetic field effect.

Pollutant	Maximum reduction		
	1500W	1900W	2500W
CO	15.5%	19%	20%
HC	19.1%	13.5%	9.7%.
NO_x	55.5%,	25%,	26.4%

Table (4) Maximum reductions in engine emissions when NG was used

Pollutant	Maximum reduction	
	Gasoline	NG
CO	32.7%	19.1%
HC	52%	15.5%
NO_x	46.4%,	55.7%,

Table (5) Maximum reductions in engine emissions when NG was used

From the previous discussion, it can be concluded that using magnetic fuel treatment enhances the combustion characteristics of natural gas which results in better combustion and reduction in engine exhaust emissions. This reduction can reach 50% or more for some of these emissions.

VII. CONCLUSIONS

In the present study, two sets of experiments were carried out; the first set was focused on exploring the impact of magnetic fuel treatment on engine performance using gasoline as a liquid fuel, while the second set was concerned with natural gas as a gaseous fuel.

Three different coils having different features were compared at different operating conditions. The main results are summarized as follows:

1. Magnetic coil design has a considerable effect on the engines measured parameters. Total wire length, coil length, magnetic flux intensity, current source are some examples of these design parameters. The difference between AC and DC current on the engine performance parameters is limited to the stability in the behavior of the data recorded by the DC current compared to AC current.
2. Magnetic fuel treatment has an acceptable effect on engine performance. Fuel consumption was reduced by more than 20 % at some operating conditions, and BSFC was reduced by more than 27 % for some other conditions.
3. A reduction in the engine pollutants was clearly observed when magnetic field was applied to reach reductions of 50 % or more depending on the operating conditions and design of the coil used.
4. Higher influence of magnetic fuel treatment was recorded for liquid fuels compared to gaseous fuels.

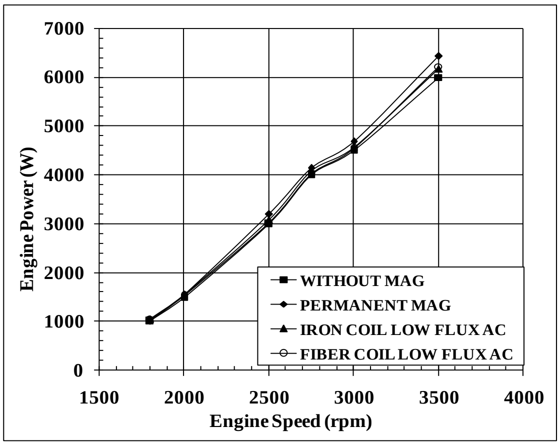

Figure (1) Effect of low flux intensity on engine power using AC current.

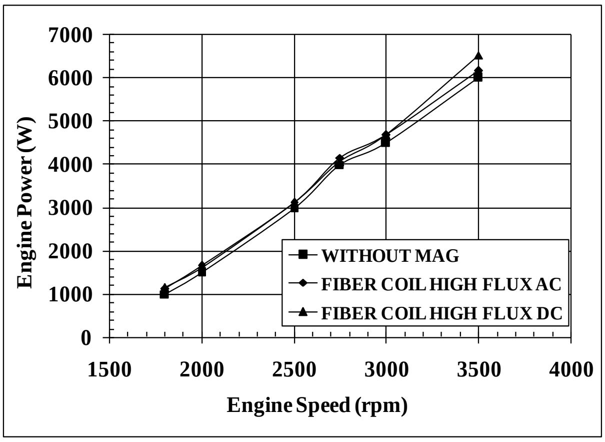

Figure (2) Effect of current source (current type) on the engine output power using fiber coil at high flux.

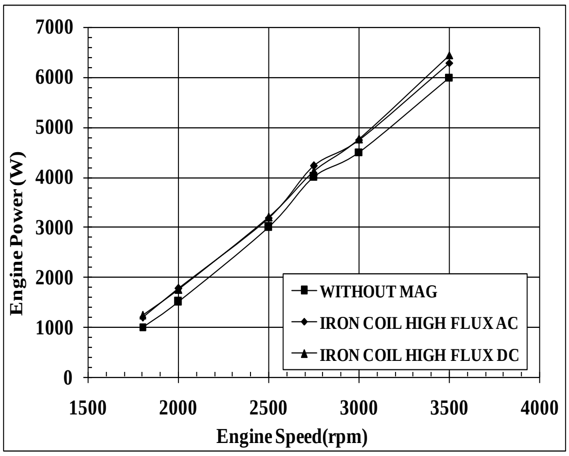

Figure (3) Effect of current source (current type) on the engine output power using iron coil at high flux.

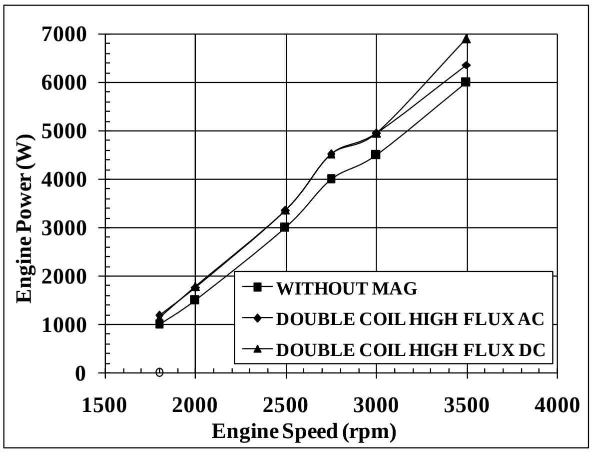

Figure (4) Effect of current source (current type) on engine output power using double coil at high flux.

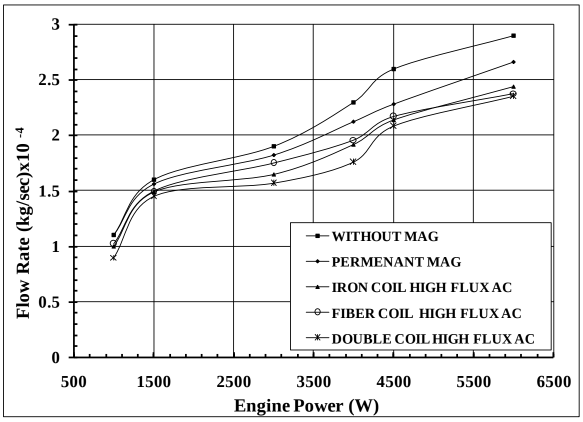

Figure (5.a) Effect of magnetic treatment on fuel flow rate using AC.

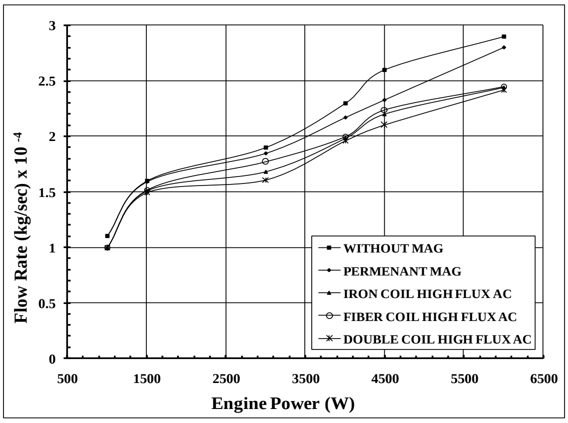

Figure (6.a) Effect of magnetic treatment on fuel flow rate using AC.

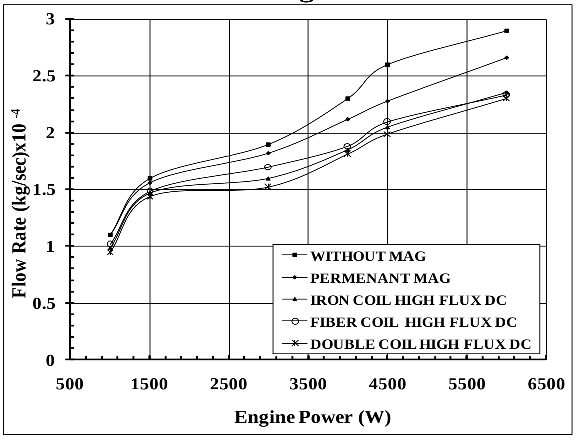

Figure (5.b) Effect of magnetic treatment on fuel flow rate using DC.

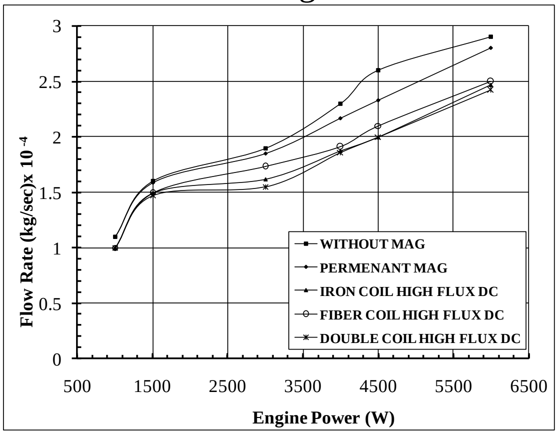

Figure (6.b) Effect of magnetic treatment on fuel flow rate using DC.

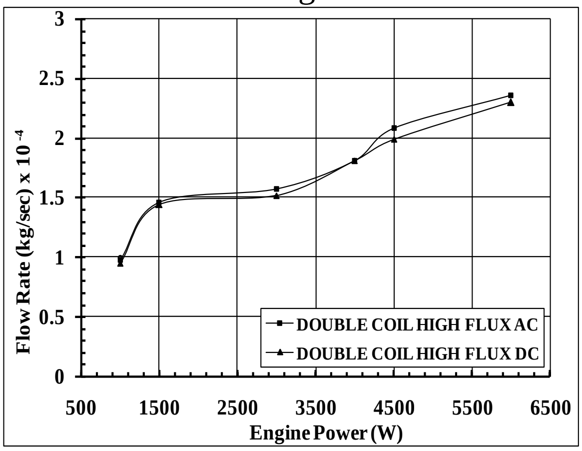

Figure (5.c) Comparison between AC and DC.

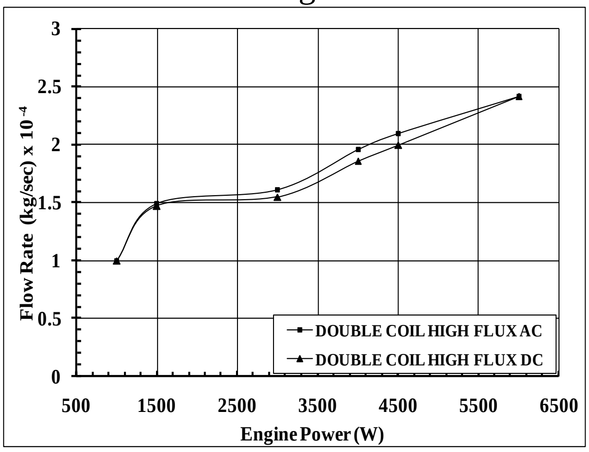

Figure (6.c) Comparison between AC and DC.

Figure (5) Effect of magnetic treatment on fuel flow rate using AC and DC current sources and maintaining the engine speed constant at the same power.

Figure (6) Effect of magnetic treatment on fuel flow rate using AC and DC current sources and maintaining the same throttling position at the same power.

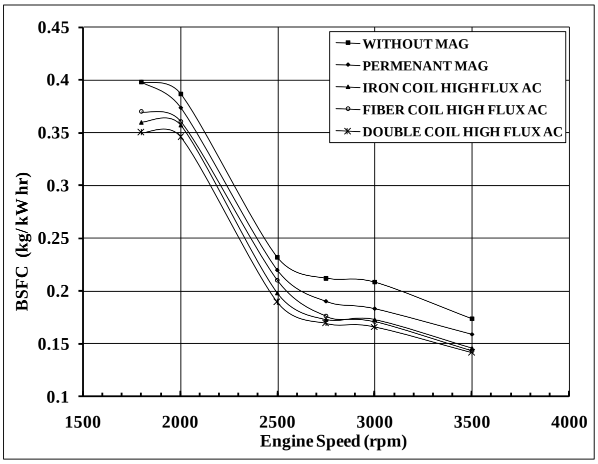

Figure (7.a) Effect of magnetic treatment on BSFC using AC.

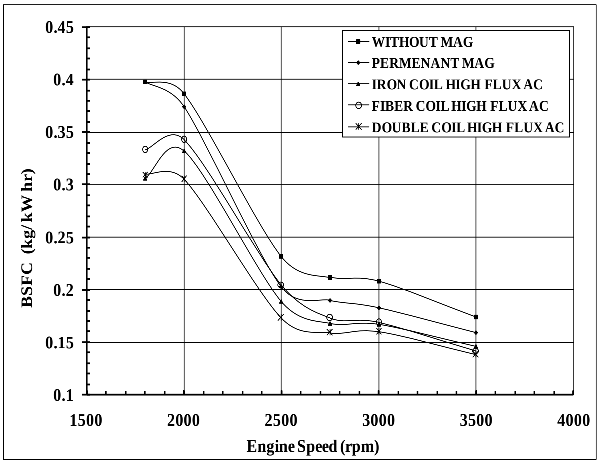

Figure (8.a) Effect of magnetic treatmen on BSFC using AC.

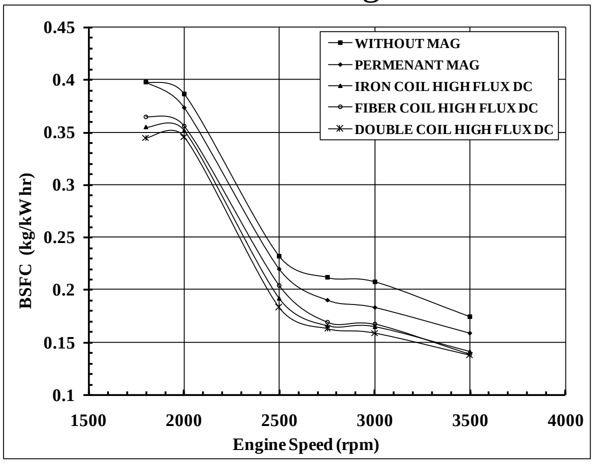

Figure (7.b) Effect of magnetic treatment on BSFC using DC.

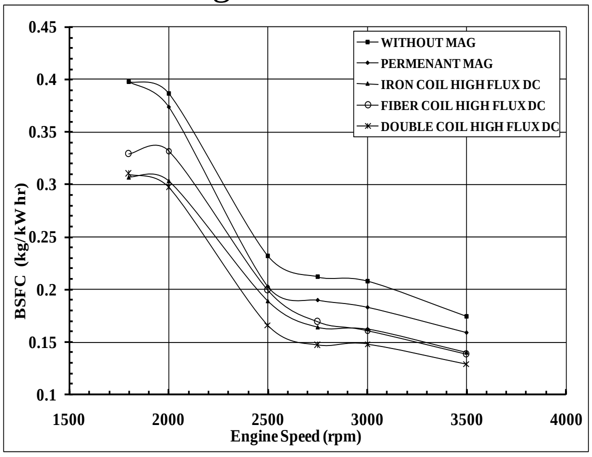

Figure (8.b) Effect of magnetic treatment on BSFC using DC.

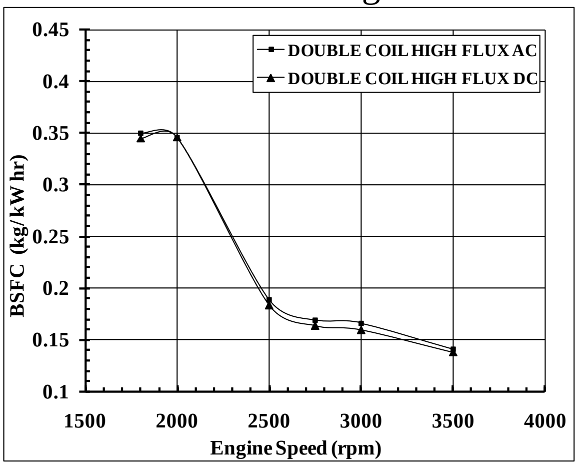

Figure (7.c) Comparison between AC and DC sources.

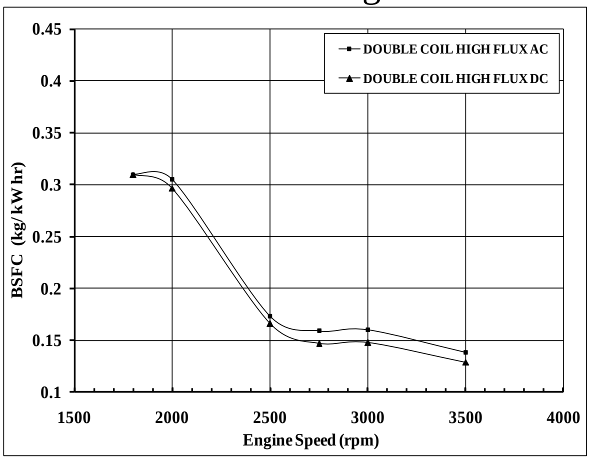

Figure (8.c) Comparison between AC and DC sources.

Figure (7.b) Effect of magnetic treatment on BSFC using DC and AC sources while maintaining engine speed at the same compared power.

Figure (8.a) Effect of magnetic treatment on BSFC using AC and DC sources and maintaining the same throttling position at the same power.

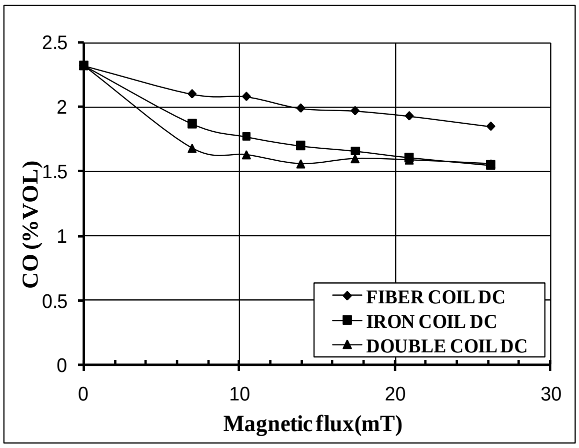

Figure (9-a) 1500 W, 2000 rpm.

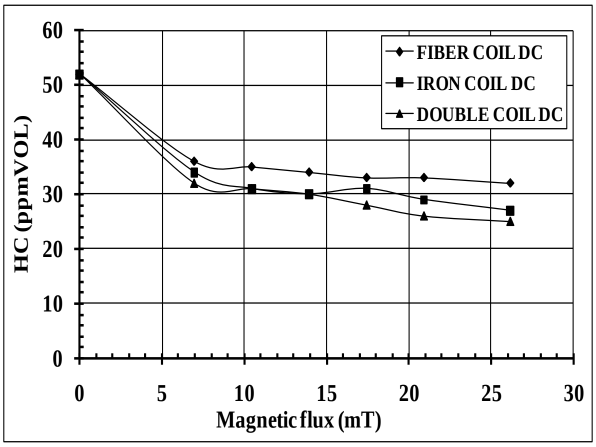

Figure (10-a) 1500W, 2000 rpm.

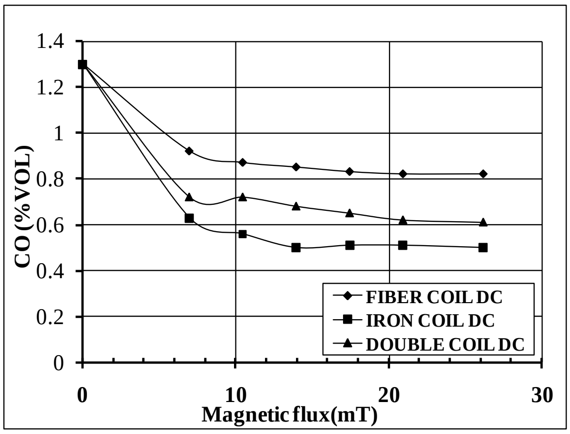

Figure (9-b) 3000 W, 2500 rpm.

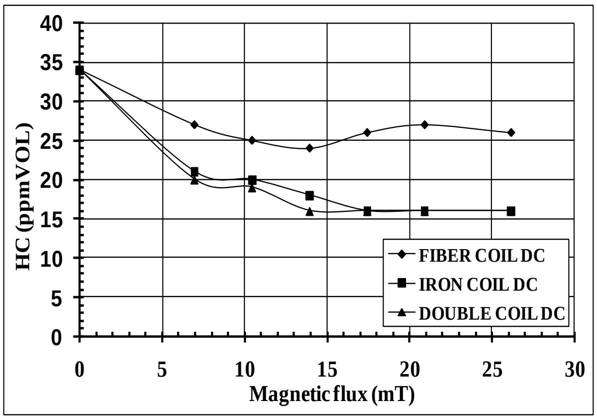

Figure (10-b) 3000W, 2500rpm.

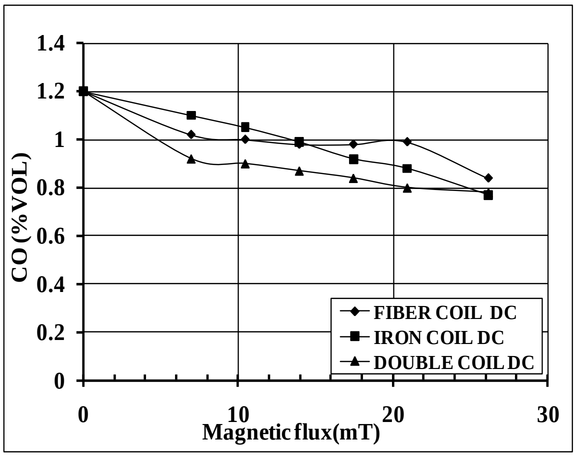

Figure (9-c) 4500 W, 3000 rpm.

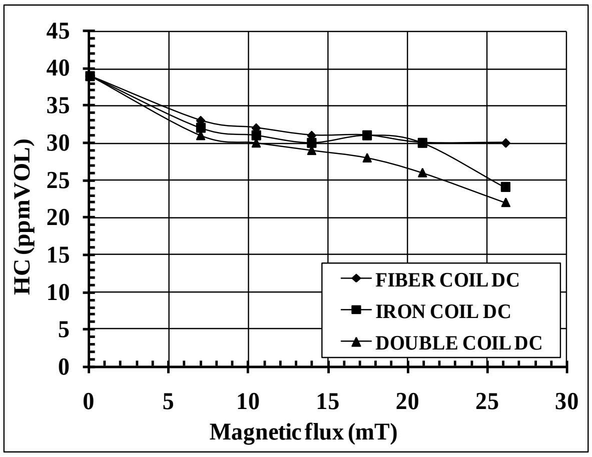

Figure (10-c) 4500W, 3000rpm.

Figure (9) Effect of magnetic treatment on CO emission using DC for different output powers and speeds.

Figure (10) Effect of magnetic treatment on HC emission using DC for different output powers and speeds

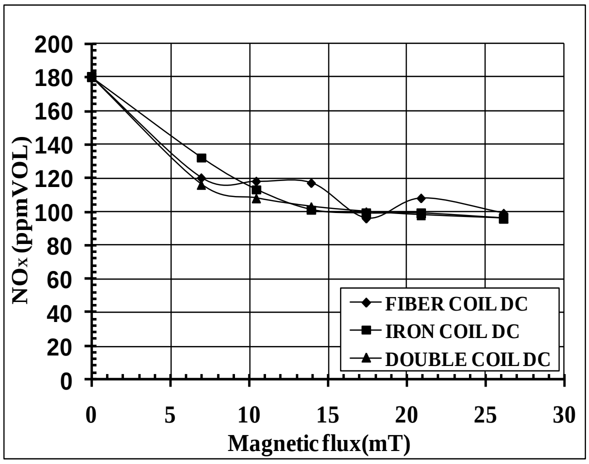

Figure (11-a) 1500 W, 2000 rpm.

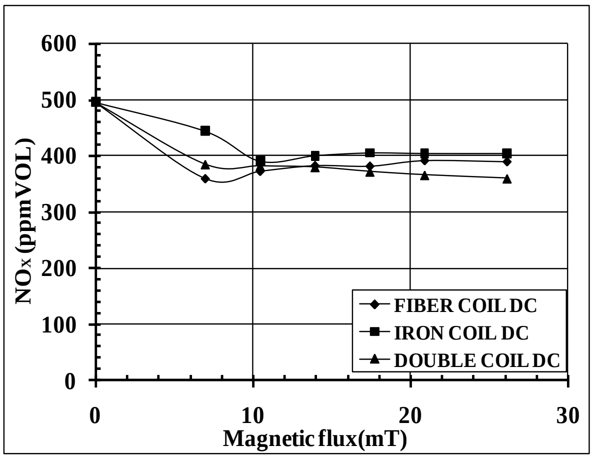

Figure (11-b) 3000 W, 2500 rpm.

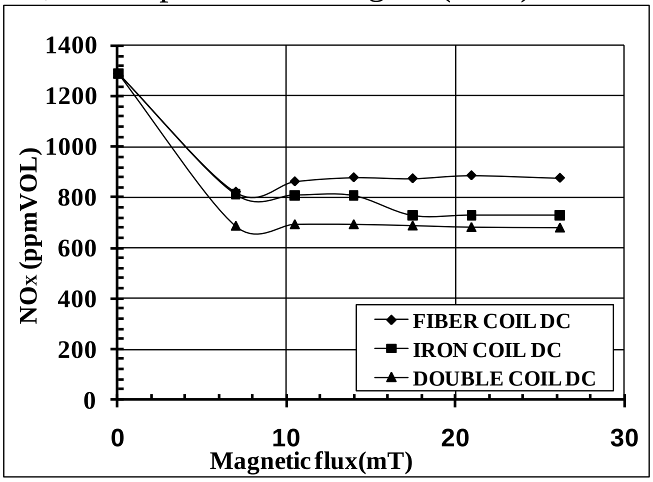

Figure (11-c) 4500 W, 3000 rpm.

Figure (11) Effect of magnetic treatment on NOx emission using DC at different output powers and speeds.

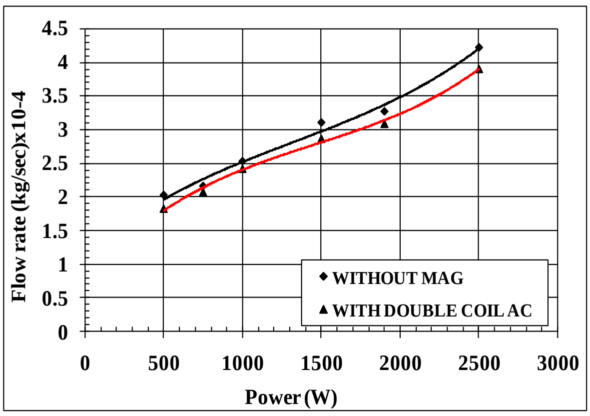

Figure (12): Effect of magnetic treatmen on fuel flow rate for NG.

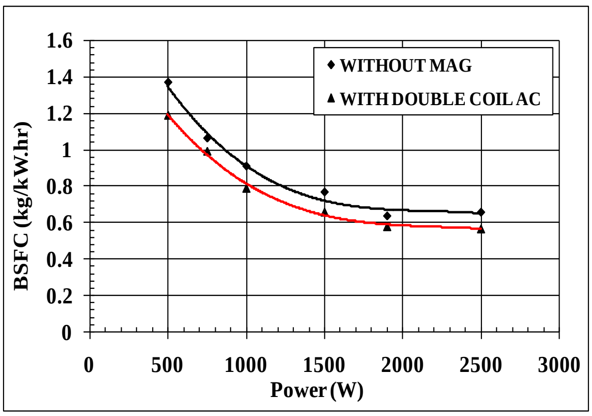

Figure (13): Effect of magnetic treatment on BSFC for NG.

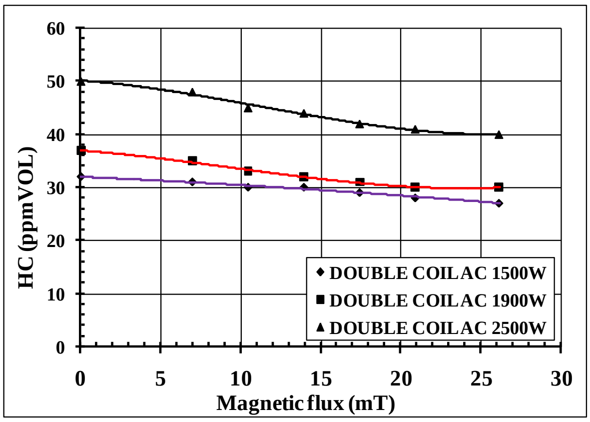

Figure (14.a) HC

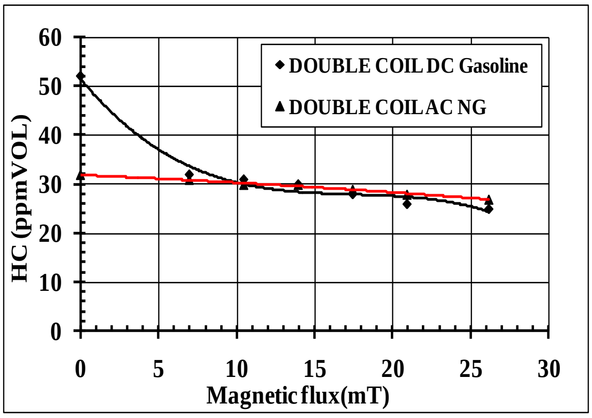

Figure (15.a) HC comparison.

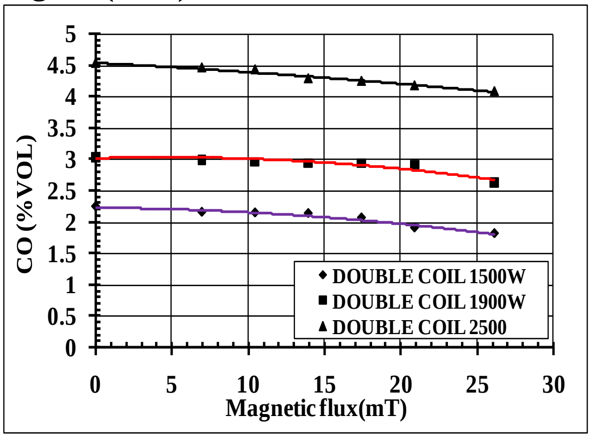

Figure (14.b) CO

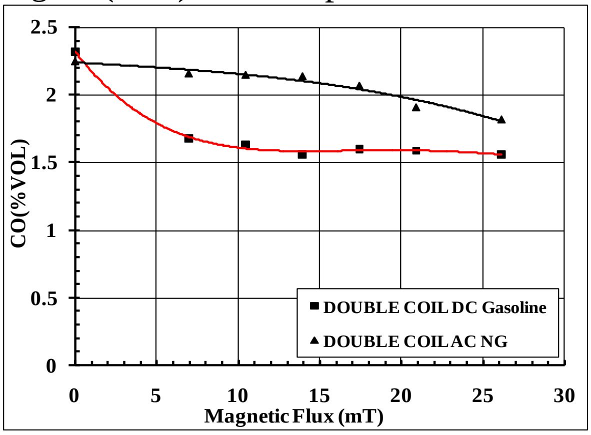

Figure (15.b) CO comparison

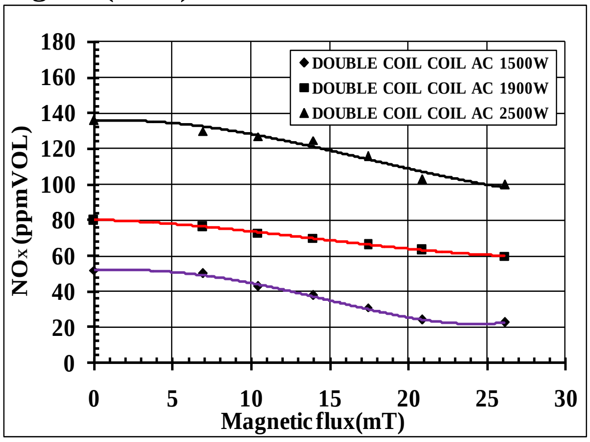

Figure (14.c) NOx

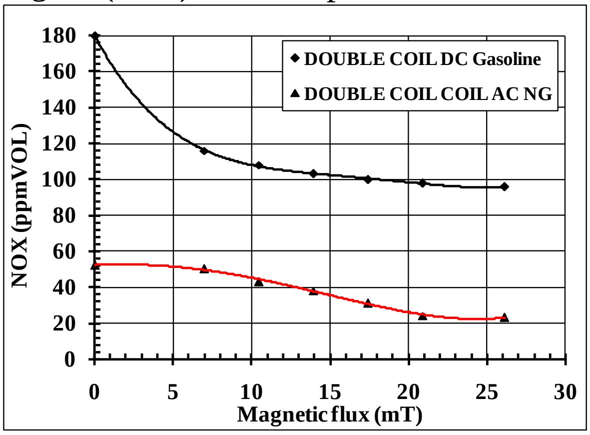

Figure (15.c) NO_x comparison

Figure (14) Effect of magnetic treatment on CO, HC, and NO_x for NG at 1500, 1900, 2500 Watts and variable speeds.

Figure (15) A comparison between the effect of magnetic treatment on gasoline and NG for engine emissions at the same conditions of λ =0.95, 1500W and maintaining engine speed at the same compared points.

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Appendix (A): A schematic diagram of the experimental setup