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Magnetic Repulsion Piston Engine

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Abstract: ***Demand is growing for the need of alternative fuels for transportation. Electricity with its versatile applications is being utilized to switch from conventional combustion vehicles to electric vehicles. The scenario of travelling is changing rapidly with metros, electric rails, electric aeroplanes (solar), etc. Basically it indicates that electrical energy is being used almost everywhere to drive our life. But the current machines we use today are low in efficiency. Hence we require products with more power but also with higher efficiency. Magnetism possesses a magnificent opening for development. Bullet trains using the technology of magnetic levitation have proved the strong nature of electromagnetic fields. Keeping in mind the arising needs of the industry, in this project we tried to design and experiment, a system called Magnetic Repulsion Piston Engine, which makes use of magnetic force to drive a load. The working principle is based on attraction and repulsion between a permanent magnet and an electromagnet. The forces thus developed are used to generate mechanical power. Successful development in this field can actively help switch over IC Engines.***

Keywords: Magnetic Engine, Repulsion and Attraction, Electromagnet, Permanent magnet, Relay, H – Bridge circuit.

1. Introduction

IC Engine, one of the greatest inventions of mankind, is one of the most important elements in our life today. It's most important application being in automobiles, trains, and aeroplanes. Our lifestyle today cannot exist without a way to commutate. IC engines make use of gasoline and diesel. The population is in the rising trend; this means more the number of individuals, more the requirement of automobiles to commute. Every year there are around 50 million automobiles being manufactured all over the world. This situation is very grim. With this rise in use of fossil fuels, there arises a need to switch to alternative sources of fuel, to drive our engines. But the challenge is to develop machines which have much higher efficiencies than what we make use today. The most versatile form of energy that is widely used is electricity. Electric motors are replacing existing IC engines rapidly. But the storage of electricity holds a drawback, as a large amount of energy cannot be stored. This demands our machines to possess higher efficiencies, consuming lesser energy and producing more output.

With this rising need of switching to alternative fuels, and alternative sources of energy, magnetism shows a bright spot in the current scenario. Magnetism is a phenomenon which exists in our body, our earth as well as our universe. The virtual concept of black holes have been said to be related to strong magnetic fields. The tremendous energy within a black hole pulls matter inside it to nowhere. If magnetism can possess such potential, then tapping it the right way can create wonders. Various researches across the world have proved that magnetic power can be used to develop over-unity devices. Though practically it possesses a lot of limitations to gain efficiency over unity, achieving near around the same can change the scenario a lot.

The development the magnetic repulsion piston engine refers to the system where the piston attached with a permanent magnet is being pushed by an electromagnet, and again being attracted. The reciprocating motion of the piston is converted into rotary motion by the con rod and crank.

The uniqueness of the development is that Magnetic Repulsion Piston Engine can be incorporated in various machines performing various tasks. Not only in automobiles, but it can be used as the prime mover in locomotives, lawnmowers, golf cart as well. They can complement or replace existing internal combustion engines that use fossil fuels. This system is environmentally friendly, and does not pollute the ecosystem and its application tends limitless with working cost being minimal.

With this we would like to bring forward the most important components of our system. The power generation system consists of the solenoid, permanent magnets, and a battery. The mechanical sub-system mainly consists of the slider crank mechanism. And the electronic control system comprises a sensor and switching circuit.

1.1 Permanent Magnet

Magnetism is a phenomenon where a force arises between magnets and objects, creating a magnetic field around, which in turn may create a repulsive or attractive force. All materials experience magnetism, but at different intensities. Permanent magnets usually governed by ferromagnetism produces the strongest effects in a magnetic field. Others such as paramagnetic materials attract only certain materials, and diamagnetic materials are repelled by magnetic fields. Also recent developments show the existence of anti-ferromagnetism in a very complex manner. Magnetic fields are a mathematical representation to show how magnetic materials interact with electric currents. The fields indicate values of strength as well as in the directions they are acting. Magnets are dipoles in nature, i.e., one face possess a north pole, and the other south. The origin of magnetism sources to the motion of electrically charged particles which are exerted by a force called Lorentz force. Developments in quantum physics say that the attraction of magnets is due to exchange of photons between the two poles.

Permanent magnet is an object made from material that is magnetized and creates its own persistent magnetic field. Main way the permanent magnet created is by heating ferromagnetic material to a key high temperature. The temperature is specific to each kind of metal, but has the effect of fixing and aligning the domains of the magnet in the permanent position. It is conjectured that this same process inside the earth is what creates natural permanent magnets. Ceramic, Alnico, Samarium, Cobalt, Neodymiyum Iron Boron, Injection molded and Flexible are the types of magnets.

1.2 Electromagnet

An electromagnetic force is one of the four fundamental interactions of nature. Electromagnetism is the physical interaction between electrically charged particles. As proposed by Sir J C Maxwell, there are majorly four electromagnetic interactions present. First, the force of attraction and repulsion between electric charges is inversely proportional to the square of distance between them. Second, magnetic poles always come in pairs, as electric charges do. Third, current flowing in a conductor produces a magnetic field around it. Lastly a travelling electric field will produce a magnetic field, and vice-versa.

An electromagnet is a type of magnet which possesses the ability to magnetize and demagnetize as and when required. This control is established by an electric current. When current flows, magnetism is expressed, and it vanishes when there is no flow of current. When a wire is closely wound around a cylindrical object, the side faces of the core exert certain poles when current is passed. The reversal of direction of current, changes the magnetic poles across the iron core. When electric current passes around the core, there is and energy generation called magnetic flux. This magnetic flux is responsible for exerting the magnetic force.

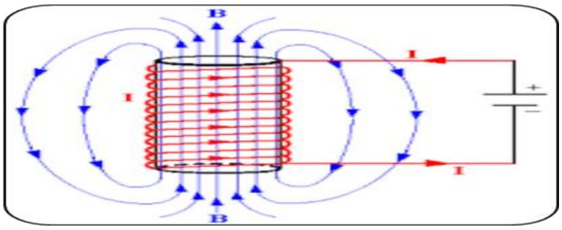


Figure 1 : Magnetic field through current carrying solenoid

The strength of the magnetic field depends upon and is directly proportional to the number of coils, the strength of the current, and the magnetic permeability of the core material. Apart from these factors, the number of turns made by the coil will determine the strength of the field. Electromagnet can be of various types such as Resistive, Superconducting or Hybrid. An electromagnet has various applications starting from a simple motor to atomic particle accelerator.

1.3 Slider Crank Mechanism

IC Engine, uses a four bar chain, in the form slider-crank mechanism. This consists of a piston, cylinder, connecting rod, and the crank. The piston can reciprocate within the cylinder, and is exerted by the combustion forces of fuels. The linear reciprocating force of the piston is converted to rotary motion by the connecting rod, and is tapped as the output by the crank. Here not concerning about how an IC engine works, we concentrate more on the slider crank mechanism, which helps in developing a mechanical rotary output, from a force in straight line.

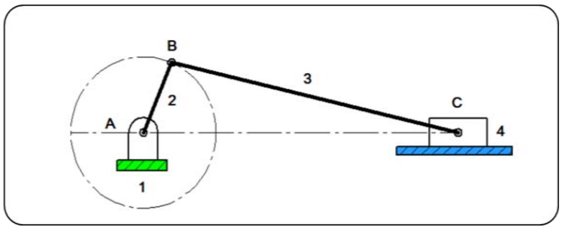


Figure 2 :Slider Crank Mechanism

The Slider-crank mechanism is used to transform rotational motion into translational motion by means of a rotating driving beam, a connection rod and a sliding body. A slider crank mechanism converts circular motion of the crank into linear motion of the slider. In order for the crank to rotate fully the condition L> R+E must be satisfied where R is the crank length, L is the length of the link connecting crank and slider and E is the offset of slider . A slider crank is a RRRP type of mechanism i.e. It has three revolute joints and 1 prismatic joint. The total distance covered by the slider between its two extreme positions is called the path length. As the slider moves to the right the connecting rod pushes the wheel round for the first 180 degrees of wheel rotation. When the slider begins to move back into the tube, the connecting rod pulls the wheel round to complete the rotation. The slider crank mechanism holds its applications in reciprocating engine, rotary engine, oscillating cylinder engine, hand pump, scotch yoke mechanism, Oldham's coupling, elliptical trammel.

1.4 Control Electronics

A control system is one of the most critical subsystems of this engine. The control system is an electronic circuit, consisting of various ICs and microcontroller units. An electronic circuit is a complete course of conductors through which current can travel. Circuits provide a path for current to flow. To be a circuit, this path must start and end at the same point. In other words, a circuit must form a loop. An electronic circuit is composed of individual electronic components, such as resistors, transistors, capacitors, inductors and diodes, connected by conductive wires or traces through which current can flow. The combination of components and wires allows various simple and complex operations to be performed: signals can be amplified, computations can be performed, and data can be moved from one place to another. Circuits can be constructed of discrete components connected by individual pieces of wire, but today it is much more common to create interconnections by photolithographic techniques on a laminated substrate (a printed circuit board or PCB) and solder the components to these interconnections to create a finished circuit. An electronic circuit can usually be categorized as an analog circuit, a digital circuit, or a mixed-signal circuit (a combination of analog circuits and digital circuits).

2. Objective

As per the literature survey, it was found that there was a need to design magnetic engines having a higher load carrying capacity. Models made earlier produced power in a very low torque range which could not be used in any application. The trial model made gave intermittent motion and did not seem powerful enough to drive a load. Also the maximum speed achieved was 250 r.p.m.
Thus we set up a target to build up a prototype of the MRPE having a load capacity satisfactory enough to be used in an application. We aimed to design the engine to run up to 1000 r.p.m. with constant torque characteristic.

3. Design of Components

Various components had been used in this system. We would like to bring about their design and selection procedure.

3.1 Electromagnet

The design of electromagnet was about using the right gauge of wire and with the right number of turns. But 1st the armature core had to be designed and manufactured. Two coils could have been designed, but this would consume more energy. Hence to minimize the power losses, we calculated to use both the power of attraction and repulsion, instead of only repulsion. This would bring about using only one coil, and more torque can be obtained directly because the power output would be the summation of both attraction and repulsion. This indicated that overall there would be power generation in every moment of the piston. Hence the core design became a curved beam like structure with two flat faces facing the pistons, on each face. This also had an added advantage that the magnetic circuit would now be a closed one, which had fewer losses in the functioning. The core was made with Mild Steel (Bright), as it acts as a soft iron core. The diameter of the core is 50mm throughout except at the end faces. At the end faces the diameter is 55mm with a thickness of 10mm. There were 5 layers of windings done, with total number of turns being 1300. The material used for winding is annealed copper.

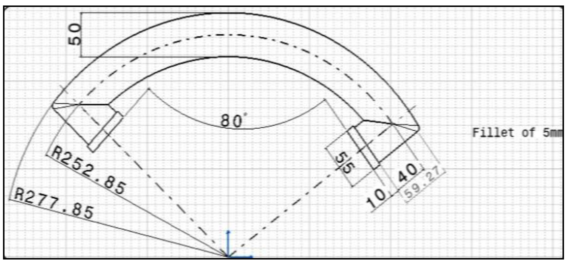


Figure 3: 2D Sketch of Electromagnet

3.1.1 Calculation for design of Electromagnet

For 20 GAUGE COPPER WIRE
Diameter of wire d' = 0.914 mm
Cross-section area of wire a = 0.657 mm^2
Addition to wire diameter for insulation t = 0.063 mm
Hence total diameter of wire d = 0.977 mm
The desired current density for a solenoid is 2.5 A/mm^2 to 3 A/mm^2

Hence, the current flowing should be between 1.6425 A and 1.971 A

At a potential difference V =24 V
Resistance of wire will range from $R=\frac{V}{I}$ = 14.61187 Ω to 12.1765 Ω
Initial diameter of armature coil D_1= 50 + 1 = 51 mm
As the layers increase the diameter also increased in steps of 2mm, hence the diameters of coil after successive layers would be 53mm, 55mm, 57mm, and 59mm.
In all introducing 5 layers
Length of each layer in each turn = π D
$L_{1'}$ = 160.22 mm
$L_{2'}$ = 166.5 mm
$L_{3'}$ = 172.79 mm
$L_{4'}$ = 179.07 mm
$L_{5'}$ = 185.38 mm

The number of turns in the 1st layer over a length of 300mm
N_1 = 300
As we went on winding the number of turn decreased in each layer.
Therefore, approximately number of turns in 2nd layer N_2 = 280
Similarly,
N_3 = 260
N_4 = 240
N_5 = 220
Hence N = 1300 turns
Total length of wire in 1st Layer L_1 = 48.066 m
L_2 = 46.62 m
L_3 = 44.93 m
L_4 = 42.91 m
L_5 = 40.78 m
Overall length of wire L = 223.4 m
Area of cross-section of wire a = 0.657 $\times 10^{-6}$ m^2
Resistivity of copper ρ_c = 0.01724 $\times 10^{-6}$ Ωm
Hence resistance $R = \rho \frac{L}{a}$ = 5.86 Ω (1)
Current $I = \frac{V}{R}$ = 4.094 A

Total Ampere turns $\bar{A}$ = 5322 A.T

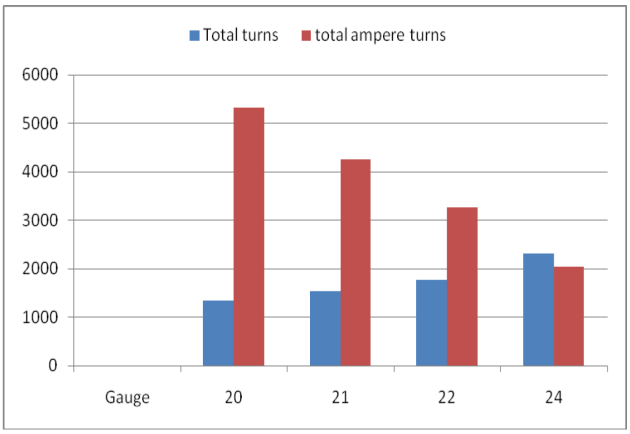


Chart 1: Total amp turns and Total no of turns of various gauges

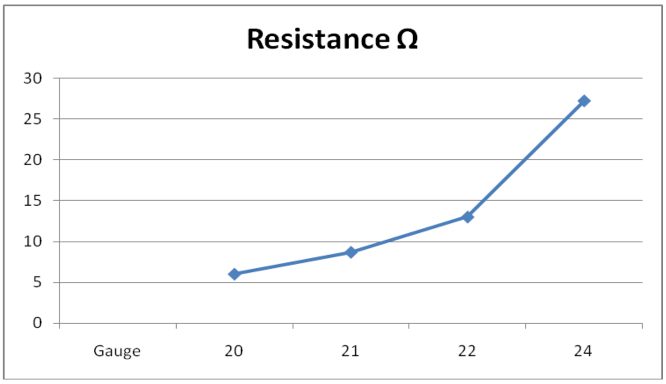


Chart 2: Resistance to current flow in various gauges of wire

3.1.2 Calculation of force of Electromagnet

Input voltage = 24 V
Input current = 4 A
Input Power = Voltage × Current = 24 × 4 = 96W
Max. Force exerted by electromagnet on piston F_1 = $\frac{NI^2 \times K \times A}{2G^2}$ (2)
Where, N = number of turns = 1300
I = Current flowing through coil = 4 A
K = Permeability of free space = $4\pi \times 10^{-7}$
A = Cross-sectional area of electromagnet (radius r = 0.0275 m)
G = Least distance between electromagnet and permanent magnet = 0.005 m
On substitution,
We get Max. Force F_1 = 1530.55 N

Figure 4 : Electromagnet

3.2 Permanent Magnet

As discussed earlier, there are various types of permanent magnet available. We required a permanent magnet which had near about magnetic flux of electromagnet. Thus we decided to use Neodymium Iron Boron Magnet. NdFeB has highest energy products approaching 50MGOe. It has very high coercive force. Because of this high product energy level, they can usually be manufactured to be small and compact in size. However, NdFeB magnets have low mechanical strength, tend to be brittle, and low corrosion-resistance if left uncoated. They are very strong magnets and are difficult to demagnetize. The working temperatures are low, hence we can use NdFeB, and else we would have to use SmCo. These magnets were adhered to the piston using 3M DP 360 Epoxy Adhesive and 4011 Adhesive Tape.

The NdFeB rare earth magnet used had diameter of 50mm and thickness of 12.5mm. The strength of the magnet as indicated by manufacturer is 3000 gauss.
Ultimate Tensile Strength = 500psi
Density = 8.4 g/cc
Curie temperature = 310°C
Max service temperature = 150°C

3.2.1 Force exerted by permanent magnet

Force exerted by permanent magnet Force

$$F_2 = \frac{B^2 \times A}{2\mu 0} \quad (3)$$

Where, B = Flux density (T)
A = Cross-sectional area of magnet (radius r = 0.025 m)
μ0= Permeability of free space = $4\pi \times 10^{-7}$

$$B = \frac{B_r}{2} \times \left[\frac{D+z}{\sqrt{(R^2 + (D+z)^2)}} + \frac{z}{\sqrt{(R^2+z^2)}}\right] \quad (4)$$

Where, Br = Remanence field = 1.425 T
z = distance from a pole face = 0.005 m
D = thickness of magnet = 0.0125 m
R = semi-diameter of the magnet = 0.025 m
On substitution we get flux density, B = 0.3448 T
Now substituting B in the equation of force, F_2 = 92.9 N

3.3 Engine

Multi piston cylinder engines are made in different configurations like inline, opposed type, V oriented, W oriented etc. based on the vehicle specifications. But our aim was to design the setup using a multi cylinder engine, and not to design the engine. Thus we decided to purchase engine from market rather than design it and manufacture it.

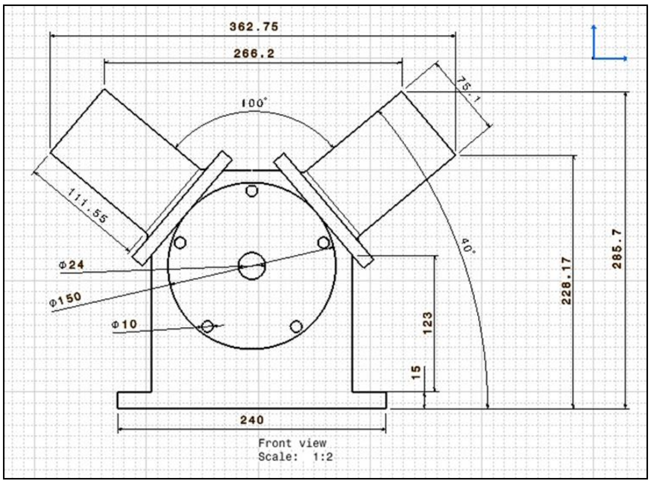


Figure 5: 2D Sketch of Engine

During the market survey, we found out that all two wheelers have single piston engine, which was not our requirement. Multi cylinder comes in four wheelers and that too in inline 4 cylinder configuration which was unaffordable for us. The only option we were left with was to use compressor heads as the base for entire setup which comes in V configuration. So instead of designing two cylinder engine using two single cylinder engine and manufacturing its crankshaft again, we went ahead to work with twin V-type compressor head as it was feasible and satisfied our requirement.

The compressor head was made of Cast Iron. Cast iron is magnetic in nature. The permanent magnet would be reciprocating inside the cylinder. But the magnetic nature of the material would interfere in its working. Hence, the cast iron cylinder was removed. It was replaced by aluminium cylinders. From the raw material, the cylinders and flanges were manufactured in the college on the CNC machine to fit its specific dimensions.

3.4 Control Circuit

The use of magnetic sensor was prominent in the proposed previous setups of Magnetic engine. There were many options for constructing the sensor circuit. There were capacitive proximity sensors, optical sensors, ultrasound proximity sensors and optical encoders. We chose to use the optical method to sense the position of the piston. These sensors are fast, and can be used without any complicacies. To simplify further we used the emitter and detector separately. At one end was the infrared emitter, and diametrically opposite was the detector located. Whenever there was a break in the path of light, a high signal used to pass from the circuit.

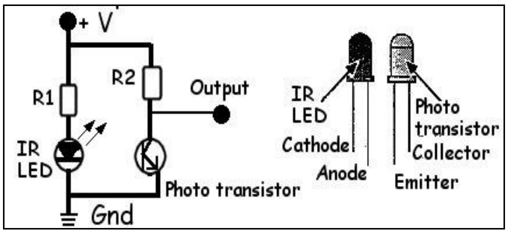


Figure 7: Infrared Emitter Detector pair

Controlling the electromagnet was a tougher task. Power MOSFETs does provide high speed switching, but doesn't help in polarity change. Thus an H bridge IC L298 was used for providing opposed polarity to electromagnet. Basically there were three circuits, one was sensor circuit which comprised of two pairs of TIL32 sensors. Second was driver circuit consisting of L298 motor driver circuit. Third was electromagnet, from which a feedback signal was indirectly given to sensors.

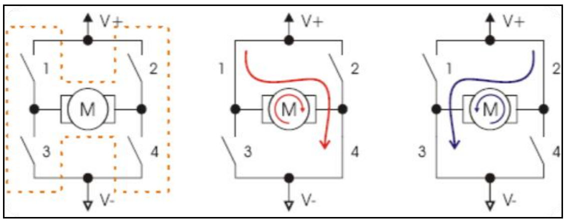


Figure 8: H-Bridge showing different direction of flow of current

During experimentation it was realized that the peak current drawn by the electromagnet burned the L298. L298 has a current carrying capacity of 2A, but the electromagnet had drawn about 4A of current at 24V. Hence the option of L298 was dropped off. Then we used four MOSFETS by connecting them in an H-bridge formation. These power MOSFETS now could drive the electromagnet in both the directions. The H-bridge circuit was driven separately driver circuit using GATE driver IC. But when this circuit was tested, it was found that there was a huge voltage drop at the load. Due to which, even after giving 24V to MOSFETs, voltage across load was only 3V, which further didn't allow the electromagnet to generate enough magnetic field.

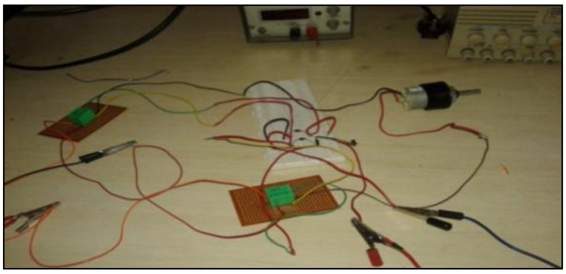


Figure 9: H bridge using relays

Two relays were connected such that NO (Normally Open) of one was given to 24V and NC (Normally Closed) to ground and opposite connection was made for another relay. This resulted into flow of current in one direction at one particular time.

The control System consisted of the following parts:

a) Industrial Rating IRED pair
b) H bridge circuit using relay
c) Transistor BC 547
d) Power Source

4. Working

The mechanical sub-system consisted of a piston, which reciprocated within a guide way made of a non-magnetic material. The cylinder was open to the atmosphere, i.e. there was no cylinder head. Further the piston was connected to a connecting rod which was further linked up with a crankshaft, providing rotary output. Particularly in our system, the standard engine was of V-type twin cylinder configuration. It consisted of two connecting rods, linked commonly to one crank shaft, which also later became the output shaft.

In this system, a permanent neodymium iron-boron magnet was adhered to the top surface of the piston. Hence the magnet travelled along with the piston with reciprocating motion. So there were two magnets stuck to each piston which reciprocated within the cylinder. The magnets were fixed in such a way that the pole orientation was in the same direction. For e.g. if the south poles of both the magnets were fixed to piston surface, then the north poles were exposed to the atmosphere.

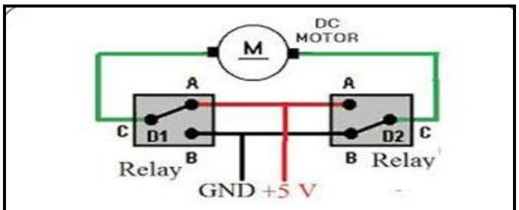
A solenoid is such an electromagnet which when charged by passing a current, creates a dipole at the two end faces, hence one becomes North and the other South. The solenoid consisted of a soft iron core, which was bent to a particular angle so that it could easily be accommodated over the engine. Also the presence of two flanges at the end of the bent core allowed complete interaction between magnetic fields. The curved beam like core consisted of copper windings over it, in various layers. A 24V standard Li ion battery was used to provide energy. When current was passed through the solenoid, one flange acted as the North Pole, and the other as south.

This electromagnet was placed over the cylinders, which were non-magnetic. It was held sturdy with the help of a rigid frame consisting of differential positioning arrangements. This electromagnet was such placed that there was almost zero gap between its flange and the permanent magnet, when it was at its TDC (Top Dead Centre).

When Piston 1 was at TDC, the electromagnet's flange was charged such that it had the opposite pole to that of the Permanent Magnet 1. This introduced a repulsive force on the piston. At the same time, the other flange of the electromagnet would be charged oppositely, which would attract the Permanent Magnet 2, which was in between the TDC and BDC (Bottom Dead Centre). This attractive force was induced because the Permanent Magnet 2 was exposed to the electromagnet had the opposite pole. Now due to attraction, when Piston 2 reached the TDC, it had to be repelled. Hence at the same instant, the direction of current flow in the electromagnet was changed, which changed the poles on the flanges. This resulted in creation of the same pole as Permanent Magnet 2, which got repelled in return, while the Piston 1 was being attracted on the other side.

Figure 10: Final Setup

The switching of the direction of current in the electromagnet was controlled by the controlling circuit. The controlling circuit consisted of pair Infrared emitter detector sets (IRED), which sensed the position of both the pistons individually. Whenever the piston breaks the link of the emitter and detector, high value of signal is generated. Otherwise at all other positions of the piston when the infrared ray is unbroken, the signal is low. The sensors were such positioned that they provided a high output when the piston reached just near the TDC. As there were two pistons, there were two similar circuits to obtain the signal for each piston. The output signals from the op-amps were directed to H-bridge network. The H-bridge network was made with two relays connected as shown below.



RELAY 1	RELAY 2	OUTPUT
A	B	CLOCKWISE
B	A	ANTICLOCKWISE

Figure 11: H bridge circuit using relays

The H-bridge network supplied current to the solenoid in the required direction depending upon the position of the pistons. This implied the use of transistor as a switch. When there was a high signal from Piston 1, the current flowed positively in the solenoid, and when there was high signal from Piston 2, current flowed negatively. At all other situations the electromagnet was not charged. This cycle continued repetitively. H Bridge was supplied with a 24V battery, which was the voltage requirement of the electromagnet to generated sufficient repulsive force.

5. Observation

From testing of control circuits for inductance load at different voltage inputs, following observations have been drawn:

As inductive load has capacity to store charge, there should be provision of release of that charge, otherwise its reactance would increase and result into large drawing of current and heat generation. This can be done either by providing input from battery or another circuit in parallel. As battery can store charge, inductance surge can be given to battery. This would prevent damage of circuit and charge the battery as well.

Available H-bridge ICs are not a suitable for inductive load, as the current drawn was greater that their peak current carrying capacity.

The electronic circuit made of MOSFET caused problem while testing. While giving input from function generator, huge voltage drop had occurred. Even though 24V was applied at positive terminal of MOSFET circuit, output voltage across the load was only 3V, due to which electromagnet couldn't generate enough magnetic fields to pull or push the magnet. Also the MOSFETs were getting heated up very fast.

Thus as a backup, another H bridge circuit using Relays was built, which had high voltage carrying capacity. During the individual testing of the electromagnet it got heated up very soon as it was being operated at a higher voltage, than the capacity of the wire. Since the windings were manually done, it didn't allow generation of effective magnetic flux.

While taking the trial of the system, it was found that there was obstruction in the movement of pistons, they did not reciprocate freely. Also the pistons were getting stuck at a particular position due to V-angle at not being 90 degrees to each other.

6. Conclusion

Proceeding from the mechanical domain, the pistons had obstruction in their movement due to the material of the cylinder. The piston and cylinder were both made of aluminium, hence the friction was more. Also the piston rings had been removed, which didn't allow the close fitting of the piston. The design tolerances could not be met, which distorted the concentricity of the cylinder.

With repeated handling, the windings of the electromagnet got loosened up which increased the gaps between them. This caused a lot of drop in the potential energy from the power source, and did not allow effective generation of magnetic flux. It was also noticed that the energy of the permanent magnet was higher than the electromagnet. Due to this the permanent magnet was getting attracted to the iron core of the electromagnet even when the electromagnet was charged. These issues caused the seizure of the experimental setup, and did not provide us with any real time values of power, torque or speed.

The design of the engine is to be done accurately with materials have low density. The control system needs a lot of improvisation. The inductive load did not allow the system to draw power, which ceased the system. Use of micro-controllers is required, but in a very wise way because of the residual magnetism. The electromagnet's force was just 5-10% of the ideal designed one. This happened due to hand wound coiling. This sector needs accurate manufacturing and utmost care.

The MRPE has various advantages over an internal combustion engine. The most important advantage is that it is environmentally friendly. It does not use any fossil fuels, does not deplete natural resources, and does not pollute. Another point is that there is no heat generation within. Though the electromagnet heats up with continuous operation, but the temperatures are very low as compared to IC engines. It rules out the need of a cooling system, a fuel injector, valves, etc. The operating noise levels are also low. Proper development of this engine with materials like aluminium can reduce the weight significantly, and increase the efficiency. The important significance is that its development can decrease the dependence on depleting resources, which is a very important requirement today. By further research and development it can prove to be a boon in the Industrial sector.

7. Acknowledgement

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