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Conversion of IC Engine into Magnetic Engine with Minor Modifications

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Abstract

Internal combustion engines are one of the major causes of pollution. These engines work by burning fuels, hence contaminating environment through the exhaust. Due to the mentioned reason, there is a need of an alternate technology which is reusable and environment-friendly. As an effort to control the effects of engine emissions, this research suggests an alternative technique known as Magnetic Repulsion Piston Engine (MRPE). MRPE is an environment-friendly and non-polluting engine that works on the principle of repulsion between same poles of the magnet. The aim of this research is to manufacture such an engine that can use the repulsion between the same poles of the magnet to produce power and rotate the crankshaft without changing the design of the IC engines. MRPE uses a permanent and an electromagnet to achieve repulsion. The permanent magnet is attached upon the piston whereas the electromagnet replaces the cam valve mechanism. This arrangement with the proper current timing of electromagnet drives the crankshaft. The modifications are made to one-cylinder IC engine for this particular study. Successful running of the engine using the magnet attraction and repulsion is achieved. The engine produced only 189 rpm under no load.

Keywords: MRPE (Magnetic repulsive piston engine); Electromotive force; Magnetic flux; Neodymium; IC or conventional engines

Introduction

This research relates to automotive industry and green technology. The conventional piston engines of our cars run on igniting gas or oil and create a burst which lowers the piston, discharging billions of ton of CO_2 into the atmosphere. The Environmental Protection Agency had stated that carbon dioxide emission poses a threat to health. Therefore it's important to find solutions to noise, environment and health risks posed by the conventional internal combustion engine. For this purpose, an idea of a magnetic repulsive piston engine (hereinafter referred to as MRPE) for replacing the IC engines is presented. This engine doesn't have any emission that poses threat to the environment.

To design such engine an experimental research was carried to convert the conventional engine design to MRPE with few or very minor modifications. The idea of this research is to make the implementation of this engine easy in industry. The industries don't have to completely change the setup to implement this design as it uses the design of the conventional engine.

The combustion engine consists of many parts which make it heavy and the size is very large. The Cam mechanism was replaced by an electromagnet. The piston shape was same but Neodymium (Nd Fe B) a permanent magnet was placed on top of the piston with help of a screw. Electromagnet which relies on the battery to supply 12 volts was the primary element for power. This voltage was supplied to the electromagnet. When the current was passed through the core, it magnetized and when same poles of the electromagnet and permanent magnet came near to each other they repelled, a universal principle that same poles repel and opposite poles attract. The piston was spontaneously pushed down, producing a rotational force in the crankshaft which generated a mechanical back and forth motion. A cycle of attraction and repulsion helped the piston to reciprocate. When the electromagnet was demagnetized and piston coming back to TDC position attraction occurred, as magnets are attracted to iron. At this point, the power of the MRPE is proportional to the volume of the combined magnetic pistons displacement in a single movement from TDC to BDC. The research of the MRPE is an improvement of a conventional piston engine. Which is efficient, modern and sustainable for further vehicle flexibility while abating health risks and promoting technology green.

Other green technologies such as solar, hydraulic, and electric or hybrid vehicles required a lot of money for implementation. Permanent magnets are easily available at low prices which makes the implementation easy and less expensive.

The related work in the field includes

A similar research was carried out in India but the engine design was completely different from conventional engine design which made hurdle to implement such design. Neodymium permanent magnet was placed on top of the piston and electromagnet placed at the TDC position [1].

A white paper published by Sekou Industries described the need of a magnetic engine. They proposed that this engine eliminates the use of fossil fuels and produces enough output to power large machinery. A design of the engine was presented that had a compartment having a permanent magnet at TDC and BDC and an electromagnet at center. But no experiment was done to prove the point [2].

A method of engine cylinder using centrifugal casting was considered. A mathematical model and physical model were used to study the effect of centrifugal casting to manufacture cylinder. The mathematical computation provided temperature field, liquid-solid phase scattering, and status of porosity contraction. The simulation

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showed the rpm, preheating and melted metal amount to be provided for theoretical analysis was used to obtain the precision. The numerical model was more accurate and provided better results. The accurate results of temperature, rotation speed could be used to determine the defects in centrifugal casting more precisely. The numerical method. This method told that solidification was faster at outer edges and slower at inner side. This produced defects in casting. It was proposed that a numerical method should be used to determine the behavior of centrifugal casting [3].

A new design was proposed of a motor. The aerofoil shaped spokes permanent magnet were used in Brush Less Direct Current (BLDC) motor. The motor used pure ferrite permanent magnet instead of neodymium magnet. A technique was developed to amplify the torque density. Spoke type arrangement provided two pushing assistants one with additional FE-PM and other by spoke shape FE-PM. A numerical method was used to explain the optimization and increasing torque density and results were validated by FEM software for suggested aerofoil shaped spoke type BLDC motors. The purpose of this research was to lessen dependence on rare earth metals. The FEM results were compared with the numerical results and it was proposed that FEM software is reliable tools design and for analysis. This method reduced the cost and proposed that rare earth metal can be replaced by cheap magnets. Back Electromotive Force and the flux density in waveform in air gap were calculated [4].

Marzena Spyra, stated that if a small amount of molybdenum is added to low Neodymium magnet it can improve the coercivity and maximum energy product [5].

A study was done to determine the clamping force of electromagnet on basis of field theory by using a mathematical model. This model was used to operate a Mobile Robot (MR) on inclined and vertical ferromagnetic surfaces. Magnetic induction and holding force at the diverse position were experimentally determined of the holding magnet relative to the ferromagnetic surface. Maxwell software centered on FEM was used to validate dependence on gaps with different gaps between the magnet and ferromagnetic surface, which was caused by excrescences of shells and ferromagnetic surface thickness change which was caused by high-tech features. This also helped the design of MR [6].

Young Jin Hwang, designed multipole electromagnet using an iron core structure in which cores are adjusted parallel to each other. This experiment proved that this design provides the increased magnetic field densities in the air gaps. HTS coil is designed and provides better magnetic field densities than the conventional copper coil. As the structure is symmetrical that is why magnetic field densities were same throughout the core structure [7].

Dr. István Lakatos, studied the pressure inside the cylinder of the automobile is continuously changing. This study includes a procedure for pressure indication which can be further utilized to diagnose the problem. The technique uses a pressure transducer, amplifier, sign modulator, oscilloscope, and computer. The graphs obtained after the experiment showed the intervals with flaws and helped the diagnosis [8].

Alin-Iulian Dolan optimized three parameters of the acting force of DC electromagnet. Three geometrical parameters (coil shape ratio, support thickness ratio, support height ratio) were analyzed and optimized. The force which is related to the largest air gap was maximized. The electromagnetic force was calculated by Maxwell stress tensor technique implemented in FEM software. The acting force was increased by 3.17 % using the optimization method. The researcher further concluded that better results can be obtained by considering the angle of the top of the support [7,9].

Some other research on electromagnet was done, in this study, a technique was developed to control the rotation of spherical motor driven by electromagnet forces. The electromagnet placed on stator gives 2 kinds of torque, one type the torque due to flowing current and other is the cogging torque which is developed by a permanent magnet. A technique was developed to determine this torque when there are 3 electromagnets on stator and Lagrange multiplier method was used under constraint condition. Five magnets were arranged at the vertices of the rectangular pentagon to obtain the currents of electromagnet [10].

M Hussian, studied the factors for coordinate measuring machine such as scan speed, point density, probe diameter, filtration which were used to accurately check the cylindricity of engine cylinder bore. The results of CMM were accurate and its capability and accuracy to measure the geometry of cylinder bore were verified. The experiment was conducted to study all the factors and its results came very close to the target value [11].

The optimization of DC electromagnet was done before using the Design of Experiment (DOE) and was analyzed using FEM. The purpose of the optimization was to obtain the geometrical parameters to determine static force characteristic. Before this experiment Technique of screening was also used. Three parameters were considered the coil, the shape and support thickness ratio. There was some limitation in optimization that was the global dimension of the electromagnet. To solve these problems zooms without computational model was used. 3% of the gain in static force was achieved and an average of 1.12% with an air gap of 36 mm. The numerical experiment was performed on FEA using the Maxwell Stress Tensor approach. The coil shape ratio and support thickness were determined using screening technique [9].

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Marzena Spyra stated that if a small amount of molybdenum is added to low Neodymium magnet it can improve the coercivity and maximum energy product. This experiment was performed by annealing to produce nanostructure. The study further proved that 2-5% addition of molybdenum, the magnetic properties of low Neodymium without significantly altering the remnant magnetization [12].

Daniel Huger investigated the effects of temperature on neodymium iron boron. 80 magnets with four different temperature indices and coatings were tested. The temperature was kept in limits as provided by the manufacturer. The results showed the logarithmic decrease in flux density. All the thermal limits given by the manufacturer were met [13].

Yu Fu, designed a bearingless motor with neodymium bonded magnet. For this purpose, neodymium sintered permanent magnet was used to achieve the high-power density. Due to the high conductivity in ND sintered PM, the eddy current loss occurs in it. Due to the temperature raising in rotor it is very difficult to achieve continuous speed and high output operation [14].

Thomas Laurain, designed an observer which can be used to control the idle speed using a global command for the throttle and individual command for spark timing. The paper demonstrated the crucial engine values such as air mass in each cylinder and spark advance efficiency.

Without the use of any sensor these estimated values can be used in the controller to realize idle speed control which can be useful in consuming low fuel and low emissions [15].

Some study regarding cylinder liner was carried which deal with dynamic response of cylinder liner on engine performance, A finite element model was used to study the dynamic response of cylinder liner as it was difficult experimentally. The structural mode and some nonlinearities of assembly constraint were considered under nonlinear pressure excitation and piston slap on the cylinder. A wavelet analysis was also done to analyze the responses of the cylinder under different conditions and frequency range. A numerical prediction was compared with measured vibration signal and their effect on combustion and lubrication process. The FEM model was more accurate and provided more accurate results. The response of combustion excitation was in higher frequency than the piston slaps. The effect of combustion on lubrication was less as compared to piston slap [16].

An electromagnet assisted Ferrite motor (EMaFM) was manufactured that used double air gap structure. The principle was validated on 1.5 KW prototypes. The magnetic paths of electromagnet and ferrite magnets were formed separately. It was capable of good field regulation while using ferrite magnets. Following results were obtained;

The back EMF could be adjusted by changing the field current

Torque could also be controlled by changing field current [17]

Alinza Kaleli, presented a smart cooling system for automobiles. The study included the design and control of a system having a three-way thermostat and DC water pump. Feedback system was introduced which utilized the outlet of engine coolant and fed to the controller. Coolant temperature by a conventional system and the controlled system was compared; lower temperature on the controlled system was achieved [18].

Methodology

When same poles of two magnets are brought near, then they will repel each other and will move into the opposite direction and when the opposite poles of the magnets are brought nearer from far distance than they will feel the attractive force and will start moving towards each other. This phenomenon is utilized to design an engine using permanent and electromagnet [19,20].

The study was carried out after various design modifications and magnet arrangements. The final arrangement used in the study is mounting the permanent magnet on the piston whereas electromagnet at the top of the cylinder at Top Dead Centre position. The battery was attached to the electromagnet that energized the electromagnet when the piston reached TDC position.

Component Design

The design of the magnetic repulsive engine is similar to conventional engine design. The electromagnet was positioned at TDC position of the engine cylinder replacing CAM mechanism and the permanent magnet was bolted on the piston. The engine piston was connected to the crankshaft via the connecting rod. The connecting rod was connected by means of a piston pin with the crankshaft. The description of each component is given below. The schematic diagram of the magnetic engine is shown in Figure 1.

- Electromagnet: It was made of copper windings of suitable gauge winded across iron alloy core. As soon as power was turned on electromagnet repelled the piston consuming very less power
- Piston: A very strong Neodymium magnet was bolted on top of the piston
- Connecting rod: It connects the piston to the crankshaft
- Crank shaft: It was made of steel alloy which revolved as piston moved downward
- Proximity Sensor: It was used as a control switch for on and off of electromagnet or timing
- Circuit: It was used to balance the current in the electromagnet and protected it from jerks
- Crank case: It surrounded the crankshaft and was constructed with aluminum

The schematic and real image of the engine is shown in Figure 1.

Figure 2 shows the timing circuit. It was used for timing the on and off of the electromagnet. Current balancer as shown in Figure 3 was used to prevent the sensor from any kind of a jerk. The current balancer maintained the voltage of 12V and current to 50A or less as adjusted. The current balancer also prevented the sensor to burn out as the sensor is sensitive to high voltages and currents. The proximity sensor shown in Figure 4 was used to switch on and off the electromagnet. It operated at a distance of 10 mm-20 mm. The relay shown in Figure 5 was used as

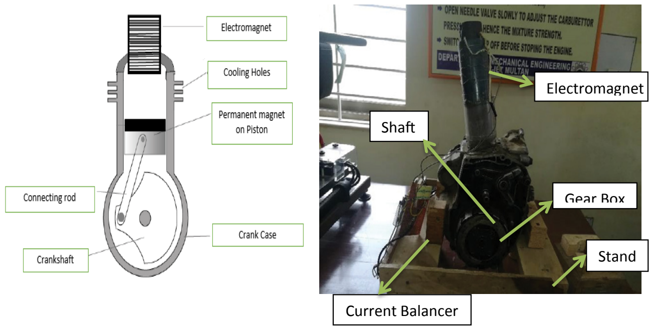

Figure 1: Schematic diagram.

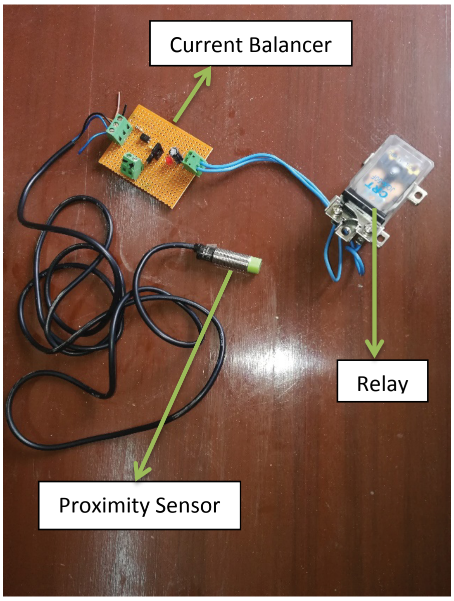

Figure 2: Timing circuit.

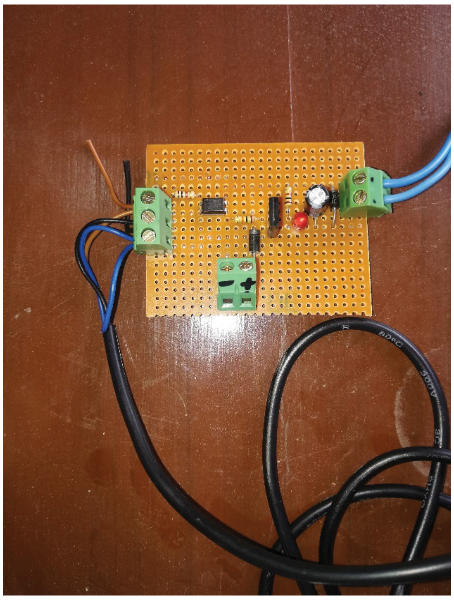

Figure 3: Current balancer circuit.

Figure 4: Proximity sensor.

a switch and it was operated when the sensor sensed a metallic plate in front of it. It sensed the presence of the metal at a distance of 20 mm. It was used with a sensor for signal transferring to object to be operated. The internal view of the engine where gears and flywheel were located in Figure 6. Each part of the experimental setup is explained below.

Electromagnet

The core was made of iron alloy it magnetizes as currently passed through it in Nano-seconds.

The electromagnet was designed that it could lift a weight of

Figure 5: Relay.

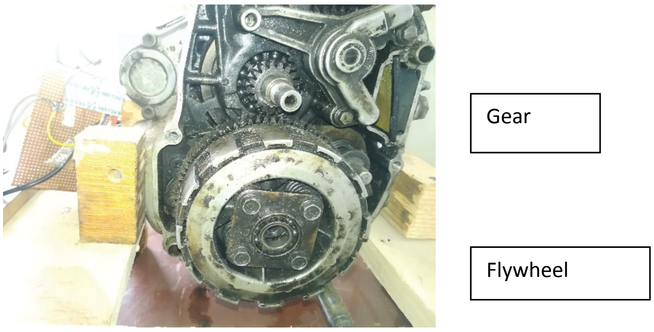

Figure 6: Gear box.

20 kg. The core diameter was kept 50 mm and the total diameter of electromagnet 60 mm. The electromagnet is shown in Figure 7. To operate the electromagnet an initial current of 8A was required. At this current supply, the electromagnet magnetized easily and effectively. Maximum ampere of 50A and 24V can be providing. A relay is attached with an electromagnet to control its operation of on and off. A sensor is attached at the end of a relay that generates a signal to operate the relay as shown in Figure 8.

Core for electromagnet

Different cores were used for different purposes. Table 1 shows the list of cores and their properties.

It was found that the soft iron was the only core that suits our requirement. It was the only core that could easily become a magnet when the current was passed through it. The strength of the magnet can be increased by simply increasing the Ampere of current through the coil. It loses its magnetic field easily when current stops flowing through it. Copper winding was used as it was more efficient than silver wire and had longer life Figure 9.

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Figure 7: Electromagnet.

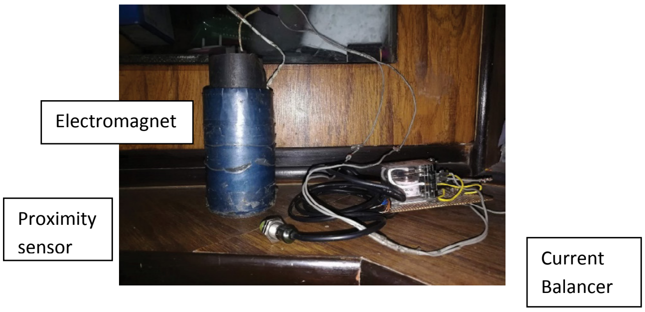

Figure 8: Electromagnet with relay.

Neodymium Magnet Behaviour

The behavior of magnet according to diameter and thickness

A calculator was used to check the behavior of neodymium magnet. Different diameters of the magnet were examined. The calculator gave the pull force and repulsive force of magnets. This calculator was designed by K and J Magnetics. This helped in choosing the grade and diameter of

Material	B_S [T]	B_R [T]	H_C [A/m]	μ_{rmax} × 1000	P [Ωm]
High purity Fe	2.1	1.3	4-240	30	9.6 × 10^{-8}
Carbon steel	1.55	0.7-1.1	40-400	0.6	.
NGO Si-Fe M400-50AP	1.7	1.23	98.2	6.9	70 × 10^{-8}
GO Si-Fe M089-27N	1.9	1.72	33	41.4	70 × 10^{-8}
$Ni_{80}Fe_{20}$	1.1	.	0.4	100	100 × 10^{-8}
$Co_{50}Fe_{50}$	2.45	1.5-2.2	160	5	7 × 10^{-8}

Table 1: Properties of materials.

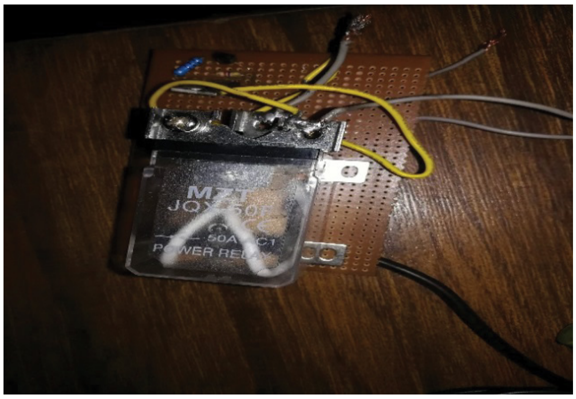

Figure 9: Relay.

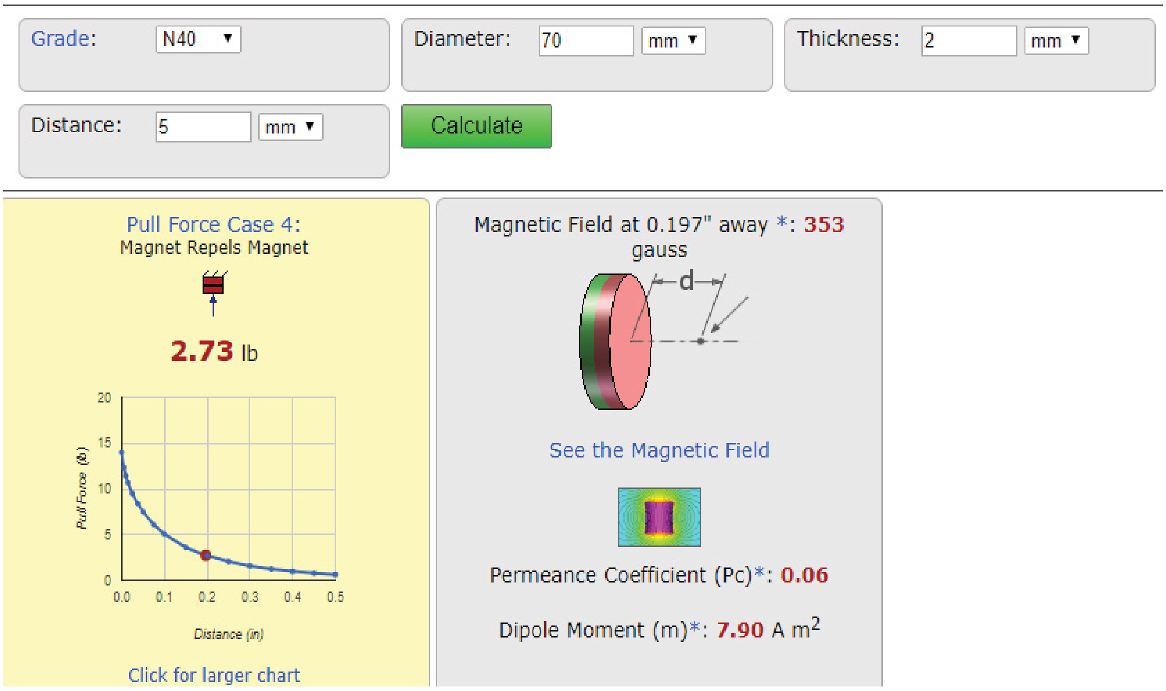

Figure 10: Pull force grade 40.

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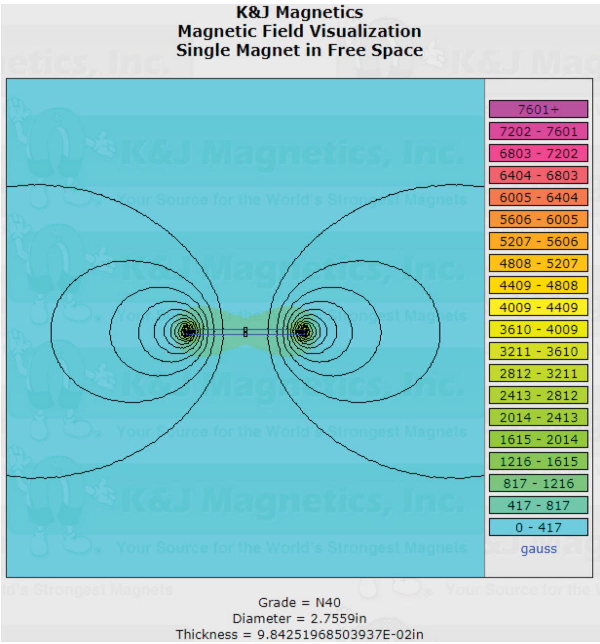

Figure 11: Magnetic field visualization.

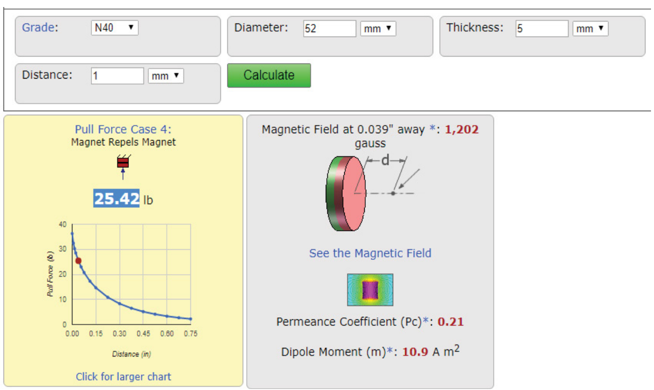

Figure 12: Grade 40 distance 1 mm.

the permanent magnet for the engine. These studies lead to the selection of the diameter of core and power of electromagnet required to operate the magnetic engine. Figures 10-16 show the behavior of the magnet.

Design Specifications

The design of the engine was kept same as the conventional one cylinder 4 stroke internal combustion engine. Engine head was replaced by an electromagnet which gets energized by battery and current was controlled by a sensor. Permanent magnet used was Neodymium grade N52 that was mounted on the custom-made piston. Figure 17 shows the assembly of the engine.

When the piston was at TDC position, battery energized the electromagnet in a way the opposite poles are in front of each other and hence repelled the piston. As the piston moved to BDC position

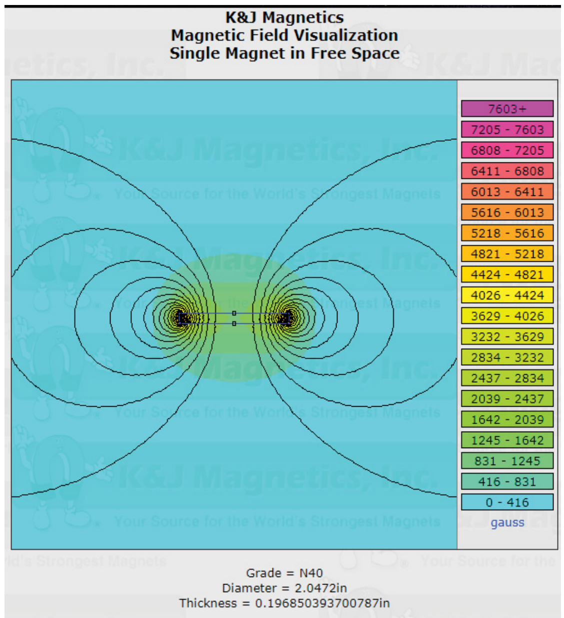

Figure 13: Magnetic field visualization.

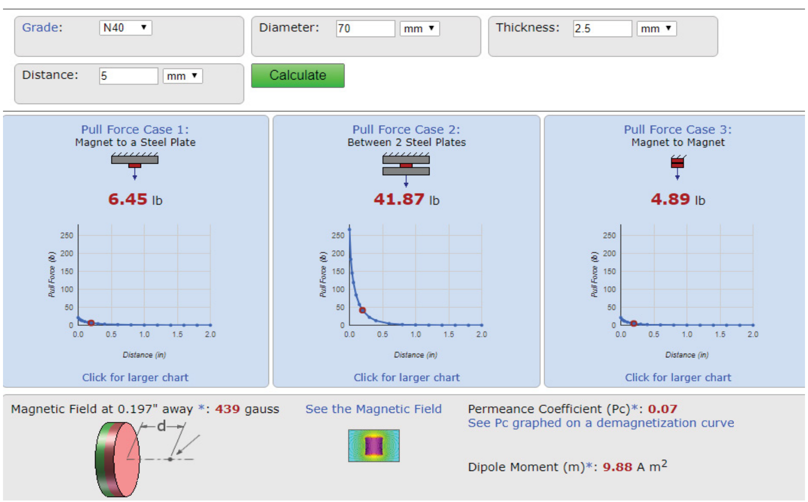

Figure 14: Grade 40 5 mm distance.

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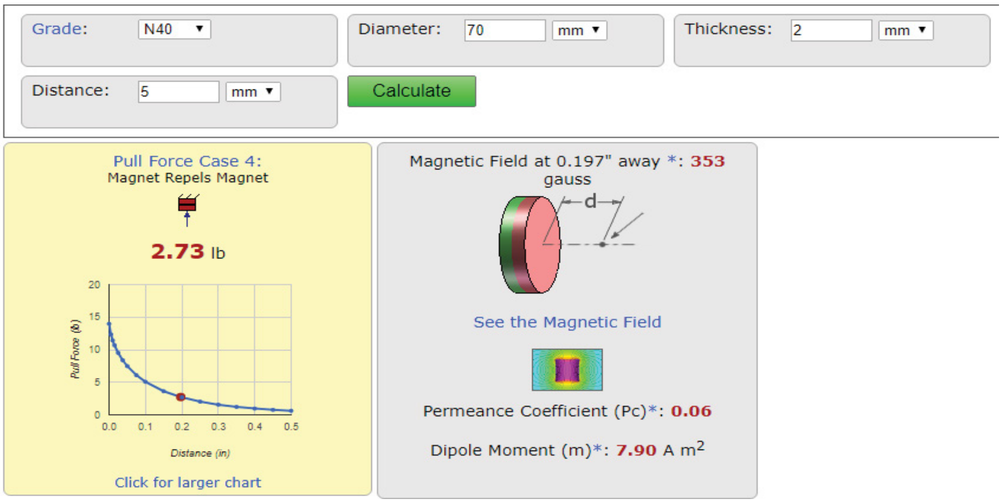


Figure 15: Grade 40 thickness 2 mm.

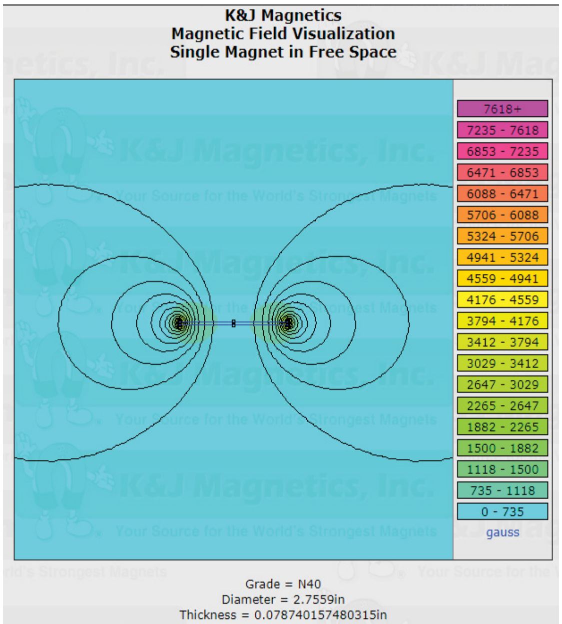


Figure 16: Magnetic field visualization.

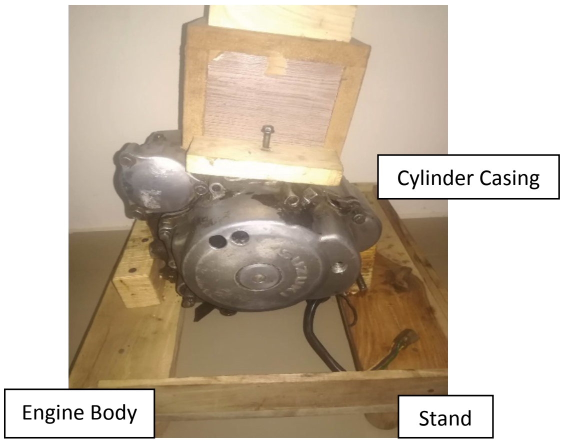


Figure 17: Complete assembly.

electromagnet de-energized and piston easily came back to TDC by the energy stored in the flywheel.

Design complications

Major complications that were faced are air entrapped and resistance in the motion of Neodymium magnet due to the presence of metallic parts in the engine. As the cylinder was fully sealed due to that air entrapped inside hurdled the motion of the piston. This problem was overcome by drilling holes in the sides of the cylinder on specific places. The entrapped air escapes out from the holes by the motion of the piston.

Secondly, the metallic parts of the engine were attracted by the permanent magnet in the cylinder. Due to attraction, the magnet got to stick to the wall of the cylinder. The magnetic attraction resisted the motion of piston; hence the required power was not obtained to run the engine smoothly.

Thirdly, the timing of switching electromagnet was not optimum to get the maximum force. The switching operation was carried out in the same way as the spark plugs are lighted in case of the internal combustion engine.

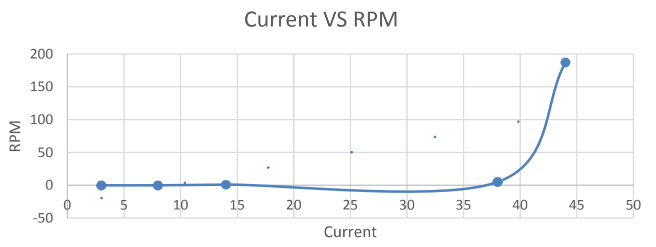
Experimental Results

A series of the experiment was performed and different results were obtained. At 3A ampere current the electromagnet did not magnetize so an addition battery was used and 8 A current was supplied. The core magnetized and pushed the piston downward but there was some interruption in the movement. So, cylinder boring was done and dia. of the cylinder was increased to 56 mm. The piston smoothly moved in the cylinder. The power of the magnet was not enough that it could push the piston downward that it could not come back upward.

A battery of 44A was used than the magnet attraction distance was experienced at a distance of 108 mm while the cylinder length was 98 mm so this also stopped the magnet attached to the piston to come up again but the timing could be adjusted. The results of current versus rpm are tabulated in Table 2 below.

Sr.no	Voltage(V)	Current(A)	RPMS
1	12	3	0
2	12	8	0
3	12	14	Only one revolution
4	12	38	5 rpm
5	12	44	187

Table 2: Results current v/s rpm.



Graph 1: Current v/s RPM.

Using the same current 44A, the timing was adjusted using a proximity sensor and piston started to reciprocate and completed its strokes. So required objective was achieved and the concept of using the same engine design to implement the idea was achieved. The acceleration could also be provided by increasing the current. But in this research, the only objective was to implement the idea of MRPE without any design modification in IC engines. The rpm of engine recorded was 187 under no loading conditions. When converted to velocity the speed is 19.782 m/s and 71.21 km/hr as shown in Graph 1.

Timing adjustment

A motion sensor called proximity sensor was used to operate on and off electromagnet. The maximum distance required to operate the sensor was 20 mm. A metallic strip was placed on the flywheel of the engine. The strip was adjusted so that when the piston was at TDC position the metallic strip was in front of the sensor and a signal was generated that operated the electromagnet. When the electromagnet magnetized at TDC position and same poles repelled each other and the shaft rotated. Thus, power stroke was obtained.

Conclusion

Thus, the idea of running a magnetic repulsive engine without changing the design of conventional engines was practically achieved through proper experiment. Still, the efficiency is not enough that it can be implemented in industry. One thing is achieved regarding industrial implementation was that the design can be implemented without changing the setup of the industry completely. The engine produced different rpm's at different current. At 3 and 8A this engine produced no rpm but at 14A only one revolution. But at 44A it produced 189 rpm's. The main problem of this engine was not having enough torque. In the future, more work can be done on getting torque from this engine by using gears system and some research on acceleration and core of electromagnet can be done. Moreover, this engine is totally green and has no impact on the environment with zero emission.

The drawback of this engine is that it consumes the complete power of the battery at once. So it should be a system should be designed that it is charged continuously. The torque of this engine is also not enough that it can be used to move the load. This needs further research. The design parameters of the engine can be decided like the parameters for designing IC engines. It is assumed that the design parameter of MRPE will be much more simple.

Recommendation

The future can include the proper gear train for the engine. How to provide the acceleration system and working on the core of the electromagnet.

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