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(REVIEW ARTICLE)

Supplementary electrical generation from exhaust fumes of fuel combustion engines

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Abstract

In the advent of low poor power output in Africa and most developing countries the need for the generation of more power is paramount. Major proportion of power generated in most counties is from fuel combustion, therefore generating from the exhaust of these systems will be helpful. The objective of the work is to increase the power output of combustion engines with the use of Magneto Hydrodynamic (MHD) system. A test was run after construction and a thirty-five percent (35%) increase was achieved. The Magneto hydrodynamic system was constructed to have a hexagonal tapered form to enhance a more efficient output. An 800watts generator was used for the test running. Hence, conversion of waste heat into useful electrical energy.

Keywords: Waste heat; Power generation; Energy efficiency; Magneto hydrodynamics; Useful electrical energy.

1. Introduction

Clean energy is not a single industry instead involves a wide variety of very different industries. Some of the broad sub sectors under clean energy include solar power, fuel cells, geothermal power, wave/tide power, bio-fuels, cleaner coal, and power efficiency (Asplund, 2008). In Asplund's work the power efficiency sub sector is being considered knowing that the extra inefficient power is a waste both detrimental to the Environment and the Economy.

According to Asplund, 'The U.S energy information administration is fully expecting double fuel consumption by 2030.' The simple fact is that burning fossil fuels, whether in power plants or in internal combustion engines, releases CO_2, other greenhouse gases, and various contaminants into the atmosphere, causing pollution and global warming problems. Energy hence needs to be derived from cleaner sources that avoid these problems (Asplund, 2008).

Since the origin of man there has always been a concern for energy production for the purpose of warming, cooking, lighting, etc. This has eventually caused man to develop heaters, turbines, stoves, etc, which have released a lot of harmful gases which are now becoming increasingly uncontrolled (Riebeek, 2010). The Magneto hydrodynamic system has been found to be beneficial in the reduction of these gases from the exhaust of engines. The work reported here is part of a wider study whose objectives are as follows:

- Design and Construction of MHD system.
- Performance evaluation of the MHD system.

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2. Project Justification

The study is intended for both diesel and petrol engines but because of some limitations we will concentrate our research on petrol engines. Petrol is got from petroleum which is a non-renewable fuel. It has a complex mixture of hydrocarbons that boils below 180^0C. The hydrocarbon constituents are those that have 4-12 carbon atoms in their structure (EPA, 1998).

Exhaust emission from petrol-driven cars include, in addition to carbon (iv) oxide (CO_2), water vapor, hydrocarbons, nitrogen oxides and carbon (ii) oxide (CO). The latter emissions may effectively be reduced by fitting a three-way catalytic converter that converts these three types of exhaust components into less reactive substances like potassium carbonate or potassium nitrate. When there is enough oxygen, hydrocarbons can be burnt to form CO_2 and water vapor releasing heat.

3. Literature review

Human influence has led to warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. This rise has been solely caused by the excess production of carbon (iv) oxide which this work sort to reduce. This evidence for human influence has grown since 2007. It is extremely likely (95-100%) that human influence has been the dominant cause of the observed warming since the mid-20th century.

Recent estimates by NASA's Goddard Institute for Space Studies (GISS) and the National Climatic Data Center show that 2005 and 2010 tied for the planet's warmest year since reliable, widespread instrumental measurements became available in the late 19th century. The World Meteorological Organization (WMO) statement on the status of the global climate in 2010 explains that, "The 2010 nominal value of +0.53 °C ranks just ahead of those of 2005 (+0.52 °C) and 1998 (+0.51 °C), although the differences between the three years are not statistically significant". Every year, from 1986 to 2013 has seen annual average global land and ocean surface temperatures above the 1961–1990 average (Trenberth*, 2007*).

On Earth, one is surrounded by the three normal states of matter, namely solids, liquids and gases, but if the temperature of gas is too high it becomes plasma or ionized gas, the fourth state of matter. Most of the universe is in the plasma state, and the main way that plasma differs from a normal gas is in the subtle and complex interaction it has with a magnetic field, responsible for much dynamic behavior (Le, 2007). The Magneto hydrodynamic system works best with plasma which we got by ionizing the exhaust fume with Potassium hydroxide.

On large scales the plasma behaves like an ideal medium, with little or no resistive dissipation of any form, and hence no significant magnetic diffusion and reconnection. So the plasma elements preserve their magnetic connections. On the other hand, magnetic stresses can create thin localized regions of small thickness say wherein the steepened field gradients create intense electric currents and non-ideal effects e.g. resistive dissipation. Hall Effect, etc become important. The Hall Effect was controlled by the tapering of the Magneto hydrodynamic pathway in this work as shown in Figures 3, 4 and 5. Here magnetic field line reconnection can take place, since the magnetic connectivity of the plasma elements is not preserved in the ensuing evolution (Barbu,, 2003).

For many purposes, the behavior of plasma and magnetic fields is described by Magneto hydrodynamics (MHD for short) and in this article we shall focus on the MHD of magnetic reconnection. MHD is a macroscopic theory that is valid when the smallest length-scale, namely the width of the diffusion region, is larger than the mean-free path for collisions. When this condition fails, collision less plasma processes come into play (Le, 2007).

The combined cycle is an assembly of heat engines that work in tandem from the same source of heat, converting it into mechanical energy, which in turn usually drives electrical generators. This is normally in electric power generation. The principle is that after completing its cycle (in the first engine), the working fluid of the first heat engine is still low enough in its entropy that a second subsequent heat engine may extract energy from the waste heat (energy) of the working fluid of the first engine. By combining these multiple streams of work upon a single mechanical shaft turning an electric generator, the overall net efficiency of the system may be increased by 50 – 60 percent. That is, from an overall efficiency of say 34% (in a single cycle) to possibly an overall efficiency of 51% (in a mechanical combination of two (2) cycles) in net Carnot thermodynamic efficiency. This can be done because heat engines are only able to use a portion of the energy their fuel generates (usually less than 50%). In an ordinary (non combined cycle) heat engine the remaining heat (e.g., hot exhaust fumes) from combustion is generally wasted (Yadav, 2002).

The practically successful combined cycles have used hot cycles with mercury vapor turbines, Magneto hydrodynamic generators or molten carbonate fuel cells, with steam plants for the low temperature "bottoming" cycle. Bottoming cycles operating from a steam condenser's heat exhaust are theoretically possible, but uneconomical because of the very large, expensive equipment needed to extract energy from the small temperature differences between condensing steam and outside air or water. However, it is common in cold climates (such as Finland) to drive community heating systems from a power plant's condenser heat. Such cogeneration systems can yield theoretical efficiencies above 95% (Yadav, 2002).

The viability of the combined cycle is of great importance and use. The MHD makes use of the product of combustion of a Gas Turbine Plant or a steam Turbine plant coal-fired or natural gas fired (these are energy sources in abundant quantities in Nigeria), (Layerni, 2006).

4. Material Selection for Construction

The Magneto hydrodynamic system constructed will encounter a corrosive environment, since the gas contains some reactive Nitrogen Oxides substances, hence the material (flat bricks) must be corrosion resistant, this is why the bricks are used inside is to ensure that the channel is resistant to corrosion. There is also need for heat resistant material, since the exhaust fume is normally hot with temperatures up to 120 ^{0}C depending on the machine. Here, the bricks inside solves the problem. The bricks are measured to match with the internal dimension of the constructed Magneto hydrodynamic system shown in Fig. 1. The channel frame and the funnel is made of gauge 17 iron sheet to ensure maximum strength needed for the constructed Magneto hydrodynamic system, since its inside is made of bricks which are breakable. The design hence adopts a two-layer system to ensure that cost is reduced and efficiency is maximized.

The magnets used are Alnico 8(cast) of density 7.3g/cm^3, 8200Guass residual induction, 550^{o}C normal maximum operating temperature details are as described in Appendix. This was selected because it has recommended high operating temperature; also the magnetic strength was higher than the next available option.

The bolts and screw used also were consider because they were strong enough to hold the iron sheet , taking advantage of the smallest possible size of bolt and screw, to minimize both cost and space inside the Magneto hydrodynamic system. The red oxide was used to paint the outside just to beautify it, and red oxide was used because it can withstand heat and harsh environment more than ordinary paint.

The potassium and sodium were the salts used for the running of the tests. The tests were ran intermittently with five (5) milligram of the salt, which was found to even remain after running the test for one hour.

Table 1 List of Materials of Construction

S/N	Material	Purpose	Qty
1.	Magnets (5x5 mm)	For the MHD duct	30
2.	Flat Bricks	For insulation of MHD duct	30
3.	25mm Bolts & Screws	To hold magnets	60
4.	Potassium	Catalyst	0.001 Kg
5.	Sodium	Catalyst	0.001 Kg
6.	Iron Sheet (Gauge 17)	For construction of MHD duct and funnel	1 length
7.	Electrode	Welding of the iron sheet	1 packet
8.	Red Oxide	For painting	cup

5. Design Goals/Considerations

The design considerations taken were firstly, the energy conservation law in equation 1, which states that for a body in motion to come to rest the must be a repelling force (friction), hence this force converts the energy of the exhaust fume in kinetic form represented by the density multiplied by the velocity of the exhaust fume (ρu), into heat as represented by the change in temperature multiplied by the density of the exhaust fume ($\partial t\ \rho$). This forms the basis of the Magneto hydrodynamic system, since the main objective is to convert the abrasion energy from the movement of the exhaust fume into useful energy.

Secondly, the law of conservation of momentum in equation 2 is considered for the resolution of the continuing ionized exhaust fume, in which (∂t ρu) and (ρuut)represents the momentum within the Magneto hydrodynamic system. The P in the equation 2 represents the external pressure of the exhaust fume leaving the Magneto hydrodynamic system.

Thirdly, the induction equation, equation 3 measures the magnetic induction energy transferred into the Magneto hydrodynamic system. Fourthly, the conservation of energy law, equation 4, similar representation of the conservation of mass, is used in the calculation of the energy tracked down by the Magneto hydrodynamic system.

Fifthly, the divergence law, equation 5 is used to compute the current trapped by the Magneto hydrodynamic as shown Fig. 2. The general representation of the flow of the exhaust fume (gas) in diagrammatic form is shown in Fig. 2.

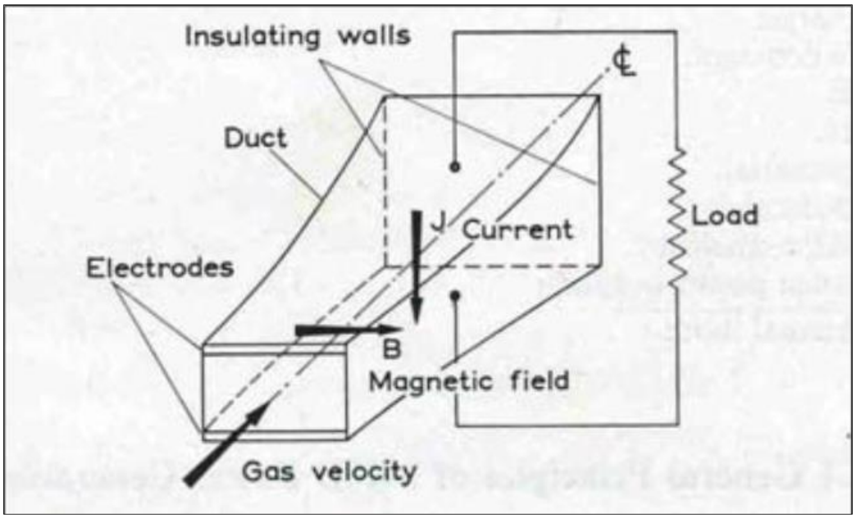

Figure 1 Schematic arrangement of an MHD duct

The compressible flow of an electrically-conducting fluid is described for the inviscid case by the equations 1 to 4 (Tillack etal., 1998).

$$\partial t\, \rho + \rho u = 0 \text{ (Conservation of Mass) } \ldots\ldots\ldots\ldots\ldots\ldots \text{ (1)}$$

$$\partial t\, \rho u + \rho uut + P = 0 \text{ (Conservation of Momentum) } \ldots\ldots\ldots\ldots\ldots\text{(2)}$$

$$\partial t\, B + uBt + But = 0 \text{(Induction Equations) } \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(3)}$$

$$\nabla \cdot \mathbf{B} = 0. \text{(Divergence Constraint) } \ldots\ldots\ldots\ldots\ldots\ldots \text{ (4)}$$

Where, u is the velocity, ρ is the density, P is the pressure, B is the magnetic field, and e is the total energy.

The basic electrical characteristics of MHD generators are power output of W, which is shown in Eqn. 5 and is generated in the working fluid volume. The local electrical efficiency η, as shown in Eqn. 6 is equal to the Electrical output density.

$$W = \int J.E.dV \ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

$$\eta = \rho \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(6)}$$

The Electromagnetic body force power density F, represented in equation 7 is a fundamental equation in the calculation of the force on the walls of the constructed Magneto hydrodynamic system. This equation 7 is known as the Lorentz Force Law, the charge of the particle Q, is computed from the YX -36TRN Multi-tester meter measurements. The velocity of particle V, is computed from the SOX3 gas meter measurements, whiles the magnetic field B, is given in the properties of the magnet used.

F = QVB(Tillack etal., 1998)………………… (7)

From the above force equations it is observed that the performance of the MHD systems is dependent on the

- Length of the channel,
- The ionization of the fluid,
- Strength of the magnetic field, and
- Velocity of the fluid flow.

The electrical power output for each trial was measured by 195 wave Tek arbitrary equipment shown in figure 2 below, to read directly the electrical voltage output, the electrical current, and the magnetic properties of the Electrical circuit. The properties and measuring characteristics of this 195 wave Tek arbitrary equipment is as shown in Appendix. The values were analyzed to give the result in figure 3.

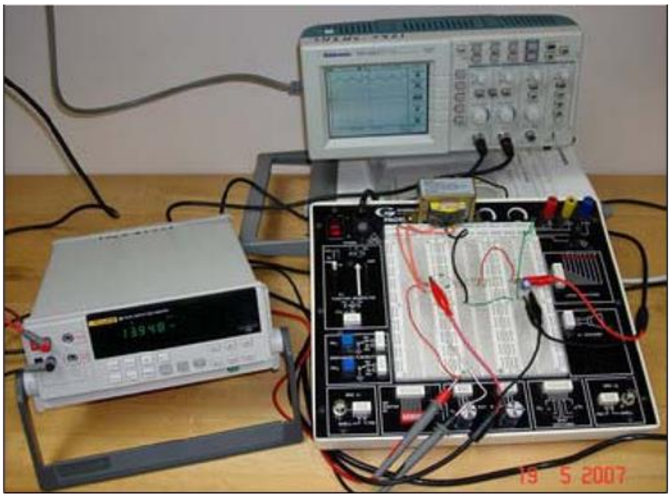

Figure 2 Electrical waveform equipment

6. Results and Discussion

According to Nagrath etal.. " if a generating system operating below the limit of steady stability condition as shown on equation 8, it may continue to oscillate for a long time if the damping is low" (Nagrath etal., 1994), In other words the stability of a generator or a generating set stabilizes in seconds as long as this condition is maintained. This explains why the efficiency remained constant, and hence has no need for the running of the generator more than thirty minutes during the tests.

$$(\partial P_w/\partial \delta)_0 > 0 \text{………………(8)}$$

Where;
P_w = useful power (work) and
δ = Torque angle.

Table 2 Average Electrical Conductivity Result

	Without MHD system	With MHD system
Voltage	Nil	-20-Volts Instantaneous Voltage
Resistance	Nil	Constant 5kΩ

Table 3 Average Sooth Content Result

Without MHD system	With MHD system
0.340grams	0.250grams

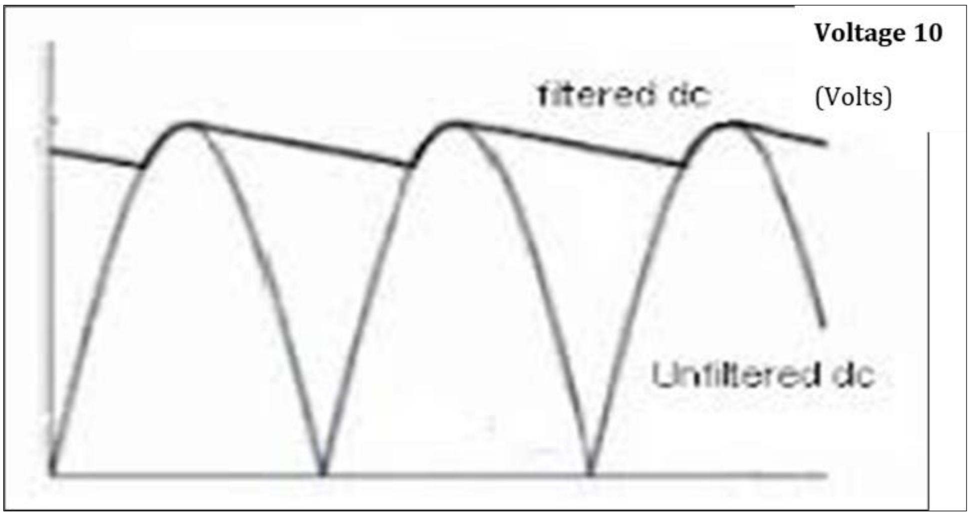

Figure 3 The output waveform

6.1. Electrical Analysis of the constructed system

A constant value of 5kΩ resistance was observed using the yx- 360 TRN Multi-tester. Also a negative 20-volts voltage shown in table 2 was observed immediately the testing generator was started. This voltage came up and went back to zero within the first 30 seconds, and never came back in subsequent measurements. The interaction of moving conducting fluids within electric and magnetic fields provides for a rich variety of phenomena associated with electro-fluid-mechanical energy conversion. Effects from such interactions can be observed in liquids, gases, two-phase mixtures, or plasmas. Numerous scientific and technical applications exist, such as heating and flow control in metals processing, power generation from two-phase mixtures or seeded high temperature gases, magnetic confinement of high-temperature plasmas — even dynamos that create magnetic fields in planetary bodies. It is important to note that a magnet loses its magnetism to produce the Electrical power (Tillack etal., 1998).

The no**r**mal plots of Efficiency in Fig. 4, there was an increase from 83% to 87% on the average, this shows that the combustion efficiency of the Generator was increased by this margin. The Normal plots for exhaust temperature Fig. 5 showed a reduction of the exhaust temperature from 264.53^{o} C to 109.53^{o} C on the average. While the Excess-air plot for both system shown had only values for the non attachment of the MHD system. This is because the catalyst (Potassium hydroxide) used, reacted with all Carbon (iv) oxide and therefore prevented the need for excess air in the conversion of Carbon (iv) oxide from Carbon (ii) oxide.

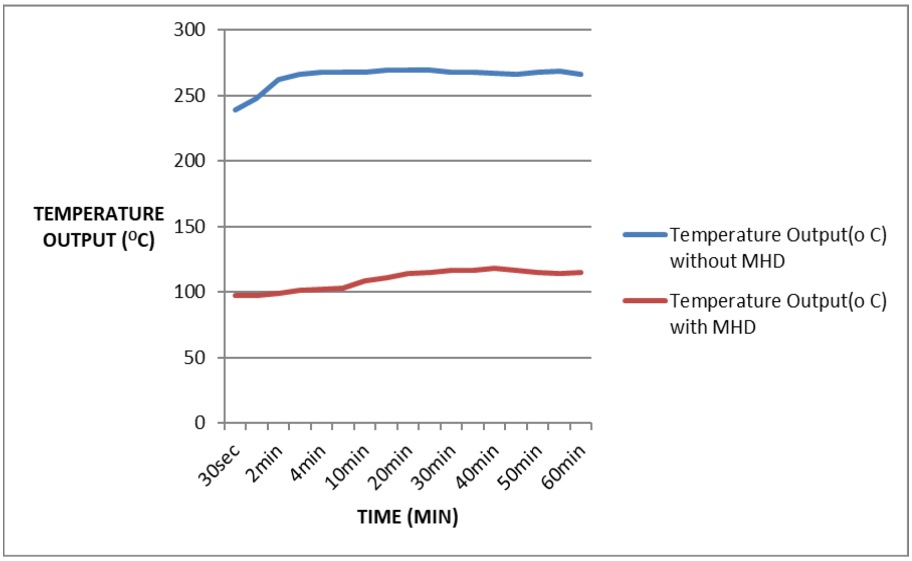

Figure 4 Plot of Temperature Output verse time

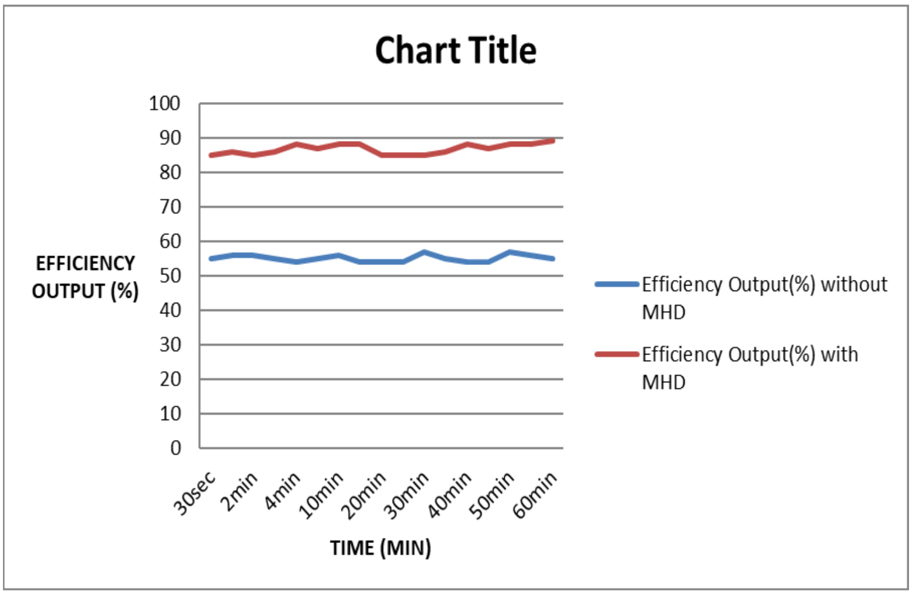

Figure 5 Plot of Efficiency Output verse time

These plots figures 4 and 5 show that the attachment of the Magneto hydrodynamic system was beneficial to both the environment and the generator used as was mentioned earlier. It in fact eliminated the production of Carbon (iv) oxide which was the main aim of this research.

The analysis of Covariance (ANCOVA) combines the traditional analysis of variance (ANOVA) and the Regression analysis. The ANCOVA hence, is recommended when an experimenter suspects that certain uncontrolled, but measurable character(s) his/her experiment would influence his/her treatments and probably make interpretation of his/her result difficult (Obi, 1995). The general Covariance Analysis results in Table 4.

A Matlab program was written for the computation of the different equations for the analysis of covariance (ANCOVA) of the two sets of results, and the Table 4.4 shows the different sum of squares, deviations about regression, and the difference for testing adjusted variety means. From the total difference for testing adjusted variety means value of 14777.98 which is one hundred times the computed value 150, it is thus proved that the addition of the constructed Magneto Hydrodynamic (MHD) system is ten times recommended. The major purpose for the Matlab program is to make the project adaptable to different environments, different sizes of Generators and different forms of fuels – Petrol, Diesel, etc. Since the Matlab program runs with an Excel data sheet of which values could be adjusted for different situations/purposes.

Table 4 General Covariance Analysis Results Table of an RCBD Experiment of Flue Gas

		Sum of Squares and Products			**Deviations About Regression**		
Source	D.F	$\sum x^2$	$\sum xy$	$\sum y^2$	$\sum x^2 - (\sum x^2)/\sum x^2$	D.F.	Mean Square
Blocks	16	68.66	71.85	199.46	484.09	63	7.68
Treatments	4	757285.15	299351.28	177438.21			
Error	64	1239.07	575.28	751.18			
Treatment + Error	68	758524.23	299926.56	178189.38	59596.02	67	889.49
Difference for testing adjusted variety means					59111.93	4	14777.98

The cost estimate shown in the Appendix 1 has the details of the quantity and cost of the 800Watts Generator used, the cost and quantity of Magnets, the cost and quantity of flat Bricks, the quantity and cost of Bolts and Screws, the quantity and cost of Potassium hydroxide, the quantity and cost of Iron sheet, the quantity and cost of Electrode, and the quantity and cost of the red oxide. Also, in the Appendix 1 is seen, the period used in the construction, and performance evaluation of the constructed Magneto hydrodynamic system. There it is seen that two weeks was used for the design, four weeks for the fabrication, two weeks for testing and performance evaluation, and three weeks for laboratory tests, in all giving a total of eleven weeks.

7. Conclusion

The work succeeded in generating a total of 40% of the output of the 800Watts generator from the exhaust fume of the generator. It is also seen that the voltage waveform of the constructed Magneto hydro dynamics system is a ripple free waveform.

With the advent of environmental decay, the work is very beneficial because not only was extra energy generated but the environment was also mitigated.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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