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DEVELOPMENT AND PERFORMANCE TESTING OF A MAGNETIC RECIPROCATING ENGINE

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Abstract: Toxic pollutants emitted from automobiles have caused serious environment-related issues that need implementation of environment-friendly technologies. Fossil fuel based automotive vehicles causes high emission of COx/ SOx/ NOx through burning of hydrocarbon fuels. For this reason, electric vehicles come into picture. As the price and demand of fossil fuel are increasing over the past and have made the society looks for alternatives in the vehicle sector. Electric vehicles reduce toxic emissions to a large extent reducing global warming. 'Magnetic Reciprocating Engine' proposed in this work operates without a motor and requires no fuel to run. Working principle of this engine is totally based upon the concept of magnetic repulsion and attraction property. Details of its fabrication and design are discussed in this paper. Some performance tests done on this setup are also presented in this article. In fine, there is some future prospects of introducing this kind of 'Magnetic Reciprocating Engine' system.

Keywords: Toxic pollutants, fossils fuels, magnetic reciprocating engine, magnetic repulsion and attraction property.

1. INTRODUCTION

"Necessity is the mother of invention". Needs for locomotives have been growing, so also the number of automobiles being manufactured equally to meet the demand. This causes an impact on raising the possibility of global warming. For this, use of electrical engine is gaining focus. The concept of Magnetic Reciprocating Engine is also going to attract focus to be a vehicle. Forces and torques act on magnets following the rules of electromagnetism.

Previously researchers used microcontroller [1, 2] for the illustration of circuit, which controlled the frequency of current. Later on researchers had used solenoid [3, 4] principle in which losses were dominant. Some other researchers also worked on twin engine [5], replacing spark plugs by electromagnets.

Actually Magnetic reciprocating engine is a new topic and that is why less work was done on this area. Considering this lack of investigation and possibilities of implementation of this engine, in this work, an MRE has been fabricated and its performance is tested. This engine is proposed to reduce the use of IC engine, as quantity of fuels is continuously decreasing and to introduce this engine to be an environment friendly green vehicle.

2. WORKING PRINCIPLE

According to the “Laws of Electro-Magnetism” If two magnets are placed near to each other, the opposite pole of those magnets attract, at the same time the same poles repel. This principle is used in “Magnetic Reciprocating Engine”, to convert the electrical power into mechanical work done.

When power is supplied to the Electromagnet, it gets magnetized and attracts permanent magnet situated at one end of the piston and repels at the same time another permanent magnet situated at other end and produce a linear motion on the piston. An Arduino system is used to control the current direction syncing with the piston position. When the piston reaches to the IDC (inner

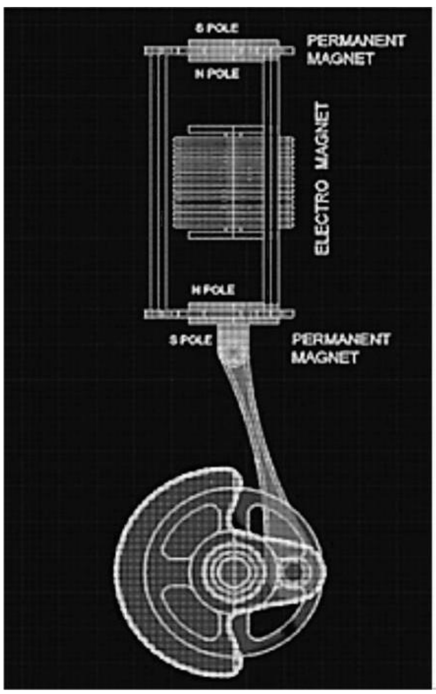


Fig.1. Schematic of the engine

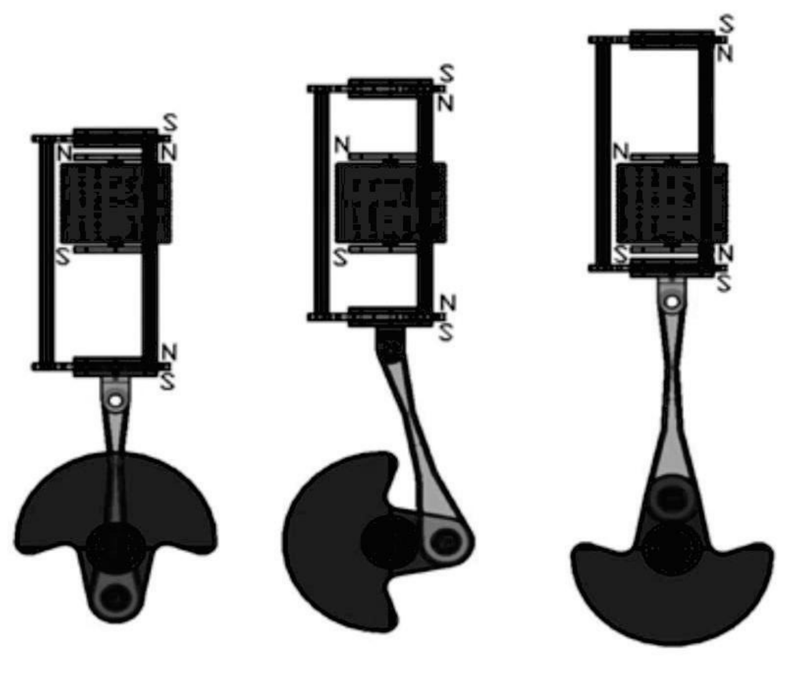


Fig.2. Positioning of the piston

dead center) the sensor senses the piston position and control four relay switches to change the current direction. As a result, the piston starts to move towards the ODC (outer dead center), create a reciprocation motion. This reciprocating motion is converted into rotary motion by using a slider-crank mechanism to get mechanical work done, which is connected with the bottom of the piston with the help of a gudgeon Pin.

The piston of 'MRE' consists of two Permanent Magnets, such as the bottom face of upper PM (Permanent Magnet) and top face of lower PM are placed towards the face of the 'Electromagnet' (as shown in the figure). The whole piston and the EM are mounted inside a case such way that the EM is constrained with regard to the base and the piston can reciprocate along the axis of the EM (as shown in Fig. 1 and Fig. 2).

3. FABRICATION OF MRE

Fig.3 shows the system of Magnetic Reciprocating Engine

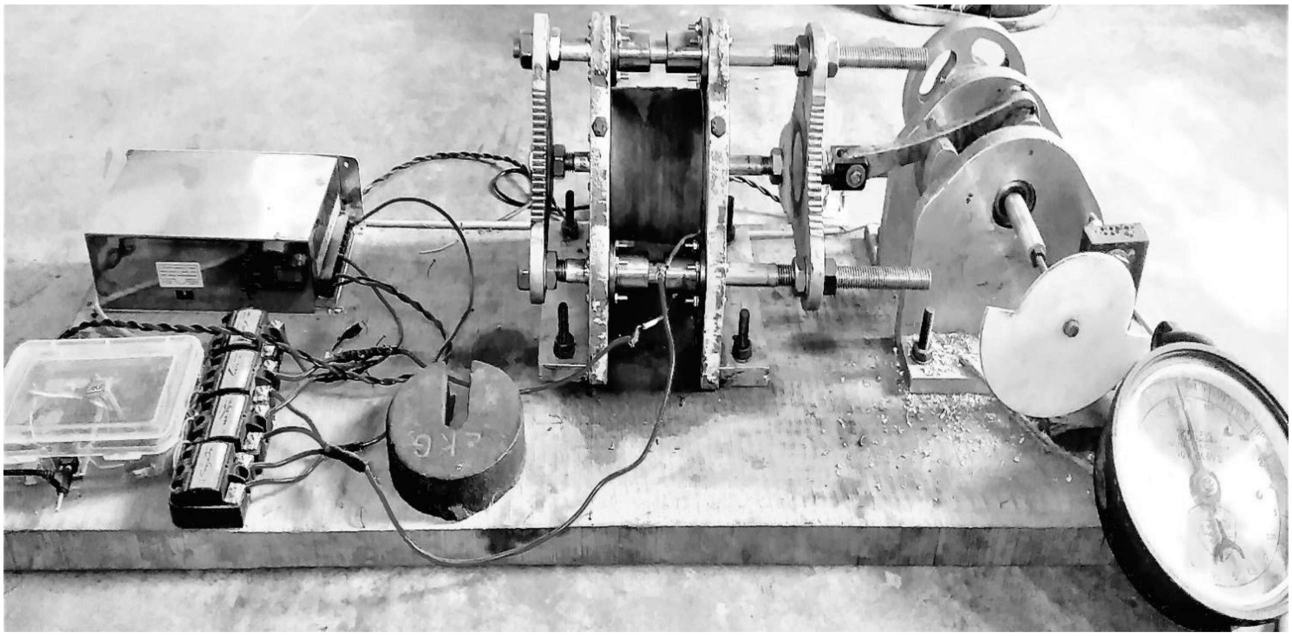


Fig.3 Magnetic Reciprocating Engine

3.1 DETAILS OF CIRCUIT

The circuit is the most important and intelligent part of the engine. The controlling is working under the H-Bridge concept [9, 10]. This consists of Arduino [11], PCB, Diffuse Photoelectric Sensor, LCD monitor [15, 16], Solid State Relay (SSR) [12] and a Trigger plate. The trigger plate is mounted with the crankshaft with an M6 screw. The sensor is mounted in such way that it will turn on (High or 1) when the piston reaches IDC (inner dead center) and turn off (Low or 0) when the piston reaches ODC (outer dead center). The Arduino board [11] is programmed in such a way that when it senses the data, it controls four SSR syncing with the piston position. The relays are connected as the connection of an H-bridge [9, 10]. Fig.5 shows the circuit schematically. Pictographic views of circuit, Arduino and SSR are shown in Fig.6-8 respectively.

Basically H-bridge is used to convert a DC current into controlled AC Current as per requirement. The direction of current changes followed by the feedback of the sensor. Fig.3 shows working of H-bridge connection.

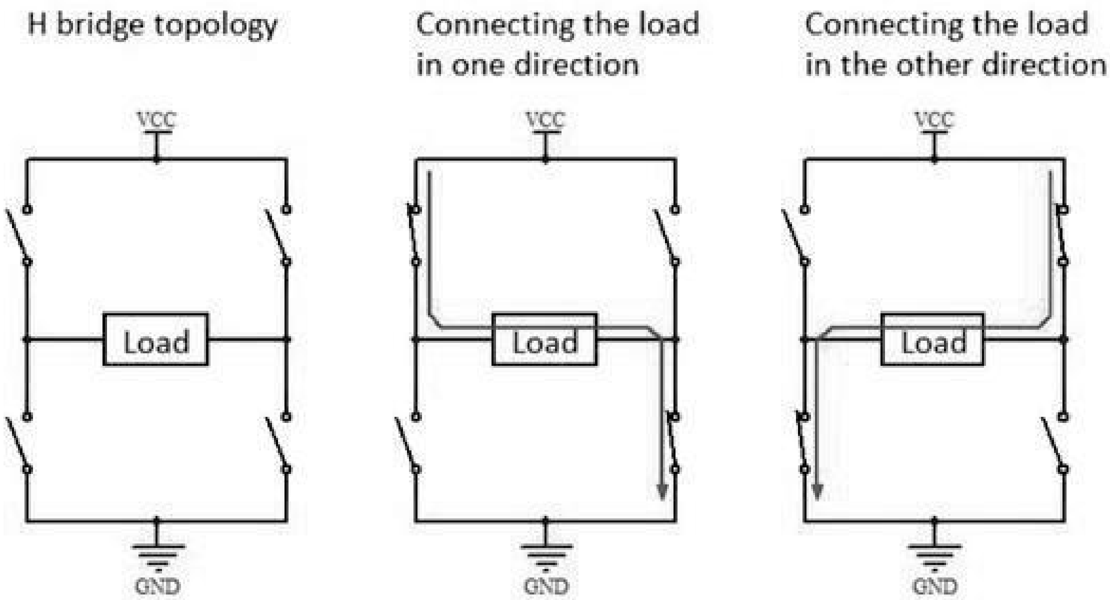


Fig.4. Working of H-bridge Motor driver

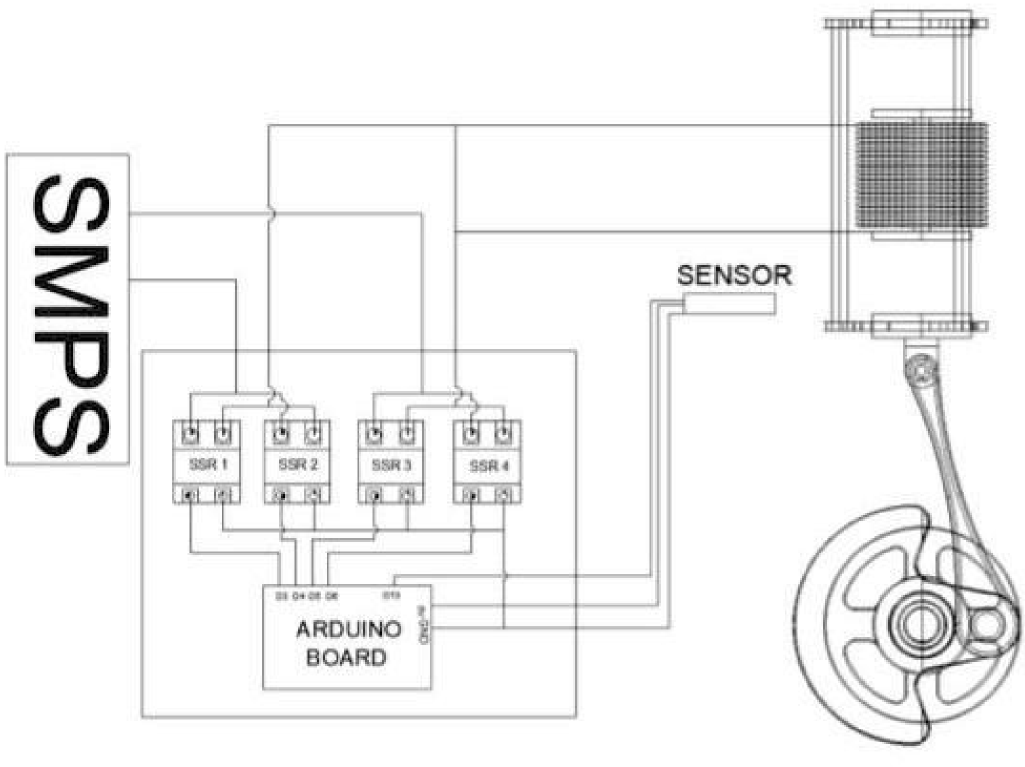


Fig.5. Schematic Digram of Circuit

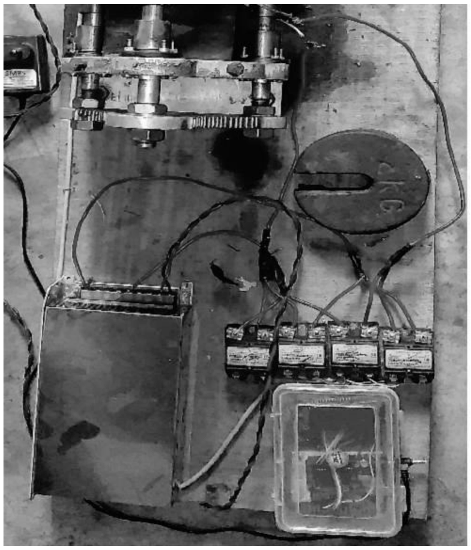


Fig.6 Picture of circuit

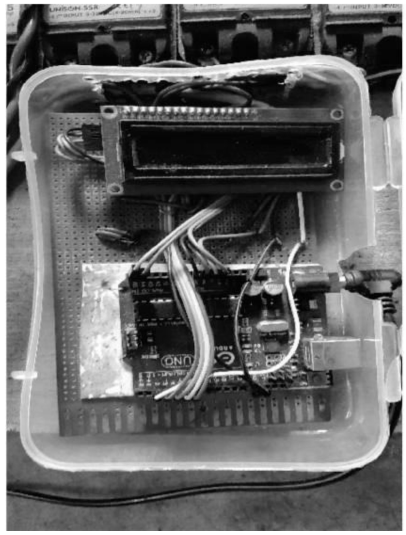


Fig.7 Arduino and Lcd Monitor

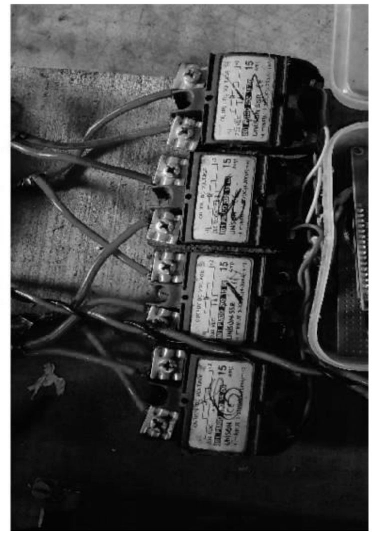


Fig.8 Solid state Relays

Arduino measures the time interval of the sensor being High too Low to calculate the engine RPM. Then this data is displayed on an LCD monitor. The whole system is soldered in a PCB board and mounted inside a circuit box. The microcontroller system is powered by a 1A, 12 V power supply.

3.2 DESIGNING THE SYSTEM AND MATERIALS SELECTED

3.2.1 Piston

Pictographic view (Fig.10) and AutoCAD design (Fig.9) is given below along with its specification (Table.1).

Table.1 Specification of Piston

Sl. No.	COMPONET NAME	DIMENSION	MATERIAL	USEFUL PROPERTY
1	Permanent Magnet [14]	Thickness-15 mm Diameter- 50 mm	Neodymium	Most powerful magnet available
2	Permanent magnet holder	Inner ring diameter- 60 mm, Outer ring diameter- 90 mm	Aluminum	Light, durable, Easy for machining
3	Piston rods Length-170 mm, Diameter-10 mm	Length-170 mm Diameter-10 mm	Aluminum	Light, durable, Easy for machining

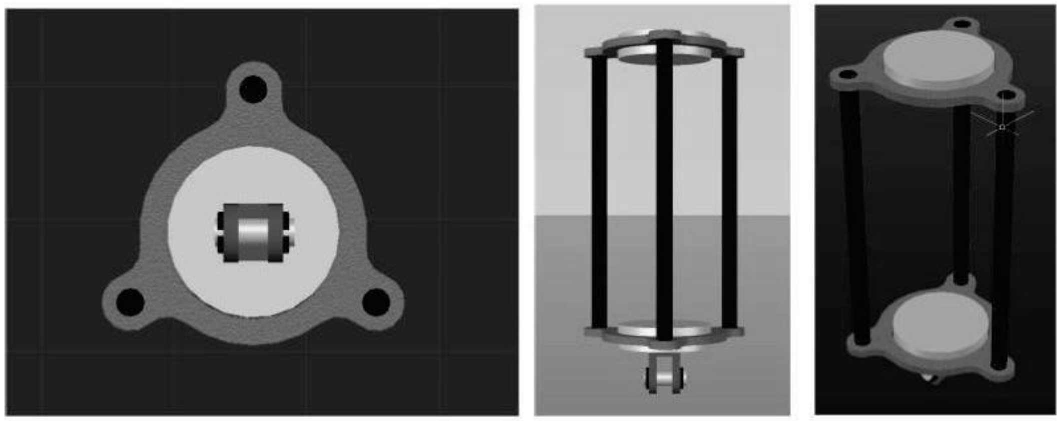


Fig.9 AutoCAD design of Piston

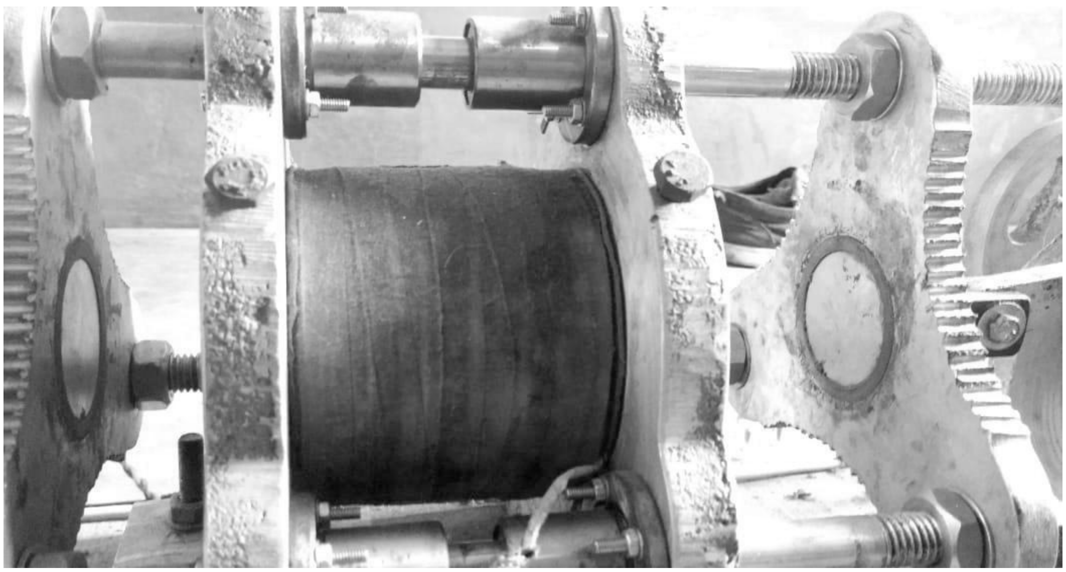


Fig.10 Pictographic view of Piston

3.2.2 ELECTROMAGNET

AutoCAD design (Fig.11) and Pictographic view (Fig.12) are given below along with its specification (Table 2).

Table.2 Specification of electromagnet

Sl. No.	COMPONENT NAME	DIMENSION	MATERIAL	USEFUL PROPERTY
1	CORE	Length- 80 Mm, Diameter- 60mm	Wrought iron	Minimize the hysteresis loss. Help to increase the magnetic flux density.
2	WIRE	1500 turns	Copper	Good electrical and thermal conductivity

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. The 'I' shaped core is made of wrought iron. A coil is formed using insulated solid copper wire which is wound around a core. When electricity is passed through this coil, the coil gets energized and a magnetic field is generated. A winding is usually referred to as one loop of the copper wire around the core. It is always better to coat the coils with varnish or wrap them with insulating tape as they provide enhance their insulating properties. Further insulation is given between each layer of winding.

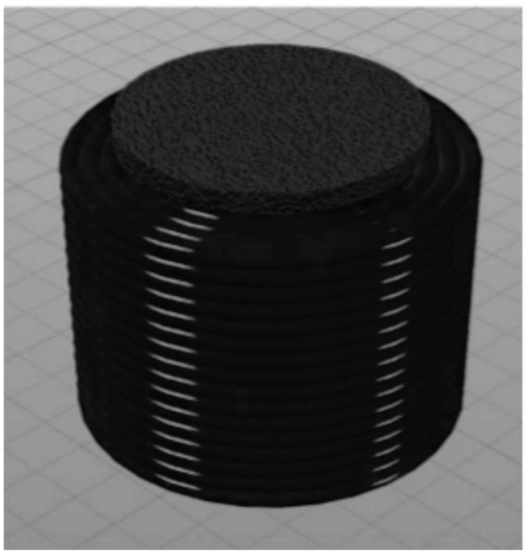


Fig.11 AutoCAD Design of Electromagnet

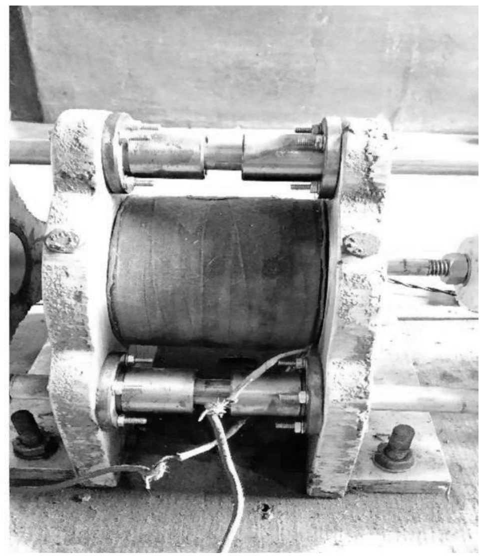


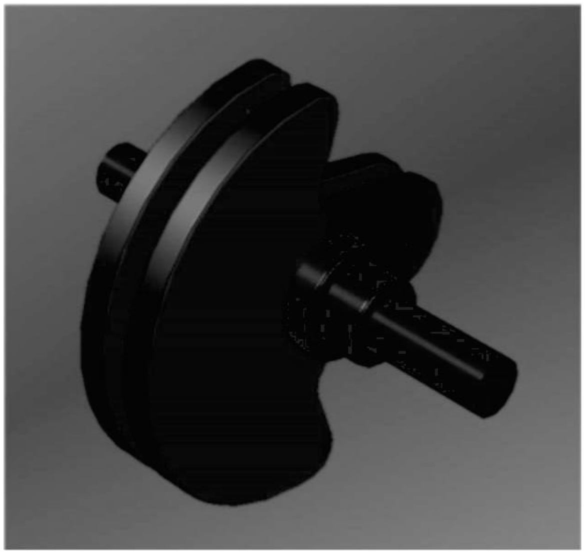
Fig.12. Pictographic view of Electromagnet

3.2.3 Slider Crank Mechanism

Table.3 Specification of slider crank [8].

Sl. No.	COMPONENT NAME	DIMENSION	MATERIAL	USEFUL PROPERTY
1	Crankshaft	Crank Length- 40mm	Aluminum	Machinable
2	Connecting rod	Length-160 mm	Aluminum	Machinable
3	Gudgeoned pin	Pin dia-20 mm	Stainless steel	Toughness

AutoCAD drawings of crankshaft, connecting rod and Gudgeoned pin are shown in Fig.13, Fig. 15, Fig. 16 respectively. Fig.14 shows Pictographic view of Crankshaft. Fig.17 shows the pictographic view of connecting rod and gudgeon pin.



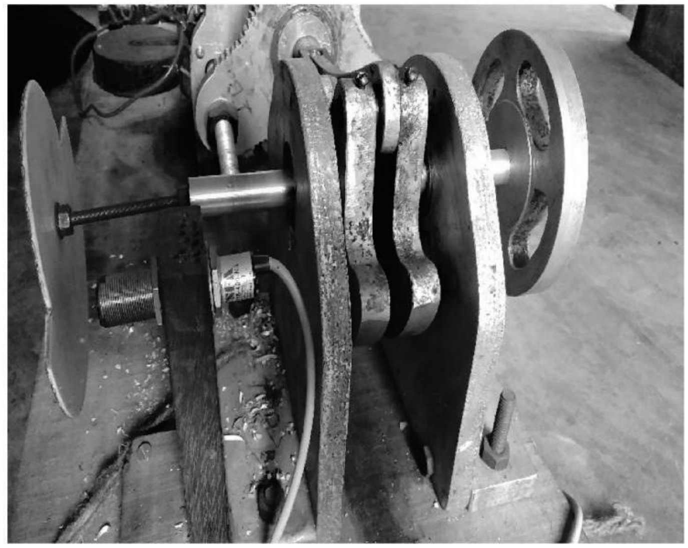
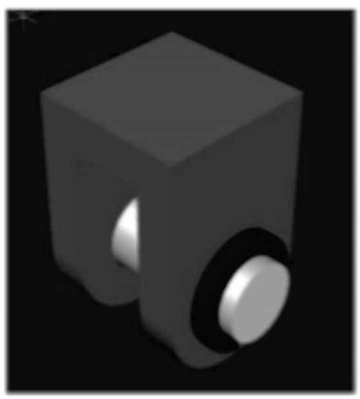


Fig.13 AutoCAD design of crankshaft

Fig.14 Pictographic view of crankshaft



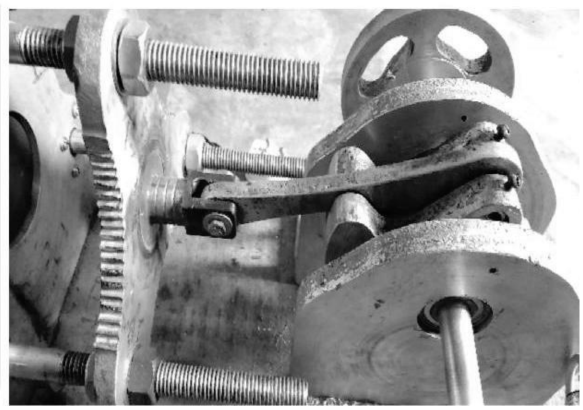


Fig.15 Connecting rod

Fig16. Gudgeon pin

Fig.17 Pictographic view of connecting rod

3.2.4 FLYWHEEL & BEARING

Specifications and dimension of flywheel and bearing is listed below in Table.4.

Table.4 Specification of flywheel and bearing

Sl. No.	COMPONENT NAME	DIMENSIONS	MATERIAL
1	Flywheel	Dia-60mm, Hole dia-17 mm	Aluminum
2	Bearing	Inner dia-17mm, Outer dia-40 mm	Steel

Fig.18 and 19 shows AutoCAD designs of flywheel and bearing respectively.

Fig.18 AutoCAD drawing of Flywheel

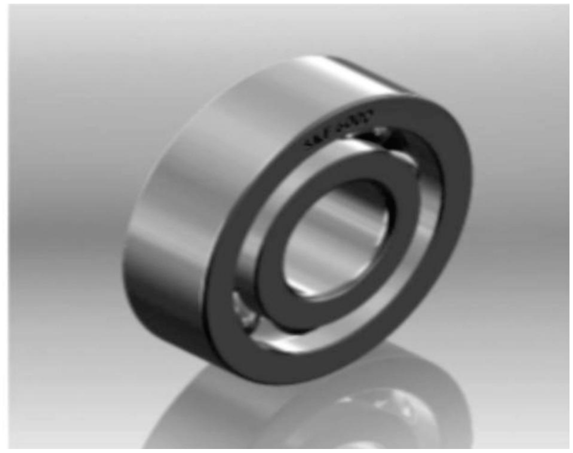


Fig.19 AutoCAD Design of Bearing

3.2.5 FOUNDATION

Foundation is one of the most important parts of our assembly. In working condition, the piston and crankshaft will rotate at very high speed, which makes the system Unbalanced. To overcome this problem a foundation should be imparted in the system which reduces the unbalance forces and acts as constraint relative to the motion. AutoCAD design is given in Fig.20 and Fig.21.

Assembly is the main thing for construction of a mechanical system. The assembly of this engine is designed in such a way there is no contact between electromagnet and piston frame so that no frictional loss will occur. Traditionally reciprocating system has more contact and this causes more friction. It makes the system less efficient. Keeping the above-mentioned issues in mind design of assembly is done in such a manner that contact resistance will be very less which makes the system more efficient.

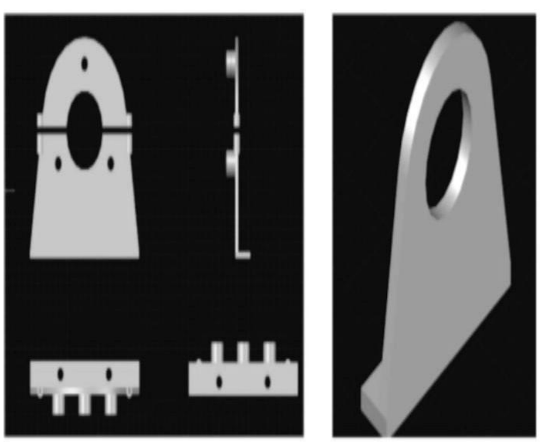


Fig.20 Holders

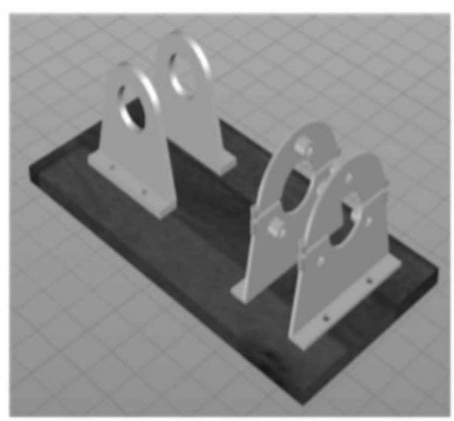


Fig.21 Holders and Foundation

4. DISCUSSION ON EXPERIMENTAL RESULTS

A rope brake dynamometer is arranged to measure the load carrying capacity and its corresponding rpm. Following table of taken readings is given below.

Using the equations, torque is calculated with the change in crank angle.

$F = (\mu_0 / 4\times\pi) \times (q_1 \times q_2 / x^2)$
Or, $F = (\mu_0 / 4\times\pi) \times q_1 \times q_2 \times ((1/(80+x)^2) + (1/(80-x)^{2)}))$
Or, $T = r\times F = r\times (\mu_0 / 4\times\pi) \times q_1 \times q_2 \times ((1/(80+x)^2) + (1/(80-x)^2)))$

Where, $X = r(n-\sqrt{}(n^2 - (\sin\theta)^2)) + r(1-\cos\theta)$ $q^1 = (N\times I\times A/L)$, Input = 36 V × 15 A = 540 W

$T\ mean = (\int (T\times d\theta))(0, 2\times\pi)/(2\times\pi)$
Output = $(2\times\pi\times N\times T\ mean)/60$
Efficiency = $\eta = (2\times\pi\times N\times T\ mean)/(60\times540)$

Where,
F = Force between two magnetic dipoles [7]
q_1, q_2 = pole strength of electromagnet and permanent magnet [7]
T = Torque acted upon crank
N = L/R
L = length of connecting rod
N = No. of turns in electromagnet
I = Current passing through Cu wire
Tmean = Mean torque

Table.5. Experimental Data

SL. NO	LOAD(W)(kg)	TENSION IN ROPE (T) kg	W-T (kg)	RPM
1	0.1	0.075	0.025	220
2	0.2	0.1	0.1	208
3	1	0.5	0.5	180
4	1.2	0.55	0.65	172
5	1.3	0.68	0.62	162
6	2	0.95	1.05	150
7	2.2	1	1.2	140
8	2.3	1.1	1.2	139
9	3	1.25	1.75	105
10	3.2	1.65	1.55	93
11	3.3	1.7	1.6	80

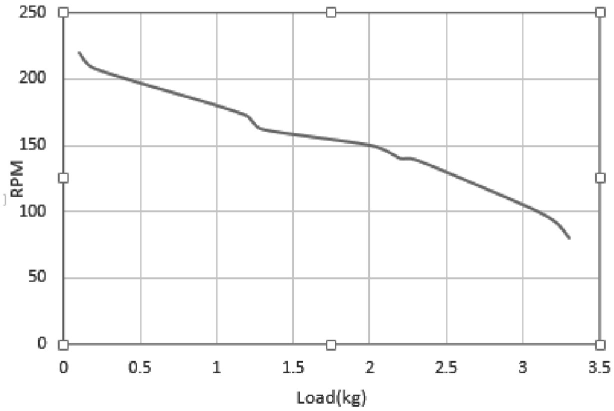


Fig.22 Plot of variation of RPM With Load (Kg)

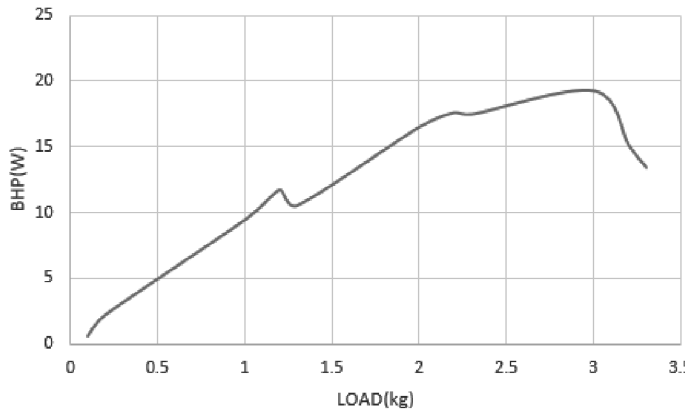


Fig.23 Plot of variation of BHP(W) with Load(kg)

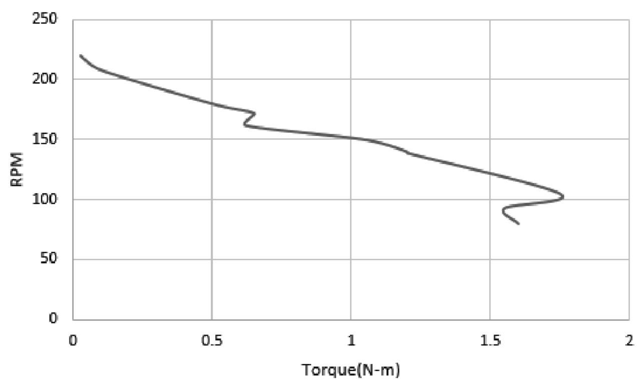


Fig.24 Plot of variation of RPM with Torque(N-mm)

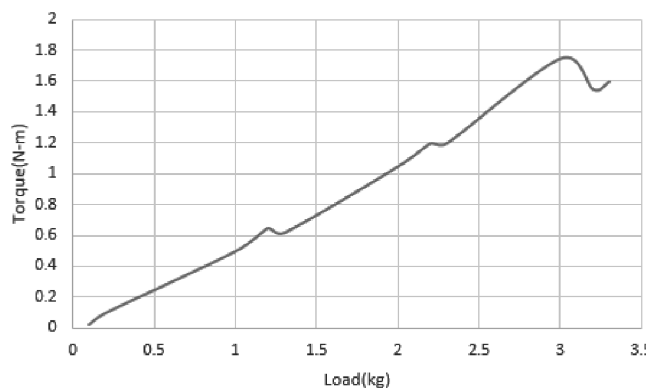


Fig.25 Plot of variation of Torque(N-m) with load(kg)

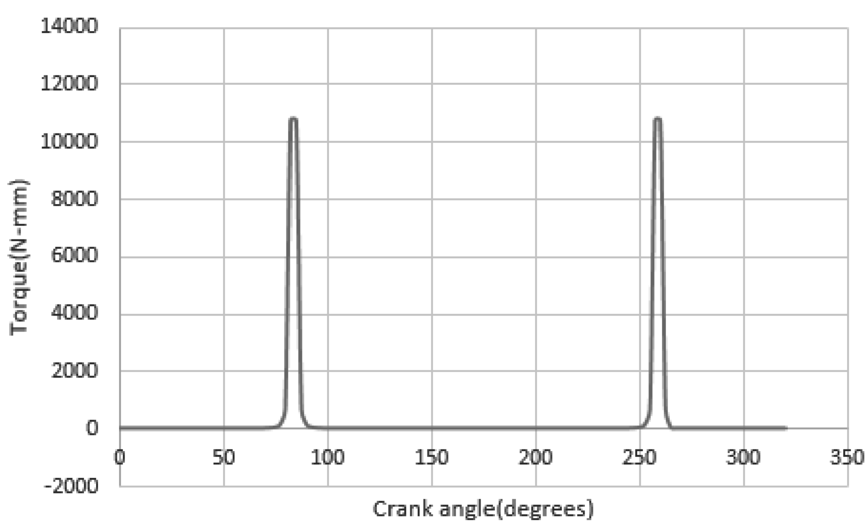


Fig.26 Plot of variation of Torque (N-mm) with crank angle (Degrees)

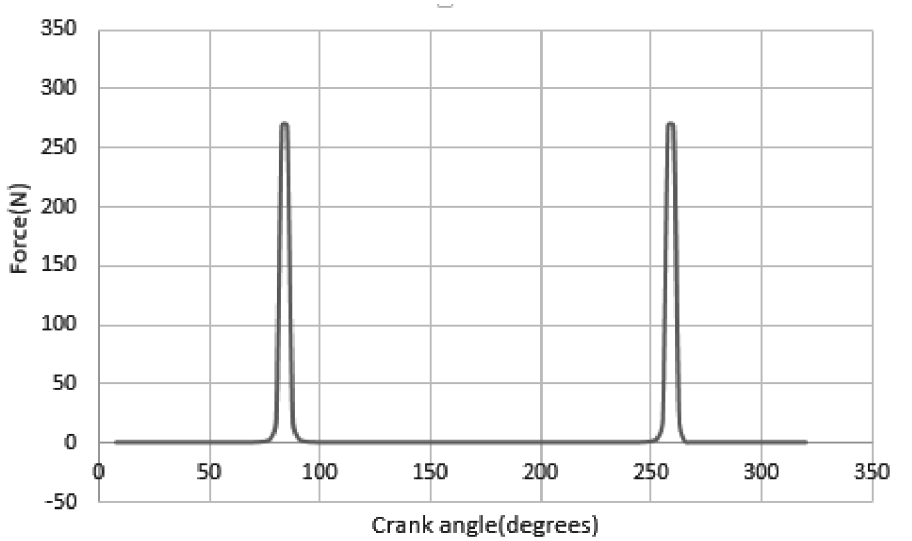


Fig.27 Plot of variation of Force (N) with crank angle (Degrees)

Analysis is done on the basis of following trends of graphs.

1) From Fig.22 RPM has a decreasing tendency with load, which is quite natural.
2) Fig.23 shows that BHP increases up to a certain load and then it decreases. As per engine capacity it can sustain up to that load.
3) As known, torque is inversely proportional to RPM. So, in Fig.24 torque has a decreasing trend with RPM.
4) In Fig.25 torque is increasing with given load. As the difference between given load and spring weight increases torque increases.
5) It is found that there are two power strokes in 360 degrees of crank rotation. Periodic nature of Fig.26 & 27 justifies this statement.

As no planimeter arrangement is present, indicator diagram cannot be drawn. That is why indicated power cannot be calculated. So, Mechanical efficiency cannot be calculated properly.

5. POSSIBLE APPLICATIONS

As its efficiency is thought of to be higher compared to an I.C. engine or Electrical engine, it can be used in automobile or industrial applications. In valve controlling system of IC engine, the principle of this engine can be employed. It can also be used instead of pneumatic actuators, and in the field where reciprocating concept plays a vital role, like reciprocating pump and compressor.

6. IMPLEMENTATION ISSUE

During fabrication of this engine, it should be noticed that the position of electromagnet will be perfectly constrained with the help of a clamping device, otherwise the device becomes unstable due to vibration caused by reciprocation. Permanent magnet should be properly and tightly located at their position. Connection should be properly done and there should be a leak proof cover of magnetic proof material, so that there will be no flux loss from the system.

7. CONCLUSION

In case of Honda splendor bikes, maximum torque of engine is 8.5-10 Nm though power input is very high. Magnetic reciprocating engine can develop a maximum torque of near about 10 Nm with an input of 540 W, which is lesser than one HP. Further modifications can make this better.

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Appendix A

This is the Arduino programme[11,15,16] written for synchronizing the frequency with electromagnetic pole change with crank rotation.

```
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x3F,2,1,0,4,5,6,7,3, POSITIVE);
#define RELAY_ON 1
#define RELAY_OFF 0

#define Relay_1  2
#define Relay_2  3
#define Relay_3  4

boolean currentstate;
boolean prevstate;

int waittime;

void setup()
{ waittime = 0;
  lcd.begin(16,2);
  lcd.setCursor(1,0);
  lcd.print("WELCOME TO MRE");
  delay(2000);
  lcd.clear();
  lcd.setCursor(1,0);

 lcd.print("WELCOME TO MRE");
 lcd.setCursor (6,1);
 lcd.print ("THREE");
 delay (1000);
 lcd.clear ();
 lcd.setCursor (1,0);
 lcd.print("WELCOME TO MRE");
 lcd.setCursor (7,1);
 lcd.print ("TWO");
delay(1000);
```

```
#define Relay_4  5
#define SENSOR 13
#define ACTION 9

unsigned long prevmillis;
unsigned long duration;
unsigned long lcdrefresh;
int rpm;

}
void loop()
{ int L =digitalRead(SENSOR);

  if(L==0)

  { int time;
  duration= (time-prevmillis);
     rpm=30000000/duration;
     time=prevmillis;

 digitalWrite(Relay_1, RELAY_ON);
 digitalWrite(Relay_4, RELAY_ON);
  digitalWrite(Relay_2, RELAY_OFF);
 digitalWrite(Relay_3, RELAY_OFF);
     }

else if(L!=0)
{
int time;
      duration= (time-prevmillis);
      rpm=30000000/duration;
    time=prevmillis;
```

```
lcd.clear ();
lcd.setCursor (1,0);
lcd.print("WELCOME TO MRE");
lcd.setCursor (7,1);
lcd.print ("ONE");
delay (1000);
lcd.clear ();
     lcd.setCursor(3,0);
 lcd.print("LET'S BEGIN");
delay (2000);
lcd.clear ();
  pinMode(SENSOR, INPUT_PULLUP);
  pinMode(ACTION, OUTPUT);
  prevmillis = 0;

  digitalWrite(Relay_1, RELAY_OFF);
  digitalWrite(Relay_2, RELAY_OFF);
  digitalWrite(Relay_3, RELAY_OFF);
  digitalWrite(Relay_4, RELAY_OFF);

  pinMode(Relay_1, OUTPUT);
  pinMode(Relay_2, OUTPUT);
  pinMode(Relay_3, OUTPUT);
  pinMode(Relay_4, OUTPUT);
digitalWrite(Relay_1, RELAY_OFF);
  digitalWrite(Relay_4, RELAY_OFF);

  delay(waittime);
  digitalWrite(Relay_2, RELAY_ON);
   digitalWrite(Relay_3, RELAY_ON);
  delay(waittime);
}
else{
   lcd.setCursor(0,1);
    lcd.print("rpm = 0 ");
       }

if( ( millis()-lcdrefresh ) >= 800 )
    {
     lcd.clear();
     lcd.setCursor(0,0);
     lcd.print("Speed of Motor");
     lcd.setCursor(0,1);
     lcd.print("rpm = ");
     lcd.print(rpm);
     lcdrefresh = millis();
    }
      }
```