"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 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 environment friendly and non-polluting engine that works on the principle of repulsion between same poles of magnet. The aim of this research is to manufacture such an engine that can use the repulsion between the same poles of 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. Permanent magnet is attached upon the piston whereas the electromagnet replaces the cam valve mechanism. This arrangement with 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.

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 atmosphere. The Environmental Protection Agency had stated that carbon dioxide emission pose 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 has any emission that pose threat to 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 conventional engine.

The combustion engine consist 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 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 improvement of 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 lot of money for implementation. Permanent magnets are easily available at low prices which makes the implementation easy and less expensive.

Key words: MRPE (Magnetic Repulsive Piston Engine), electromotive force, Magnetic Flux, Neodymium, IC or conventional engines.

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 piston and electromagnet placed at the TDC position. [1]

A white paper published by Sekou Industries described the need of magnetic engine. They proposed that this engine eliminates the use of fossil fuels and produces enough output to power large machinery. A design of engine was presented that had a compartment having permanent magnet at TDC and BDC and an electromagnet at centre. 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 was 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 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 numerical method should be used to determine the behaviour 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 flux density in wave form in air gap were calculated. [4]

Marzena Spyra, in 2008, stated that if 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 mathematical model. This model was used to operate mobile robot (MR) on inclined and vertical ferromagnetic surfaces. Magnetic induction and holding force at diverse position was experimentally determined of the holding magnet relative to ferromagnetic surface. Maxwell software centred on FEM was used to validate dependence on gaps with different gaps between 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, in 2018, designed multi pole 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 conventional copper coil. As the structure is symmetrical that is why magnetic field densities were same throughout the core structure. [7]

Dr. István Lakatos, in 2015, studied the pressure inside cylinder of automobile is continuously changing. This study includes 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 experiment showed the intervals with flaws and helped the diagnosis.[8]

Alin-Iulain Dolan, in 2017 optimized three parameters of acting force of DC electromagnet. Three geometrical parameters (coil shape ratio, support thickness ratio, support height ratio) were analysed 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 3.17 % using the optimization method. The researcher further concluded that better results can be obtained by considering the angle of 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 permanent magnet. A technique was developed to determine this torque when there are 3 electromagnets on stator and Lagrange multiplier method was use under constraint condition. Five magnets were arranged at the vertices of rectangular pentagon to obtain the currents of electromagnet.[10]

M.Hussian, in 2015 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 was 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 analysed 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 global dimension of electromagnet. To solve these

problems zooms without computational model was used. 3% of gain in static force was achieved and an average of 1.12% with air gap of 36mm. The numerical experiment was performed on FEA using Maxwell Stress Tensor approach. The coil shape ratio and support thickness were determined using screening technique.[9]

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Marzena Spyra, in 2008, stated that if 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, in 2015 investigated the effects of temperature on neodymium iron boron. 80 magnets with four different temperature indices and coatings were tested. 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, in 2017 designed a bearing less 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 temperature raising in rotor it is very difficult to achieve continuous speed and high output operation.[14]

Thomas Laurain, in 2015 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 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 cylinder. A wavelet analysis was also done to analyse the responses of 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 that the piston slap. 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 prototype. The magnetic path of electromagnet and ferrite magnets were formed separately. It was capable of good field regulation while using ferrite magnets. Following results were obtained;

1. The back EMF could be adjusted by changing the field current
2. Torque could also be controlled by changing field current.[17]

Alinza Kaleli, in 2017, presented a smart cooling system for automobiles. The study included the design and control of system having three-way thermostat and DC water pump. Feedback system was introduced which utilized the outlet of engine coolant and fed to controller. Coolant temperature by conventional system and controlled system was compared, lower temperature on controlled system was achieved. [18]

Methodology

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

The study was carried out after various design modifications and magnet arrangements. Final arrangement used in the study is mounting the permanent magnet on the piston whereas electromagnet at the top of cylinder at Top Dead Centre position. 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 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 in below. The schematic diagram of the magnetic engine is shown in Figure 1:

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.

2. **Piston:** A very strong Neodymium magnet was bolted on top of piston.

3. **Connecting rod:** It connects the piston to crank shaft.

4. **Crank shaft:** It was made of steel alloy which revolved as piston moved downward.

5. **Proximity Sensor:** It was used as a control switch for on and off of electromagnet or timing as shown in Figure 4.

6. **Circuit:** It was used to balance the current in the electromagnet and protected it from jerks.

7. **Crank case:** It surrounded the crankshaft and was constructed with aluminum.

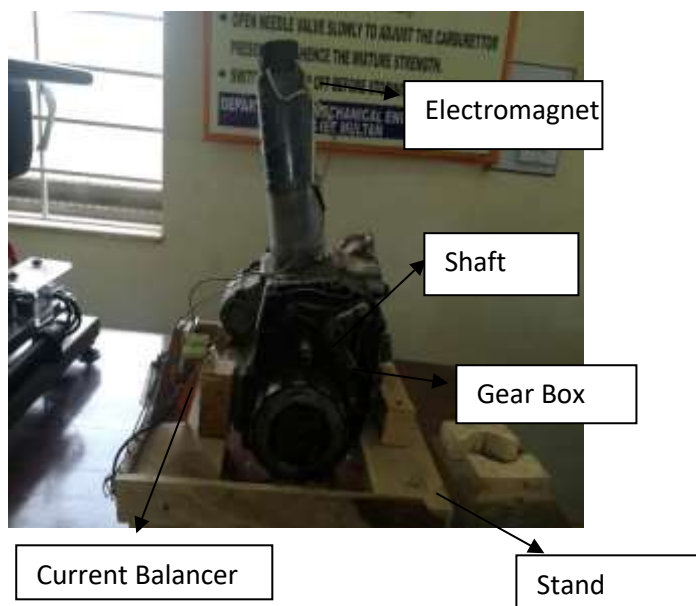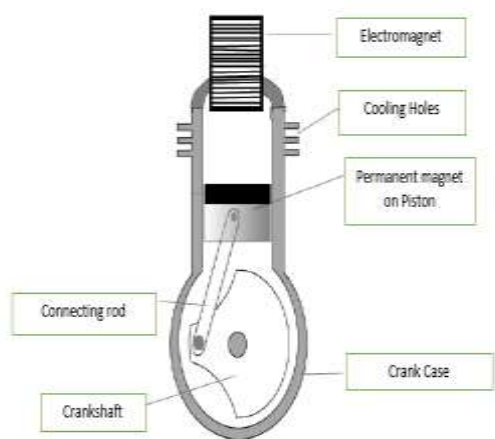The schematic and real image of the engine is shown in Figure 1.
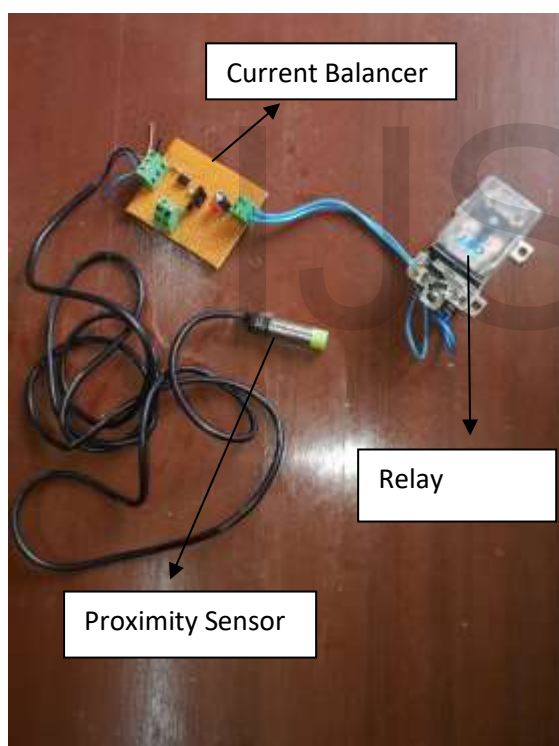
Figure 1 schematic diagram

Figure 2 Timing Circuit

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 the any kind of jerk. The current balancer maintained the voltage of 12 V and current to 50 A 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 10mm -20mm. The relay shown in the Figure 5 was used as a switch and it was operated when the sensor sensed a metallic plate in front of it.
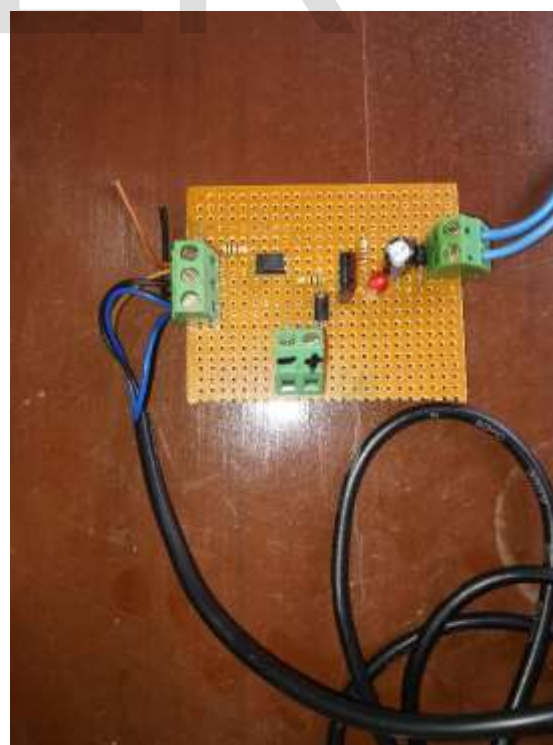

Figure 3 Current Balancer Circuit

Figure 4 Proximity Sensor

It sensed the presence of the metal at a distance of 20 mm

Figure 5 Relay

It was used with sensor for signal transferring to object to be operated.

Figure 6 Gear Box

The internal view of the engine where gears and flywheel were located. Each part of experimental setup is explained below.

Electromagnet:

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

The electromagnet was designed that it could lift a weight of 20kg. The core diameter was kept 50 mm and the total diameter of electromagnet 60 mm. The electromagnet is shown in Figure 7.

Figure 7: Electromagnet

To operate the electromagnet an initial current of 8 A was required. At this current supply the electromagnet magnetized easily and effectively. Maximum ampere of 50A and 24 V can

be provide. A relay is attached with electromagnet to control its operation of on and off. A sensor is attached at the end of relay that generates a signal of to operate the relay as shown in Figure 8.

Electromagnet

Figure 8: Electromagnet with relay

Proximity sensor

Current Balancer

IJSER

Core for Electromagnet

Different cores were used for different purposes. The table 1 shows the list of cores and there properties.

Table 1: Properties of Materials

Material	$B_S[T]$	$B_R[T]$	$H_C[A/m]$	$\mu_{rmax} \times$ **1000**	$\rho[\Omega m]$
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}

Figure 9 Relay

Neodymium Magnet Behaviour

Behaviour of Magnet according to Diameter and Thickness

It was found that the soft iron was the only core that suites our requirement. It was the only core that could easily become magnet when current was passed through it. The strength of magnet can be increased by simply increasing the Ampere of current through 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.

A calculator was used to check the behaviour of neodymium magnet. Different diameters of 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 permanent magnet for engine. These studies lead to the selection of diameter of core and power of electromagnet required to operate the magnetic engine. Figure 10-16 shows the behaviour of magnet.
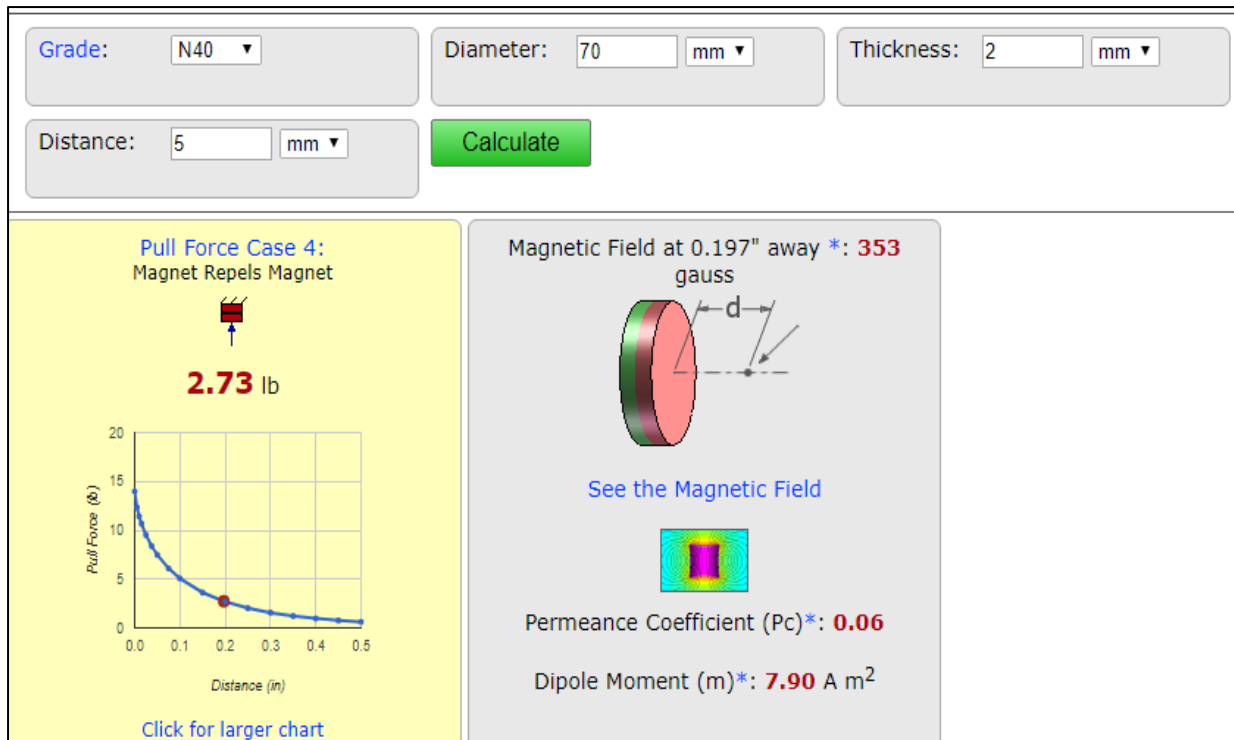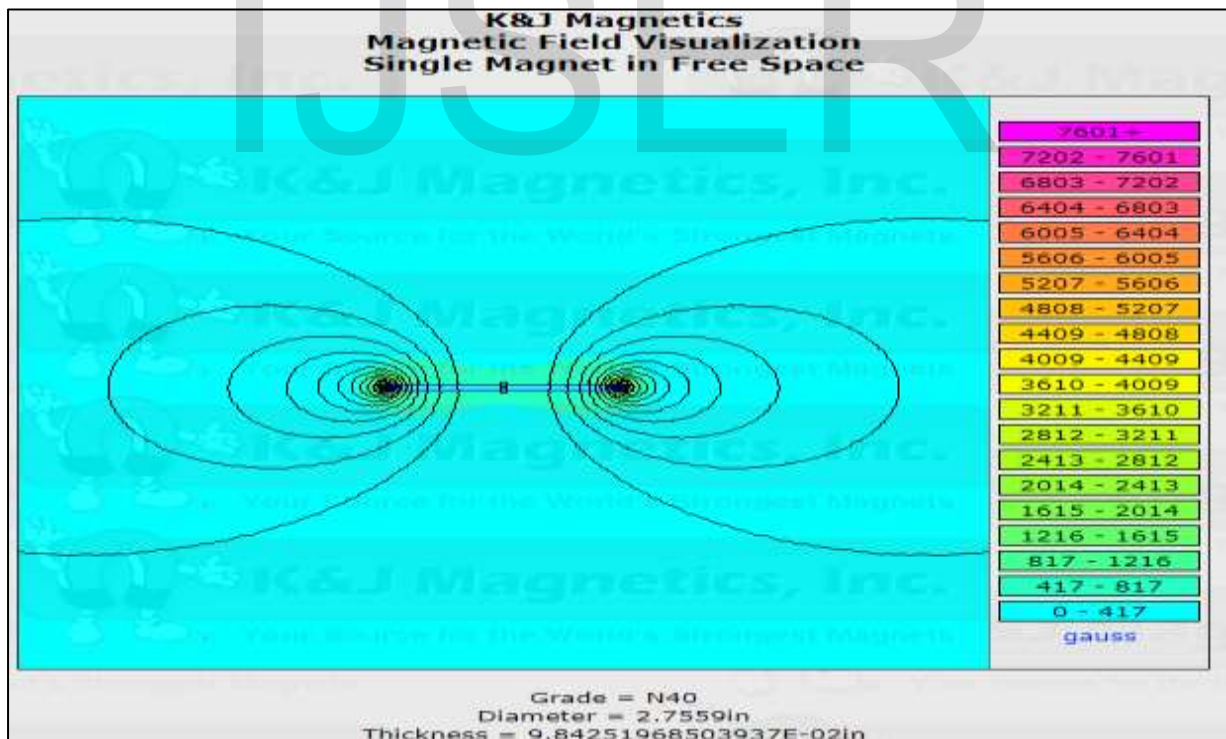
Figure 10 Pull Force Grade 40
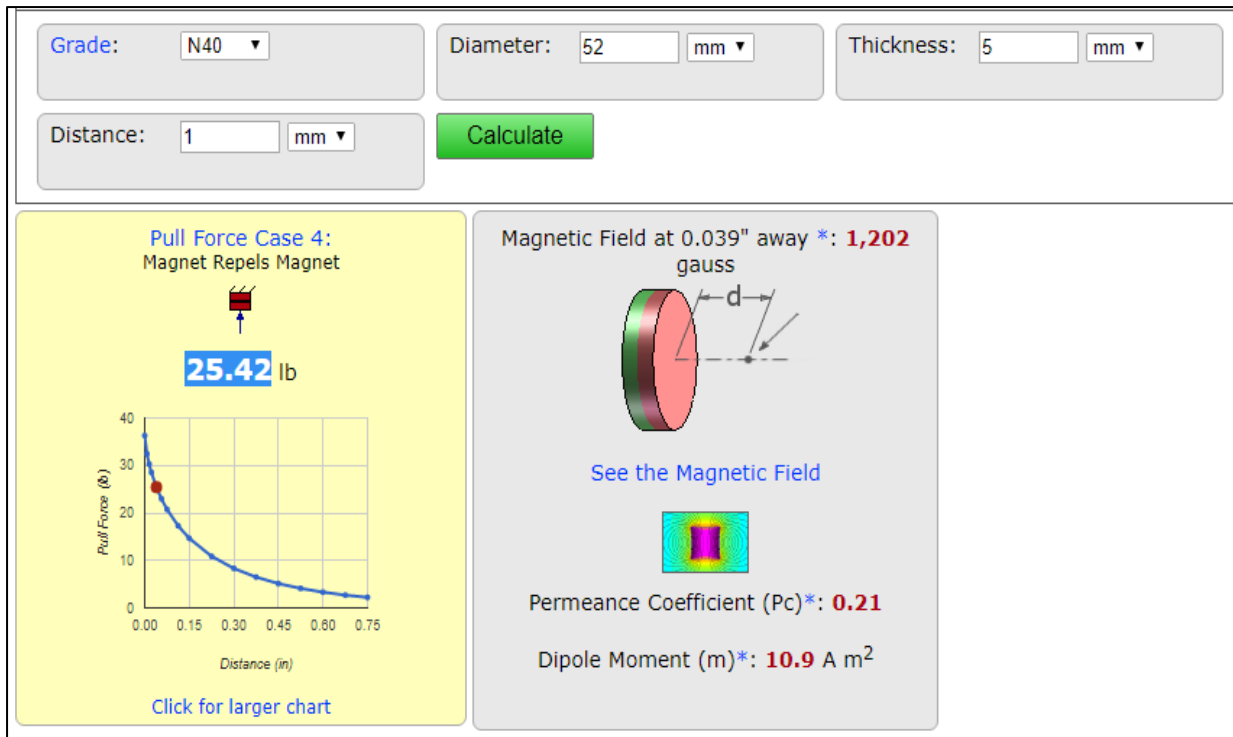

Figure 11 Magnetic Field Visualization

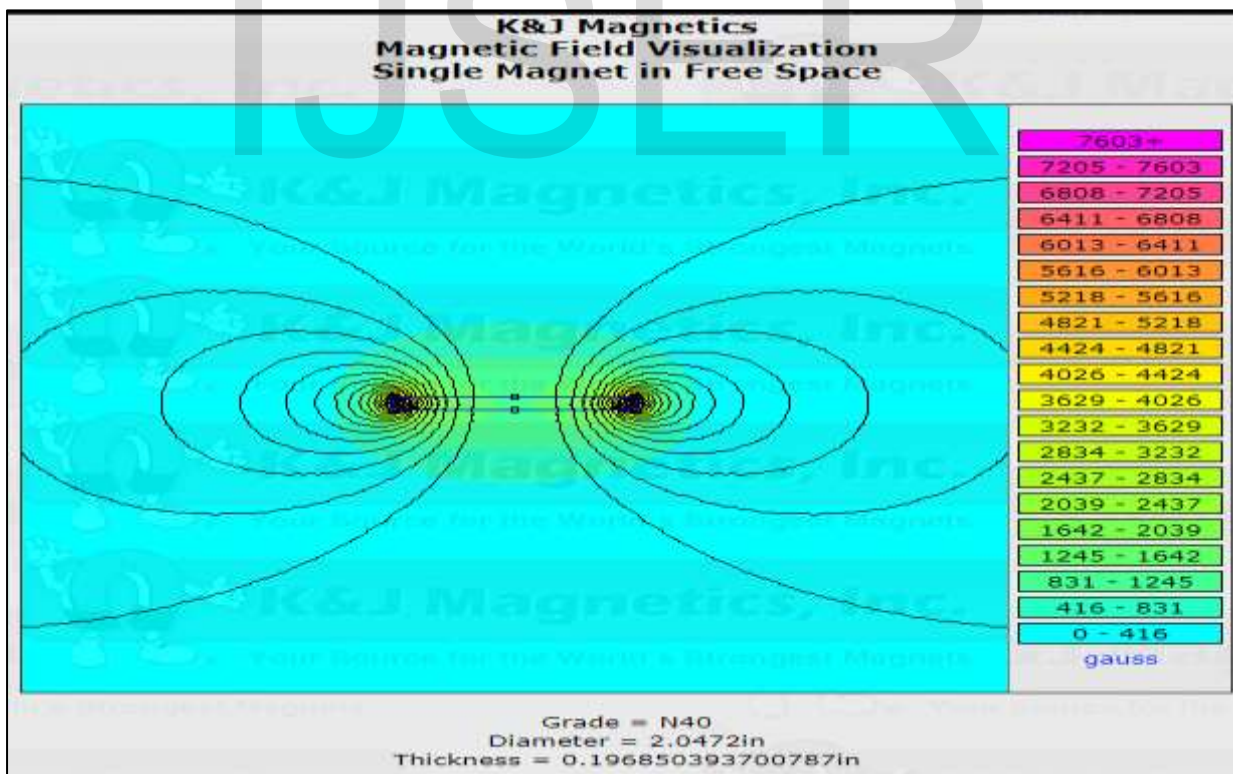*Figure 12 Grade 40 Distance 1 mm*

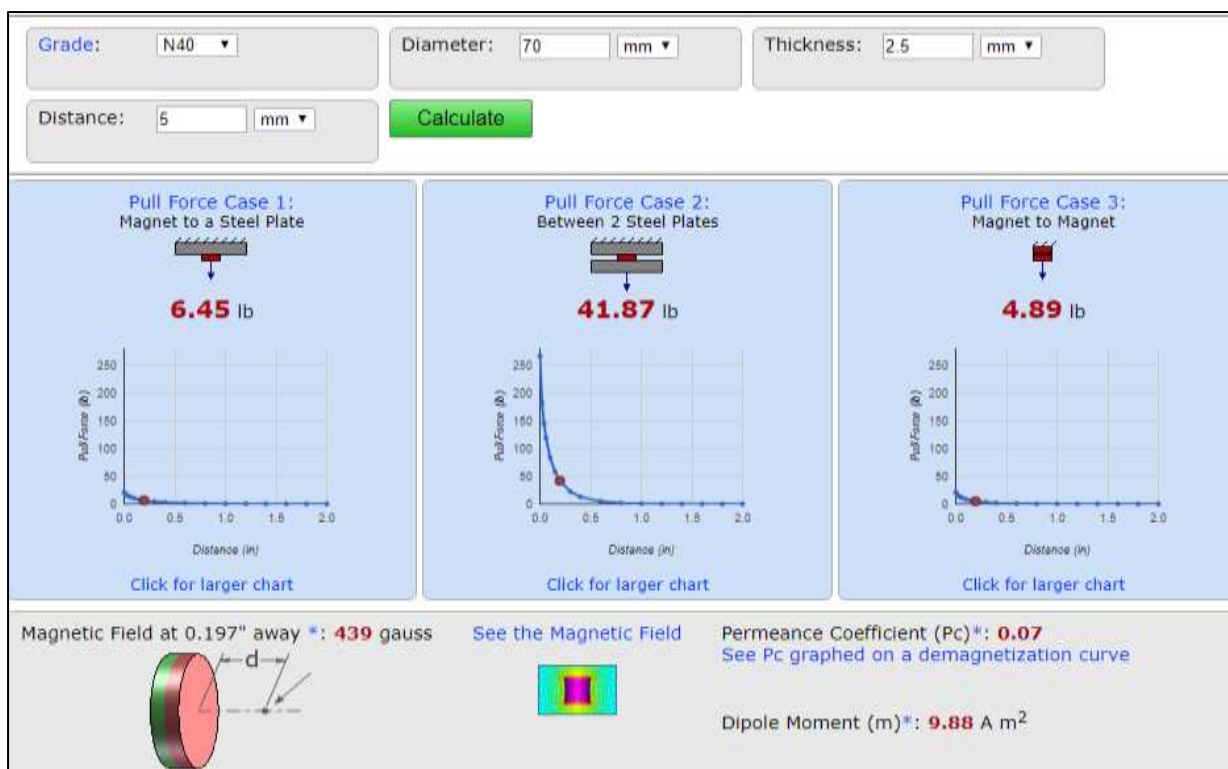*Figure 13 Magnetic Field Visualization*

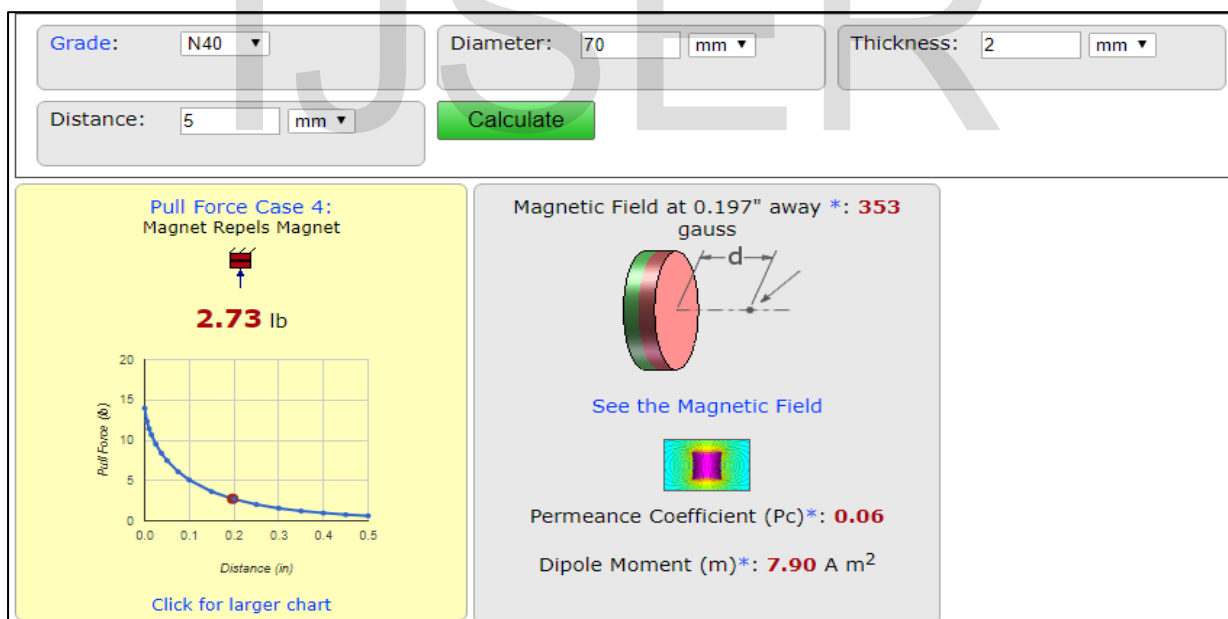*Figure 14 Grade 40 5mm distance*
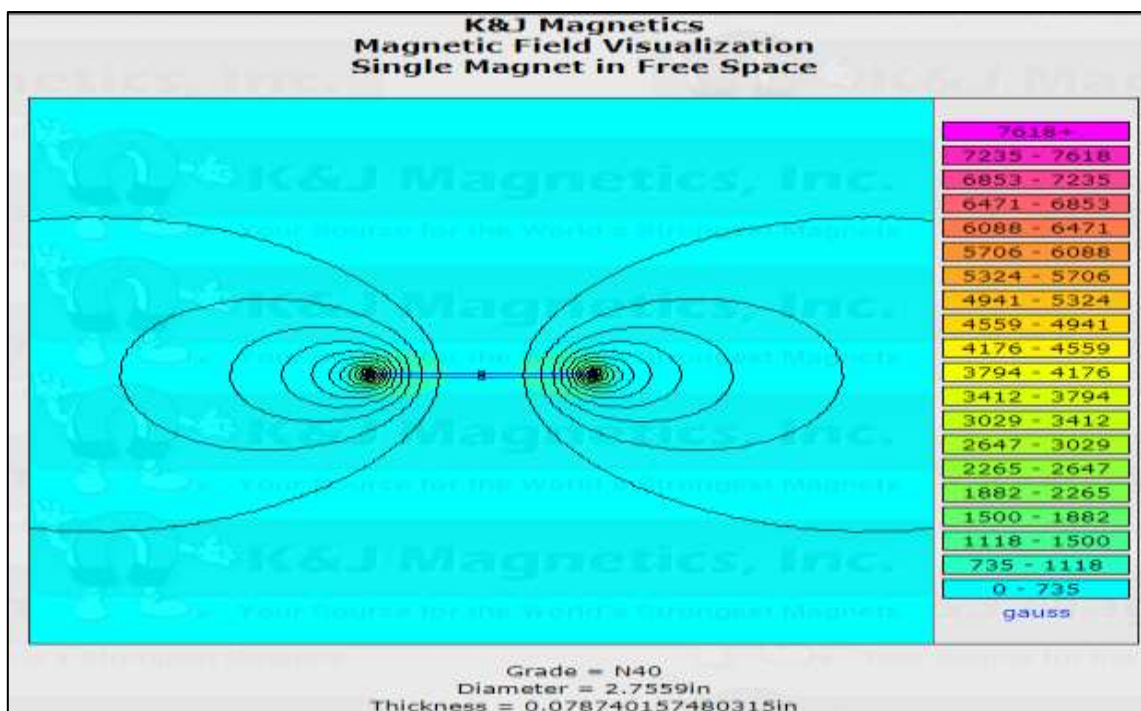

Figure 15 Grade 40 Thickness 2mm

Figure 16 Magnetic Field Visualization [20]

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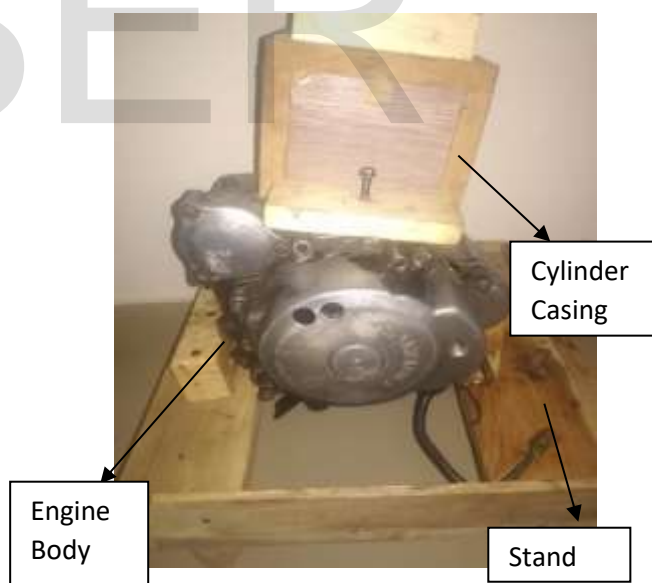

Figure 17 Complete Assembly

Design Complications

Major complications that were faced are air entrapped and resistance in motion of Neodymium magnet due to presence of metallic parts in engine. As the cylinder was fully sealed due to that air entrapped inside hurdled the motion of piston. This problem

was overcome by drilling holes in the sides of cylinder on specific places. The entrapped air escapes out from the holes by the motion of piston.

Secondly, the metallic parts of engine were attracted by the permanent magnet in the cylinder. Due to attraction the magnet got stick to the wall of 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 maximum force. Switching operation was carried out in the same way as the spark plugs are lighted in case of internal combustion engine.

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 electromagnet which got energized by battery and current was controlled by current balancer. Permanent magnet used was Neodymium grade N52 that was mounted on the custom-made piston with screw. Figure 11 show the assembly of the engine.

When the piston is at TDC position, battery energizes the electromagnet in a way the opposite poles are in front of each other and hence repel the piston. As the piston moves to BDC position electromagnet was de-energized
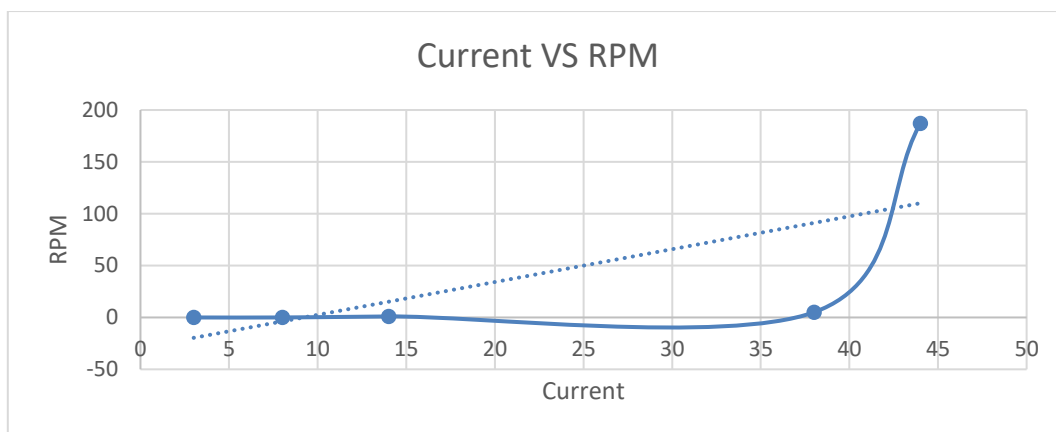
and piston could easily come back to TDC by the energy stored in flywheel.

Experimental Results

A series of experiment were performed and different results were obtained. At 3 A 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 cylinder was increased to 56 mm. The piston smoothly moved in the cylinder. The power of magnet was not enough that it could push the piston downward that it could not come back upward.

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

Table 2 Results current vs rpm

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

Graph 1 Current VS RPM

Using the same current 44A, timing was adjusted using proximity sensor and piston started to reciprocate and completed its strokes. So required objective was achieved and 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 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 table 2.

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 20mm. 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 industry completely. The engine produced different rpms at different current. At 3 and 8 A this engine produced no rpm but at 14A only one revolution. But at 44A it produced 189 rpms. The main problem of this engine was not having enough torque. In 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. More over this engine is totally green and have no impact on 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 design that it is charged continuously. The torque of this engine is also not enough that it can used to move load. This need further research. The design parameters of the engine can be decided like the parameters for designing IC engines. It is assumed that 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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