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AUTOMOTIVE MHD BY IONIZING THE EXHAUST GAS: AN INSPIRING CONCEPTION

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ABSTRACT

It is really mortifying to hear the fact that only 30% of the energy from the fuel used reaches the wheels of a typical automobile implying most of the remaining energy is lost as heat. Since most of the energy consumed by an internal combustion engine is wasted, capturing much of that wasted energy can provide a large increase in energy efficiency. So the possibilities of where and how to capture this lost energy are matters of great significance. Also the situation now existing in internal combustion engines is that a part of the engine power generated is consumed by the alternator incorporated in the automobile which leads to an increase in fuel consumption of the engine. So there persists before us a challenge to come up with a new technique that would help in efficient utilization of fuel in automobile. The plan opted for was to incorporate an Magneto Hydro Dynamic (MHD) power generation unit in the exhaust pipe line which actually is a device that converts the energy loss through exhaust into useful electric power by making use of the Faraday's effect. This device works on the basis of magneto hydro dynamic power generation and it is a new unique method of power generation. Working of this device is by converting thermal energy and kinetic energy of gases into electrical energy. Externally added ions to the fast moving gases are allowed to pass through an externally applied magnetic field. This will give rise to generation of electric power on the plates kept at the sides.

Keywords: Magneto Hydro Dynamics, Exhaust Gas Temperature, Exhaust Gas Heat Recovery, Magnetic Flux, Gas Velocity.

I. INTRODUCTION

In the last years the rapid rise in the use of electric power has raised the problem how to provide the power increases. From sector studies the total electrical power consumption has almost doubled in the last twenty years. The problem of finding appropriate technologies to produce cheap

energy and ensure the right standard of environmental compatibility has in recent years led to an increase in technological progress. Nowadays electrical energy is the form of energy to which all other forms of energy may be converted. It is easy to transport, easy to control and easy to transform. Most of the times, however, energy can be converted into electricity only through many intermediate transformations, which leads to limitations in efficiency, reliability, and compactness. The critical point in general in the energy conversion is the combination of heat and mechanical energy of the conversion system, which limits the maximum temperature involved. To avoid the mechanical limitations it seems promising to convert directly heat into electricity.

We all know that it is a matter of global concern regarding the depletion of fossil fuels like petrol, diesel, natural gas etc. because of their extreme need in many of the practical applications such as in automobiles, aircrafts, power plants, locomotives etc. Especially when dealing with automobiles, the use of fuels like diesel and petrol for its running is just inevitable. These fuels have their applications in internal combustion engines of automobiles to derive power required for motion. But the problem that protrudes out from the studies conducted is that about 70% of the energy derived from the fuel is lost as heat which implies that only 30% proves beneficial for a vehicle's running. Since most of the energy consumed by an internal combustion engine is wasted, seizure of much of this wasted energy can provide a large increase in energy efficiency. For example, a typical engine producing 100 kilowatts of driveshaft power expels 68 kilowatts of heat energy through the radiator and 136 kilowatts through the exhaust. So the prospects of where and how the capture of this lost energy is accomplishable are matters of great significance. Also the enduring situation in internal combustion engines of a part of the engine power generated being consumed by the alternator incorporated in automobile leads to an increase in fuel consumption of the engine. So there persists before us a challenge to come up with a new technique that would help in efficient utilization of fuel in automobile.

The strategy adopted was to amalgamate a Magneto Hydro Dynamic (MHD) power generation unit to the exhaust pipe line, thereby generating electric power which would thus replace the use of a conventional alternator and hence provide an efficient means of fuel management. Magneto hydro dynamics is the physical-mathematical framework that concerns the dynamics of magnetic fields in electrically conducting fluids, e.g. in plasmas and liquid metals. The word magneto hydro dynamics is comprised of the words magneto- meaning magnetic, hydro- meaning water (or liquid) and dynamics referring to the movement of an object by forces. Synonyms of MHD that are less frequently used are the terms magneto fluid-dynamics and hydro-magnetics. Yet an another factor that is propitious to the proposed methodology is that there are no moving parts incorporated in this method, thereby energy losses due to friction are next to zero. Hence the MHD power generation technique considerably has a higher efficiency.

II. WORKING PRINCIPLE

A. Faraday's Law of Electromagnetic Induction

Electromagnetic induction is the production of a potential difference (voltage) across a conductor when it is exposed to a varying magnetic field. Faraday's law of induction is a basic law of electromagnetism predicting how a magnetic field will interact with an electric circuit to produce an electromotive force (EMF). It is the fundamental operating principle of transformers, inductors, and many types of electrical motors, generators and solenoids.

B. Fleming's Right Hand Rule

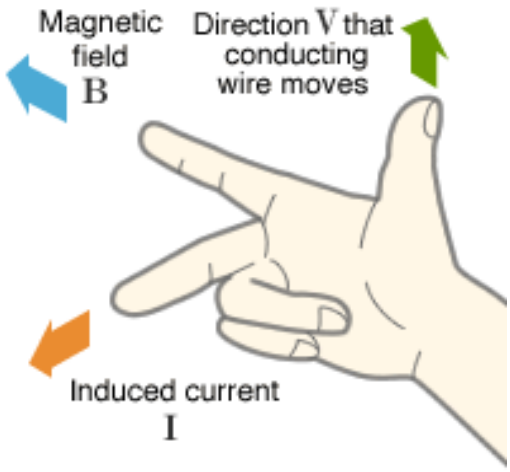


Figure 1: Fleming's Right Hand Rule.

Fleming's right hand rule (for generators) shows the direction of induced current when a conductor moves in a magnetic field.

The right hand is held with the thumb, first finger and second finger mutually perpendicular to each other (at right angles), as shown in the diagram.

The thumb represents the direction of motion of the conductor. The first finger represents the direction of the field (North to South). The second finger represents the direction of the induced or generated current (the direction of the induced current will be the direction of conventional current; from positive to negative).

C. Magneto Hydro Dynamic (MHD) Power Generation

MHD portraits the study of the interaction of magnetic fields and electrically conducting liquids or gases, such as molten metal or plasma. According to Faraday's law of electromagnetic induction, when an electric conductor moves across a magnetic field, a voltage is induced in it which produces an electric current. In MHD generator, the solid conductors are replaced by a gaseous conductor, to be specific, an ionized gas. A suitable seed is used to ionize the gas. When this ionized gaseous conductor is moved so as to cut the lines of magnetic induction, the charged particles in the conductor experience a force in a direction mutually perpendicular to the magnetic field (B) and to the velocity of the conductor (V). The negative charges tend to move in one direction, and the positive charges in the opposite direction. This induced electric field, or motional EMF, provides the basis for converting mechanical energy into electrical energy. The EMF is perpendicular to both V and B according to the Fleming's Right hand rule and induced electromotive force is found out by,

Induced EMF, $E = q. (\vec{\mathbf{V}} \times \vec{\mathbf{B}})$

Where,
'q' is the charge density.

From the relation above it is evident that large EMF is induced, if the applied magnetic flux density, charge density and gas velocity are high.

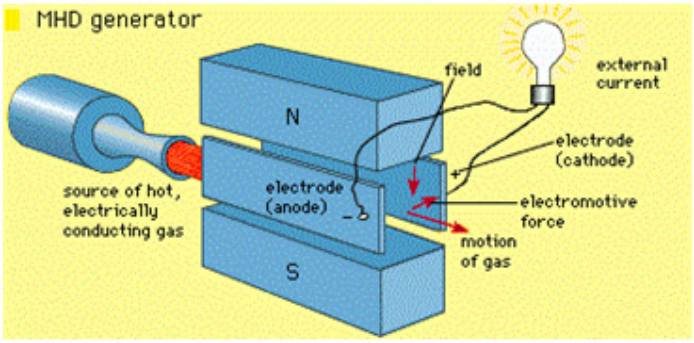


Figure 2: Principle of MHD.

III. DESCRIPTION OF THE FABRTICATED MHD POWER GENERATOR

Figure 3: Model of the Fabricated MHD Generator.

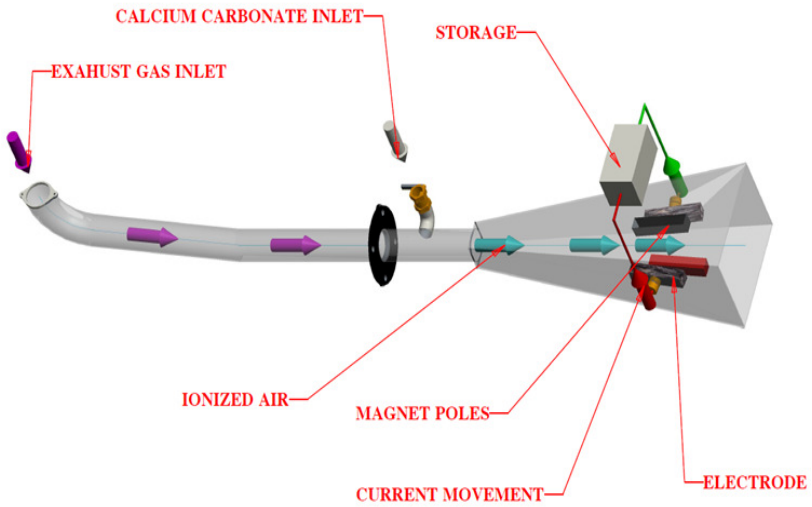
Figure 3. shows the fabricated model of MHD power generation unit for automobiles. The model was designed for Hero Honda Passion Plus having exhaust pipe diameter of 27 mm. Structural steel was used for the construction of the generator body. The nozzle forms an integral part of the MHD generator. The length of the MHD channel is 250 mm. The generator has a tapered cross-section. The height and width of the outside tapered portion through which the exhaust gas comes out are 80 mm and 110 mm respectively. The control valve through which ionized seed is added has an inlet diameter of 19 mm.

Figure 4: Placement of Magnets and Metallic plates in the MHD Generator.

Figure 4. shows the placement of magnets and the metallic plates inside the MHD generator. Magnets used are ferrite core magnets and the metallic plates are made of mild steel. From the figure, it is pretty much clear that the magnetic field acts in a perpendicular direction towards the direction of ionized gas velocity. Magnets are placed parallel to each other such that the magnetic flux gets doubled. Metallic plates are placed in such a way that the EMF induced on the plates would be mutually perpendicular to the ionized gas velocity and the magnetic field.

Figure 5: Top view of the MHD Generator.

IV. 3D MODEL OF THE MHD POWER GENERATOR FOR AUTOMOBILES



The 3D model of the MHD generator for automobiles was designed using the design software, Creo Elements/Pro (formerly known as Pro/ENGINEER), PTC's parametric, integrated 3D CAD/CAM/CAE solution, which is used by discrete manufacturers for mechanical engineering, design and manufacturing.

V. WORKING OF THE DESIGNED MHD GENERATOR

The MHD power generation unit is amalgamated to the exhaust manifold of the automotive engine through which the exhaust gas rushes out. Calcium Carbonate, as the seed is added through the inlet of a control valve in the passage of automobile exhaust gas to ionize the gas and hence to

increase its electrical conductivity. The reason for choosing Calcium Carbonate ($CaCO_3$) as the seed was that it is less polluting and more readily available compound compared to some other compounds like Zinc Carbonate ($ZnCO_3$), Sodium Carbonate (Na_2CO_3) etc. that were considered preferable as the ionizing seeds. Apart from these criteria the most important criteria was that of the exhaust gas temperature available for ionizing the seed. In two wheelers the available exhaust gas temperature range was around 150-200℃ and in case of four wheelers it ranges about 600-1200℃. Calcium Carbonate was found to be apt to be used as it has an ionization temperature of around 600℃ and it also partially ionizes around the temperature range of 150-200℃.

This velocity of the ionized exhaust gas is increased using a nozzle which is integrated to the MHD power generator and is then allowed to pass through a perpendicular magnetic field produced by a ferrite core magnet placed at the top and bottom of the MHD generator setup. Metallic plates made of mild steel are placed at the sides of the generator setup. By Faraday's law of electromagnetic induction and on the basis of magneto hydro dynamics, an EMF is induced on the metallic plates which can be used to generate current and utilized to operate loads.

VI. EXPERIMENTAL NOESIS OF THE MHD POWER GENERATOR

As a part of preliminary testing of the fabricated MHD power generation specimen and in order to affirm that the MHD generator is working without any flaws, the MHD generator was attached to the exhaust port of a single cylinder four stroke engine of a Hero Honda Passion Plus motorbike. The generator was attached to the exhaust port by removing the silencer of the two wheeler. The metallic plates placed on both sides of the MHD generator have copper wires soldered to them and this can wires can be directly connected to a multimeter to measure the induced voltage. Ferrite core magnets were placed at the top and bottom inside the MHD generator. The field strength of each magnet was 0.075 Tesla.

The engine was put into operation by starting the bike, and made to run for some time until it attained the idling speed. The seed, i.e. calcium carbonate was slowly added through the inlet of the control valve once the engine idling speed was attained. The temperature of the exhaust gas at the exhaust port was measured to be 153℃. The velocity of ionized exhaust gas was found out using an anemometer and it was found to be 5 m/s. The exhaust temperature was found to be as soon as the ionized gas started passing through the magnetic field, the digital multimeter started showing variation in readings indicating the generation of induced voltage.

A. Experimental Result

After the experiment conducted on the two wheeler it was found that the maximum induced voltage measured from the digital multimeter was measured to be 131.8 mV = 0.1318 V.

B. Governing Equation

The equation that governs the principle of MHD is the relation providing the magnitude of induced voltage and it is given by,

Induced EMF, E = q. ($\vec{\mathbf{V}}$ x $\vec{\mathbf{B}}$)
Where,
'q' is the charge density.
'V' is the ionized gas velocity.
'B' is the magnetic flux.

C. Calculation of Charge Density based on Experimental Input Parameters and Experimental Result obtained

- Magnetic Field Strength of each magnet used = 0.075 Tesla.

- Since two magnets are used and are placed parallel to each other, field strength increases and hence the total magnetic flux will be, B = 2 x 0.075 = 0.15 Tesla.

- Velocity of the ionized exhaust gas, 'V' measured using an anemometer is equal to 5 m/s.
- The magnitude of induced EMF as measured from the digital voltmeter, E = 0.1318 V.
- We know that , E = q. (V x B)
  ⇒ q = E/ (V x B)
  = 0.1318/ (5 x 0.15)

i.e. Charge Density = 0.175 C/m^3.

D. Experimental Ratiocination

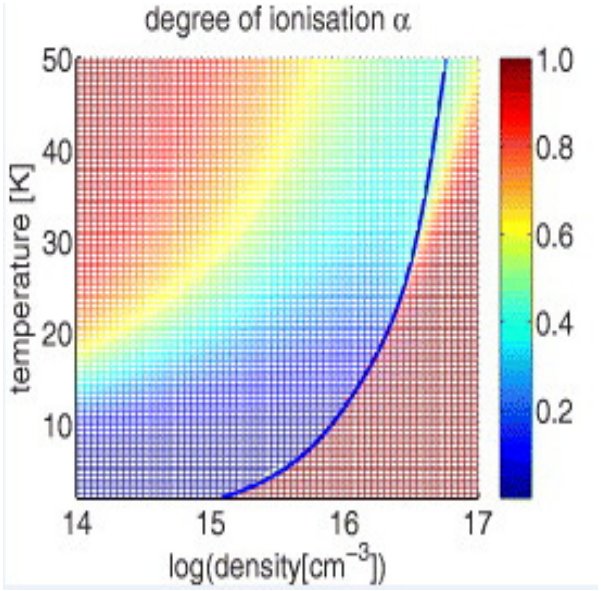


Figure 6(a): Graphical Representation of Relation between Temperature and Degree of Ionization (α) for Ionic Compounds.

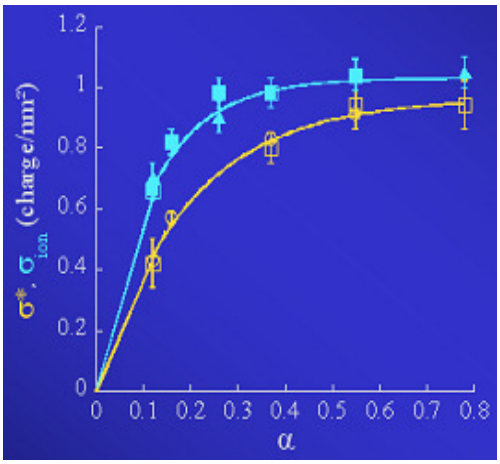


Figure 6(b): Graphical Representation of Relation between Charge density (indicated by σ_{ion}) and degree of ionization (α) for ionic compounds.

We have obtained the value of charge density from calculation as 0.175 C/m³ for a temperature of about 153℃. Figures 6(a) indicate the variation of degree of ionization of ionic compounds with temperature. We can see that the degree of ionization increases with temperature. Figure 6(b) portraits the relationship existing between degree of ionization of ionic compounds and the charge density of ions and we can see that charge density increases with degree of ionization. So on close comparison of two graphs we can finally reach the conclusion that the charge density of ions increases along with temperature. Since induced voltage is proportional to charge density, maximum output voltage can be obtained when the charge density is high, for which the exhaust gas temperature for ionizing the seed must be high which would contribute to a greater degree of ionization and hence greater charge density. Four wheels have higher exhaust gas temperature compared to a two wheeler. So a desirable magnitude of output voltage can be derived from a four wheeler.

VII. RESULTS

- Generation of electric power from automobile exhaust with ionization method has been realized.
- Maximum induced voltage of 0.1318 V was obtained from a digital multimeter.
- Only partial ionization takes place at lower temperatures (in case of a two wheeler). Greater voltage output can be obtained when the exhaust gas temperature for ionizing the seed is high (in case of a four wheeler where temperature ranges about 600-1200℃).
- Intensity of electric power is proportional to high velocity ionized gas, strength of magnetic field, amount of seed ionized.

VIII. CONCLUSIONS

- The threat of disappearing of the fossil fuels within few decades have obligated human beings to search for new energy sources which will last for a longer time.
- The magneto hydro dynamic power generation is one of the examples of a new unique method of generation of electricity.
- The MHD power generation is in advanced stage today and closer to commercial utilization. Significant progress had been made in development of MHD power generation systems.

IX. FUTURE RECOMMENDATIONS

- Increasing the power of magnetic field by using strong magnets such as neodymium magnets, can increase the output voltage to a large extent.
- Velocity of ionized gas can be increased by using highly efficient nozzles, since induced voltage has a linear dependence towards the ionized gas velocity.
- Suitable arrangements can be made for trapping seed ions such as cooling ion traps, scrubbers etc. and techniques could be adopted for re-using the seed.
- Electromagnets instead of permanent magnets would be a better method of choice, as strength of magnetic field can be retained permanently using electromagnets.
- Selection of materials for construction of generator walls must be such that it must be corrosion free.

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