

## Dual Electromagnetic Engine

Sampreeth S J<sup>1</sup>, Shruthi V<sup>2</sup>, Ravikiran<sup>3</sup>, Reshal Teena D'souza<sup>4</sup>, Ganesh V N<sup>5</sup>

<sup>1-4</sup>Dept. of Electronics and communication Engineering, MITE, Moodabidri, Karnataka, India

<sup>5</sup>Sr. Asst. Professor, Dept. of Electronics and communication Engineering, MITE, Moodabidri, Karnataka, India

\*\*\*

**Abstract** – The increasing demand for fuel conservation has led to the growth of research in developing electromagnetic engine. The existing Internal Combustion (IC) engine requires fuel for the operation. Hence, the demand for fuel has increased. An important fact to be taken into account is that fuel is a non-renewable source. This reason makes alternative sources of energy to become necessary. It is time to replace non-renewable energy with renewable source of energy. This paper presents a research based on the development of Dual Electromagnetic Engine (DEE) by increasing the force of the electromagnetic attraction. The consideration of various factors in developing an engine resulted in the new, clean and green renewable energy source. The magnetic attraction force is considered into account and latter is converted into mechanical work. The electromagnetic engine operates similar to combustion engine by rotating a crankshaft. Assuming the fact in mind, the usage of two electromagnets will result in greater efficiency.

**Key Words:** Non-renewable, Internal combustion, DEE, Crankshaft, Electromagnet.

### 1. INTRODUCTION

The increasing population and technologies in the present century resulted in people preferring automobiles for their comforts. The requirement for fuel is increasing because of the increase in the demand for automobiles. With the diminishing fuel resources, it is requires to find alternate source for operating the engine. The challenge is not to create an engine that operates on an alternative fuel but to produce higher efficiencies. The alternative energy source such as bio-fuel takes enormous resources for their production and still pollutes the environment. The absence of viable alternative has made researchers for switching to new technology by changing from traditional internal combustion engines has been a challenge [1].

A simple method to produce high efficient energy by means of magnets inside a cylinder is basically known to be an electromagnetic engine. A magnet consists of two different poles, a north pole and a south pole. When like poles of two different magnets are brought close to each other they repel and attract when unlike poles of two or more different magnets are brought together [2-4]. The above mentioned basic operation stands as the principle used in an electromagnetic engine [5].

The magnetic material or two permanent magnets are positioned at the top and bottom of piston. An electromagnet is positioned at the center, on each side, facing the top and bottom supports of the cylinder. The permanent magnets are attracted to the piston when the electromagnet is charged, thus pushing the piston downwards or upwards. This vertical movement of the piston results in rotation of the crankshaft [6].

Without using fuel, the engine performs by using battery power completely, is the main advantage of electromagnetic engine. Since the engine doesn't have combustion, valves, fuel pump, fuel lines, air and fuel filters, inlet and exhaust manifolds, and other existing parts, the complexity can be reduced in an electromagnetic engine [7]. The main challenge faced in designing a dual electromagnetic engine (DEE) is that it has to be as efficient as an internal combustion engine.

### 1.1 Motivation

Most of the automobiles use IC engine, whereas some of the vehicles operate using electric motor engines. Upon highlighting the majority of the usage of vehicles, they consume a large amount of conventional energy. They also cause an enormous amount of pollution to the environment. The engines that run on alternative energy sources can be used because it is more of non-conventional. The engines use various alternate energy sources, such as bio-fuel, solar power, wind power, electric power, stored power, etc [8] are being developed around the world. However, such engines have many limitations. They do not meet the ever-increasing energy demand as well. The main objective is to produce energy which can run the engine by means of magnets.

The electromagnetic engine has countless advantages compared to the internal combustion engines. The main advantage is the usage of battery for operation and no fuel is consumed by the engine. The exhaust gas like greenhouse gases which is harmful to environment will not be produced [9-11]. The above operation results in controlled pollution which is very acceptable in the present life situation. As there is no combustion in electromagnetic engine, the scenario inside the cylinder will be a very little heat generation. This eliminates the need for a cooling system.

## 1.2 Methodology

The electromagnetic engine works on the principle of magnetic attraction. When unlike poles, precisely different poles of two magnets come in contact with each other they will attract each other with equal and opposite force. This phenomenon of attraction is used here, to create linear motion. The engine displayed in figure 2, greatly resembles to the working of a two-stroke engine. Assume the scenario based on position, the piston is located at the lower position, commonly known as Bottom Dead Centre (BDC). The dual electromagnet is connected to MOSFET circuit through the 12V battery and is energized to produce temporary magnetic field as shown in figure 1.

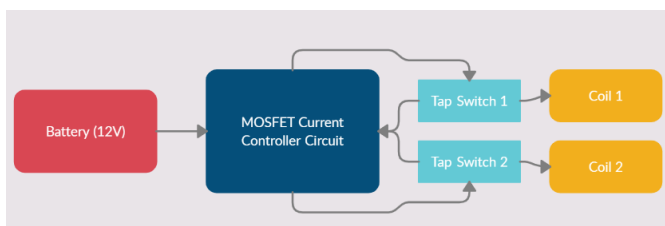


Fig -1: Block Diagram of Electromagnetic engine.

The electromagnet at the center located near to the BDC will be powered by the battery at that particular instant. The electromagnet is connected to the power driving circuit and interfaced with the microcontroller. When an electromagnet gets energized, the piston will be attracted towards the electromagnet, hence moving the piston from BDC to TDC. This linear motion helps to complete half the revolution of the crankshaft [12]. Relay is used to switch the power from the battery to the other electromagnet. Switching power timings are controlled by the microcontroller. When the piston reaches the TDC, the relay circuit switches the power to the electromagnet near to Top Dead Centre (TDC). This results in movement of piston from TDC to BDC. This linear motion helps to complete the other half revolution of the crankshaft. This arrangement converts the reciprocating motion of piston into the rotary motion of flywheel connected to crankshaft.

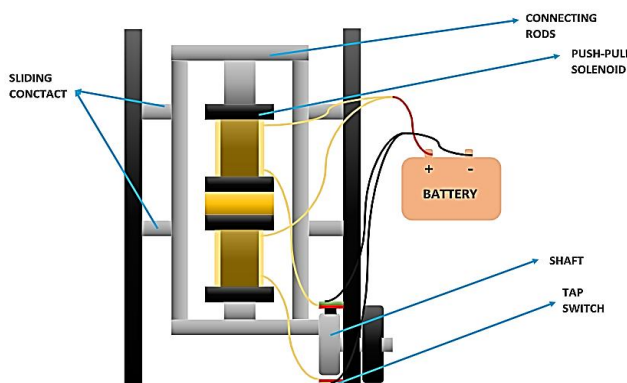


Fig -2: Design Methodology of electromagnetic engine.

Overall, this procedure helps to complete one complete rotation of the crankshaft. While one piston

moves from BDC to TDC, the below electromagnet gets de-energized and de-magnetized. At the same time other electromagnet gets energized and completes the rotation of flywheel. This completes the full stroke as shown in figure 2.

The connecting rod helps to connect piston to the crankshaft. It converts the linear motion or reciprocating motion of the piston to the circular motion of the crankshaft. The material of the connecting rod is aluminium. Aluminium is chosen, after so much research on the properties, because of its ability not to attract towards magnet. As the magnetic fields are contained inside the cylinder and highly isolated, the connecting rod will not be affected much. The connecting rod is same as that in IC engine is shown in figure 3.

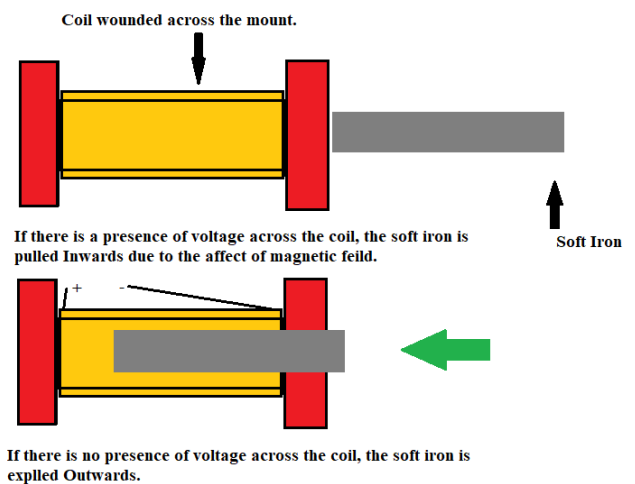


Fig -3: Effect on soft iron due to electromagnet.

A relay, an electrical device, is electrically operated switch. The existing relay uses a coil wound electromagnet to mechanically operate a switch, but other operating principles are also used. The relays are mainly useful where it is necessary to control the current whose input is a low power signal. It is also used in several circuits, where it must be controlled by one signal [13]. A simple electromagnetic relay consists of a coil of outer insulated copper wire wound around a soft iron core. An iron yoke is important as it supplies a low reluctance path for magnetic flux. It also provides a movable iron armature. It also enhances one or more sets of contacts. It is mounted tightly by a spring so that when the relay is de-energized, an air gap is formed as a result of the scenario in the magnetic circuit. In this particular condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open.

This electromagnetic engine produces more horsepower than the combustion engine and uses very less energy compared to the electric motor. This engine can be smoothly operated for any desirable sized transportation. The design of electromagnetic engine can

be developed based on conditions and size. The conditions vary vastly for electrical needs ranging from 12KW to more than 1MW. It produces desired and predicted power for every half stroke compared to the combustion engine that produces power at every fourth stroke. The decrease observed here in terms of strokes will result in increase of the horsepower [14].

## 2. HARDWARE AND SOFTWARE REQUIREMENTS

The design of any desired model needs its own hardware and software requirements. The precise measurements can be obtained from mathematical calculations generated from the software.

### 2.1 Hardware

#### 3D Printer

Comgrow Creality Ender 3 pro. 3D printer (figure 4) is used to print the designed 3D models. 3D printing itself defines that it is the construction of a three dimensional object using a digital 3D model. It can also be printed from the CAD model. The material is deposited using software by computer control to create a three-dimensional object. It is precise as it is fused and printed layer by layer.



**Fig -4:** Comgrow Creality Ender 3 Pro.

This printer can continue printing from where it was stopped due to power issue. This feature is not present in almost most 3D printers. Since power cut has been an issue in main rural areas, this feature helps to enhance the working performance of the printer. This printer is very easy to setup and in most cases it comes partially assembled. It allows you to learn about the assembling and

how exactly the printer works. This helps to enhance the information and gain knowledge on how to correct errors when it occurs practically.

#### Battery

A 12V battery as shown in figure 5 is required to power the electromagnet. The working performance of the battery has to be chosen carefully. The long lasting power of the battery would be a major advantage in electromagnetic engine. The battery used is the Sanca 12V 1.3Ah SMF/VRLA Rechargeable Battery. This battery can be used to energize the electromagnet to provide the necessary force.

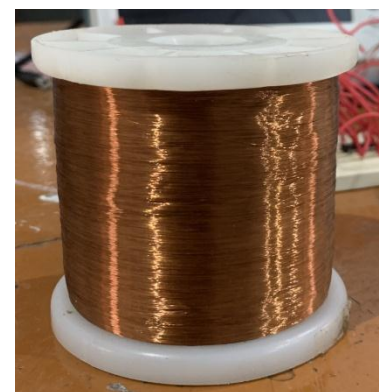


**Fig -5:** Sealed lead-Acid Rechargeable Battery.

The battery being rechargeable is a major advantage as the power can be recovered from the linear motion of the piston in the electromagnetic engine.

#### Electromagnetic Coil

An electromagnetic coil is simply a copper wire wound to a surface forming a coil, spiral or helix. Electromagnetic coils are basically used where magnetic fields are generated with the help of electric current. A current is passed to coil thereby generating magnetic field [15]. A circular magnetic field is formed across the conductor due to Ampere's law. The strength in the magnetic field is determined by the diameter and number of turns of the coil (figure 6).



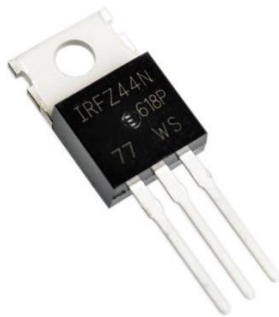
**Fig -6:** Magnetic coil.

The increase in number of turns of wire, the stronger will be the magnetic flux produced. The direction of the magnetic field generated by a coil is determined using the right hand rule of Fleming's. The magnetic field lines emerge from the North Pole.

The magnetic coil is wound across the holder to develop a push-pull electromagnet. This results in producing linear motion at the output. The magnetic coil used here is 99.9% pure copper having measurements of 27 gauge. The diameter of the copper wire is approximately 0.41mm.

**IRFZ44N MOSFET**

The IRFZ44N is a MOSFET (figure 7) based on the very small signal N-channel. It has a high drain current with 49A. It has a very low Rds value having 17.5 mΩ. The MOSFET will start conducting at a low threshold voltage of 4V.



**Fig -7:** IRFZ44N Power MOSFET.

It consists of three terminals commonly known as gate, drain and source. The gate terminal controls the supplied voltage or biasing of MOSFET. The source terminal is commonly referred to as the output terminal where the current flows out through the source. The drain terminal is generally referred to as the input terminal where the current flows in to the MOSFET through the drain.

The IRFZ44N, as mentioned earlier has very high drain current and comparatively fast switching speed. The high efficiency of switching circuits is due the parameter of low Rds value. The MOSFET with a small gate voltage of 4V is required to turn on the circuit. When a gate voltage is 10V, the drain voltage will reach the maximum value.

The MOSFET's are known to be voltage controlled devices. They can be turned off and turned on whenever required by controlling the threshold gate voltage. When there is a presence of gate voltage, these pins get closed. The MOSFET has various applications in modern research and usage. It is often used in cases where high power devices need to be switched. It can also be used to control the mechanical speed of the motors. It plays a vital role in decorations such as LED dimmers and flashers. It can also

be used in circuits like inverters and converters. It is mainly used for switching high power devices.

**Soft Iron**

Soft iron rod (figure 8) is major tool we require for enhancing the performance of the electromagnetic engine. The soft iron rod is the result of the movement of piston. The dimensions of the soft iron rod includes the diameter and length as parameters. The diameter of the soft iron rod is 0.6mm while the length of the soft iron is 40mm. The soft iron rod has the power to magnetize and demagnetize depending on the presence of magnetic field. It is stated by some researchers as the ideal core for the design and working performance of an electromagnet.

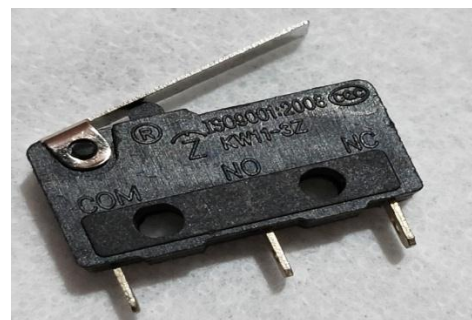


**Fig -8:** Soft Iron Rod.

Almost all scientists refer to this as the soft magnetic iron rod specifically used for electromagnetic applications [16]. It has very unique property of quickly magnetizing and demagnetizing in the presence or absence of magnetic field.

**Tap Switch**

The tap switch (figure 9) plays a very important role in switching the transferred power from the electromagnet. The dual electromagnetic engine consists of two electromagnets it is necessary to switch the power energized by the battery to the other coil. The circuit is closed only when there is a tap on the switch. This operation is mainly done by the flywheel at half the rotation [17]. The working operation of the tap switch is connected through the MOSFET.



**Fig -9:** Tap Switch.

## 2.2 Software

### MatterControl 2.20.4

MatterControl 2.20.4 is a free and open-source 3D modelling software. It is also defined as all-in-one software package that helps you design a 3D model. The operations like slicing, organizing, and managing our 3D print can be done. The design can be developed as per our requirements from scratch. It can be edited and geometric shapes can be done with exact precision. The modelling of 3D parts can be done in this software displayed in figure 10.

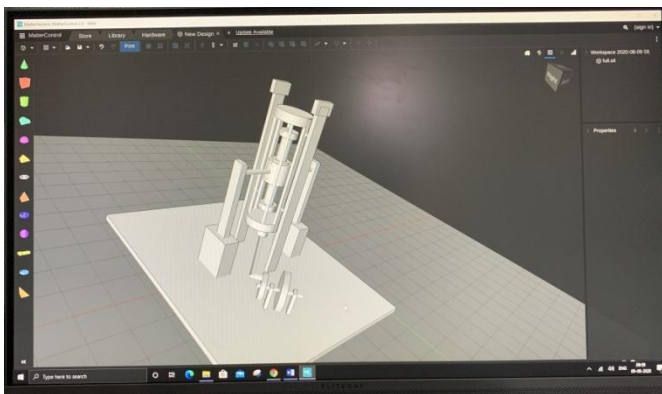


Fig -10: MatterControl 2.20.4 Software.

### Creativity Slicer 1.2.3

3D Slicer is an open source software platform for printing 3D models or CAD models. It prints the 3D model layer by layer resulting in exact precision. It also helps to detect the error and thus forbidding the loss. The time taken to print the model can be estimated. The software used to print is the Creativity Slicer 1.2.3 (figure 11). This software is originally designed by the company to avoid unexpected compatibility error. The parts where there is no support can also be detected. It helps to identify the requirement of z-axis support for the successful printing of the design.



Fig -11: Creativity 1.2.3 Software.

## 3. DESIGN OF 3D MODELS

### 3.1 Flywheel

A flywheel as shown in figure 12 is the most important part of the engine. It transfers the power received from the piston to the crankshaft. A flywheel is a mechanical model shown in figure 13, having a mass rotating around an axis. The energy in the flywheel is stored in the form of kinetic energy. It then converts the stored energy into the mechanical rotational energy.

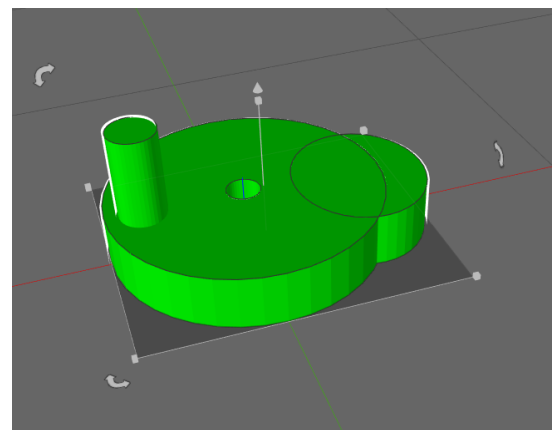


Fig -12: Primary Flywheel.

Flywheel energy storage is a promising technology for replacing conventional lead acid batteries as energy storage systems.

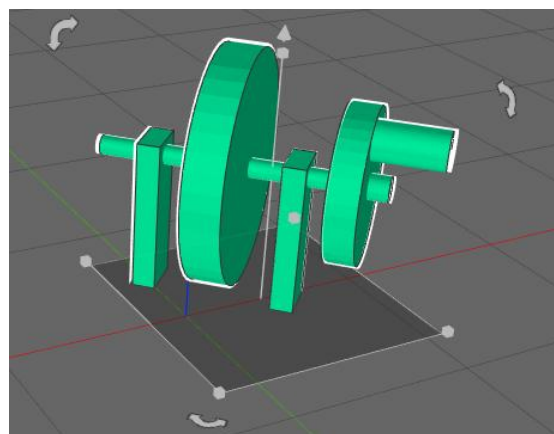
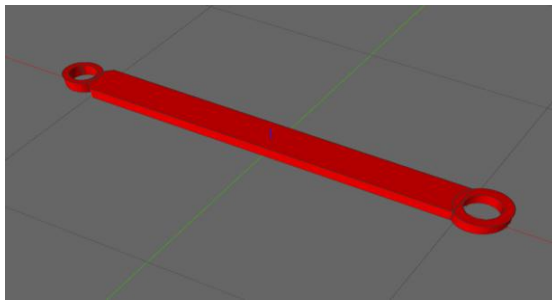


Fig -13: Flywheel Setup.

### 3.2 Connecting Rod

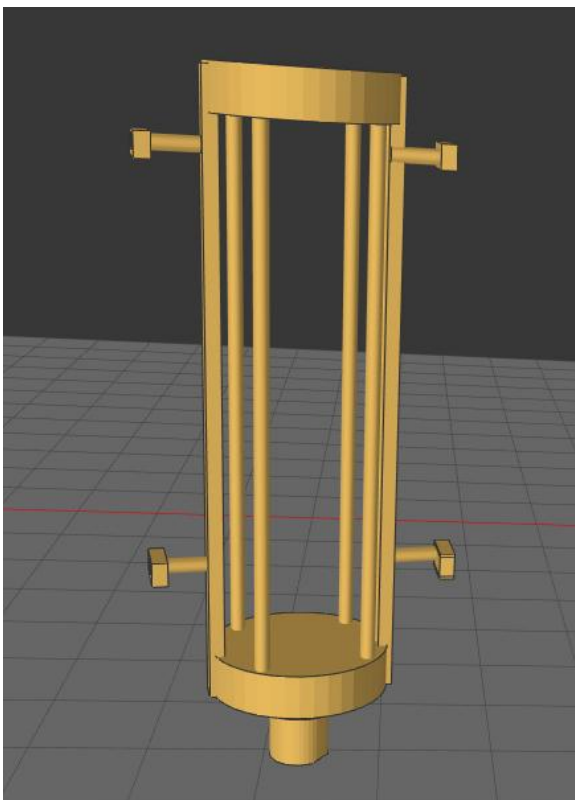
The connecting rod (figure 14) in the dual electromagnetic engine resembles to that of an internal combustion engine. It is also called a con rod. It is the part of the piston which connects to the crankshaft. It is responsible for the rotation motion of the crankshaft. It converts the reciprocating motion of the piston.



**Fig -14:** Connecting Rod.

### 3.3 Piston

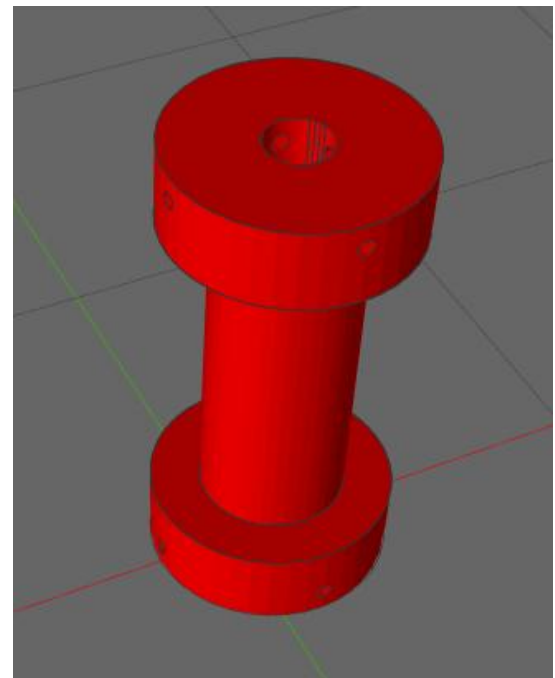
The piston (figure 15) is the moving part in the engine. It is enclosed inside a cylinder. The piston is responsible for the reciprocating or linear motion in an engine. The piston is made to rotate by the electromagnets. The top and the bottom parts of the piston are made to rotate with the help of soft iron rod attached to it. The piston movement is due to the rolling support and the stand. The call bearings are not used as it generates a lot of friction to the surface. It will thus be the reason for the reduction in force generated at the output.



**Fig -15:** Piston.

### 3.4 Coil Support

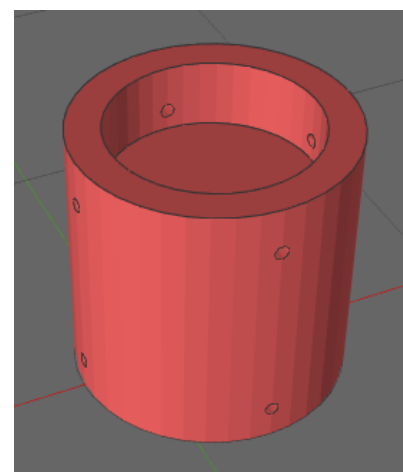
The coil support (figure 16) is the one on which copper coil is wound. The number of turns and other parameters are satisfied for measurements. The design measurements are calculated and modelled.



**Fig -16:** Coil Support.

### 3.5 Coil Holder

The coil holder supports the two coil supports to be held at a fixed position. The small holes observed in the figure 17 are for the fixing of the model. The responsibility of the support is to make sure that it stays in the fixed position irrespective of opposing force.

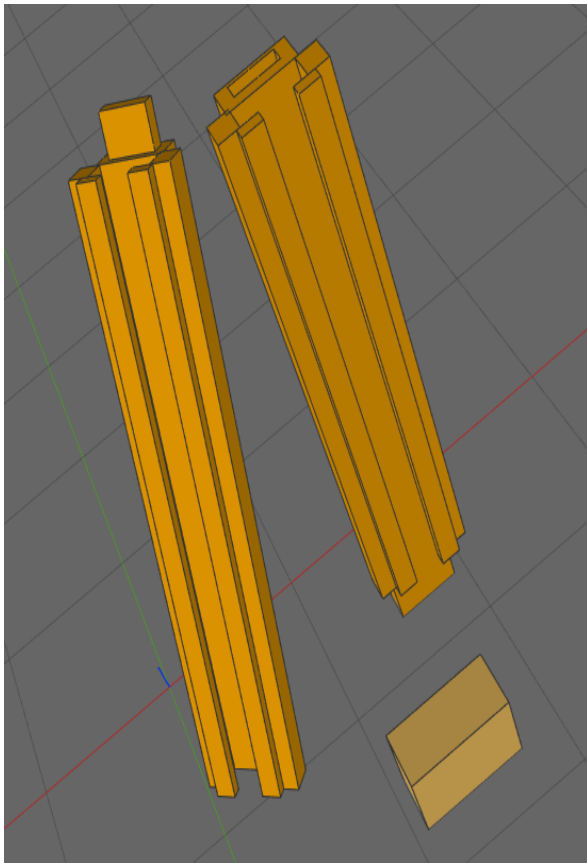


**Fig -17:** Coil Holder.

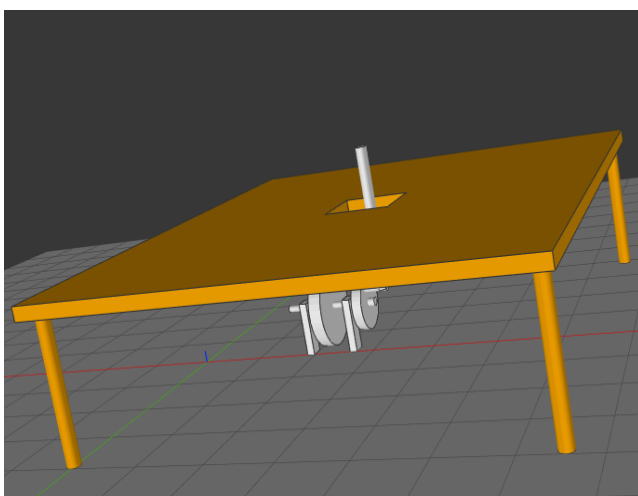
### 3.6 Rolling Stands and Supports

The stands and supports are the most important parts of an engine. They withstand the opposing forces thus making the model operation a successful one. The rolling stand and main stand are shown in figure 18 and 19 respectively, which is the place where most of the models

are placed. Below the stand is the flywheel and crankshaft setup. The linear motion of the piston is made to rotate the flywheel by the connecting rod. The hole at the center is for the connecting rod as it feels comfortable at the gap for the free movement.



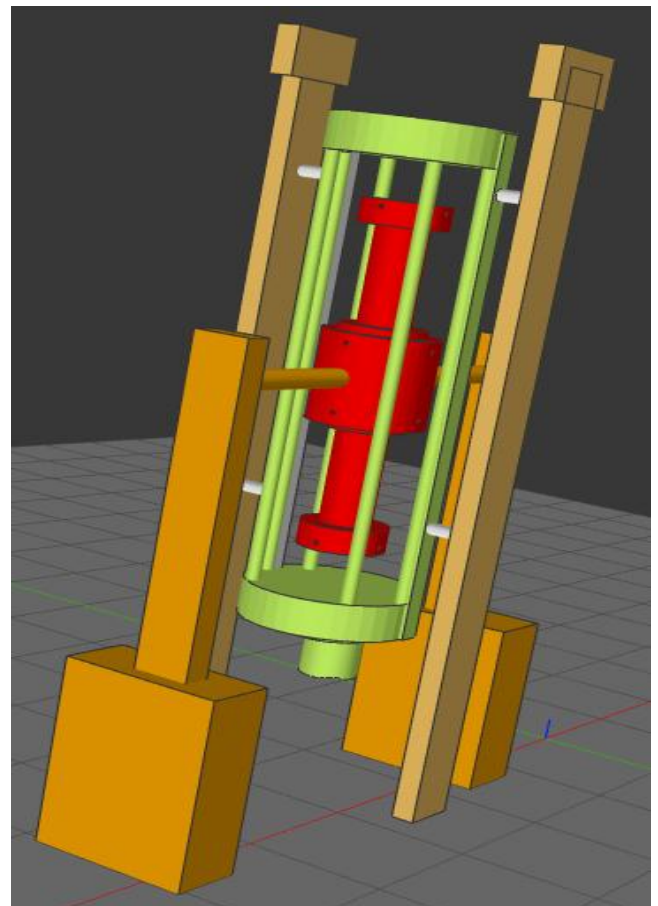
**Fig -18:** Rolling Stand.



**Fig -19:** Main Stand.

### 3.7 Integrated Model

The model is designed and embedded later after all the parts were modelled. The technique used here is the divide and conquer rule. The integrated model is shown in figure 20. The measurements thus calculated theoretically matched the practical models.



**Fig -20:** Integrated Model.

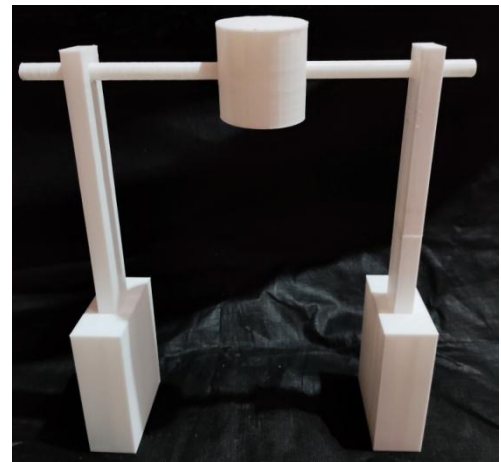
## 4. PRINTING AND CIRCUIT CONSTRUCTION

### 4.1 Printing the 3D models

The parts were 3D printed and thus and shown in the figure 21. The flywheel was the crankshaft version. The integrated model could not be printed together. Thus the individual parts were printed first and then integrated. The models were joint using adhesive gums and screws. In some areas nuts and bolts were used. The bulged part of the flywheel is made to trigger the tap switch. The cylindrical extension is to fit the connecting rod. The other end is connected to the piston. The flywheel rotates as the result of rotation of crankshaft. The power is generated by the electromagnet with the help of battery. The battery is to energize the electromagnet to produce the necessary force to rotate the flywheel.



**Fig -21:** 3D Printed Flywheel.



**Fig -24:** 3D Printed Coil Holder.

The rolling stand shown in figure 22, is the fixed part where the piston slides downwards and makes upward movement. The rectangular block of free space is locked so that the piston does not jump out of the stand. This helps to make perfect movement.

The coil holder is a support that holds the electromagnet in the fixed position. The coil holder along with stand support is shown in figure 24.



**Fig -22:** 3D Printed Rolling Stand.



**Fig -25:** 3D Printed Coil Support.

The piston is a cylindrical model which is responsible for the linear motion. The bottom part of the system is attached to the crankshaft through connecting rods. The piston material has to be stronger to withstand the opposing forces. The piston should not be affected by the magnetic field produced by the electromagnet. The piston 3D printed model is shown in figure 23.

The coil support consists of a coil to act as an electromagnet in the presence of an electric field. The coil support is shown in figure 25.



**Fig -23:** 3D Printed Piston.



**Fig -26:** 3D Printed Connecting Rod.

The connecting rod connects the piston to the crankshaft. It is the major tool that converts the linear motion generated by the piston into rotational motion. The output is the rotational motion. The connecting rod is shown in figure 26.



## 4.2 Circuit Construction

The circuit to switch the power from the battery to either coils of electromagnet is done by the electrical circuit. The MOSFET plays an important role in switching the power to either of the electromagnet. The circuit includes two resistors to either drain or source terminal thereby helpful in high power switching. The circuit diagram is shown in figure 27. The circuit also includes the tap switch as a sensor to detect the presence of flywheel at the half rotation. The MOSFET here divides the voltage as the resistor. It acts similar to power voltage divider circuit. The circuit acquires the power from the 12V DC supply.

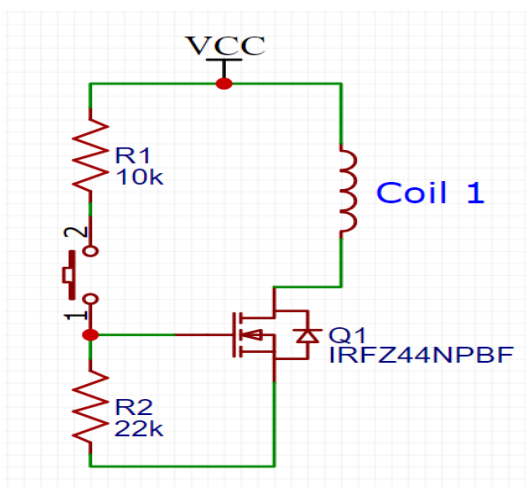


Fig -27: Circuit Diagram of MOSFET.

The respective connections for both the electromagnetic solenoids were made as per the circuit diagram shown in figure 28. The tap switches were connected and tested for action like sensors. Initially the circuit was done for testing purposes on the breadboard. The components were then soldered onto the PCB. The soldering was done carefully in order to reduce the human error. The simulation was done using TinkerCad and the behavior of the circuits under various conditions was tested.

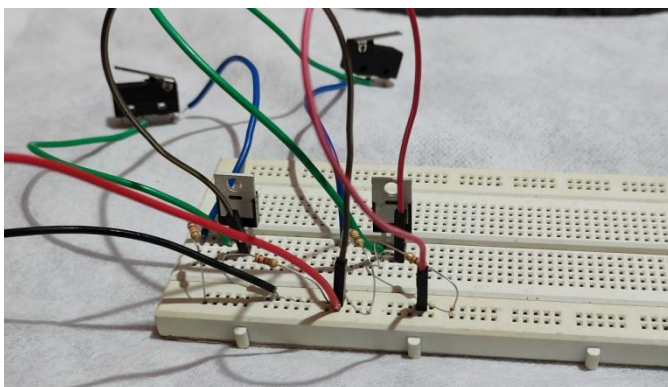


Fig -28: Implementation of switching circuit.

## 5. RESULTS

### 5.1 Design

The maximum force exerted by electromagnet on the piston,

$$F = (N^2 I^2 K A) / 2G^2$$

where, N = Number of Turns

I = Current flowing through coil

$\mu_0$  = Permeability of free space =  $4\pi \times 10^{-7}$  H/m

A = Cross-sectional area of electromagnet

G = 0.005m, Least distance of electromagnet to soft iron.

The torque is calculated by the equation shown below:

$$\text{Torque } T = F \times r$$

The power at the output is thus calculated from the obtained torque, shown in equation below:

$$\text{Power output} = (2\pi N T / 60)$$

where, F = total force on piston

r = crank radius = 0.02m

N = rpm of shaft

The efficiency is simply the definition of how much input reaches the output. The calculation of efficiency is obtained using the below equation:

$$\eta = (\text{Power output} / \text{Power input}) \times 100$$

### 5.2 Experimental Analysis

To analyze the working performance of dual electromagnetic engine an experimental results were obtained from the calculated values. The DC power was supplied at different voltages. The transformer can be used and rectification can be done with transistor rectifiers [18].

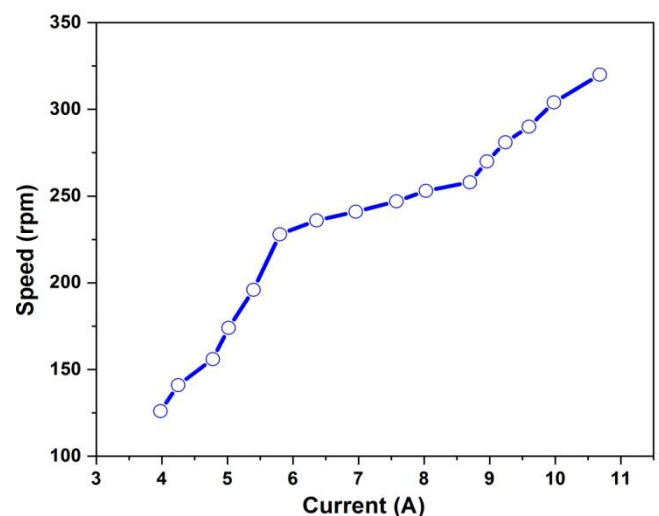


Fig -29: Variation of speed with current.

The measurement of various parameters paved a way to the behavior prediction of electromagnetic engine [19]. The transformer was used to observe the behavior at different voltages. The measurements were taken down and were plotted with Origin software. The behavior with respect to input power and the generated output is plotted with speed and torque. The data was then analyzed to perform the final conclusions in this research. The increase in voltage generated powerful magnetic fields thereby increasing the power force at the output, increasing its efficiency. The linear increase of speed (rpm) with current and input power is shown in figure 29 and 30 respectively.

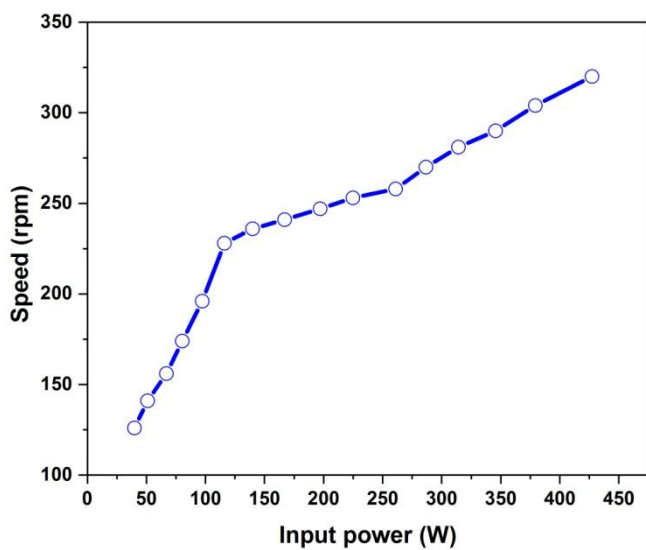


Fig -30: Variation of speed with input power.

The efficiency and torque of the newly developed dual electromagnetic engine is observed and recorded. The variations of these parameters are shown in figure 31 and 32 respectively.

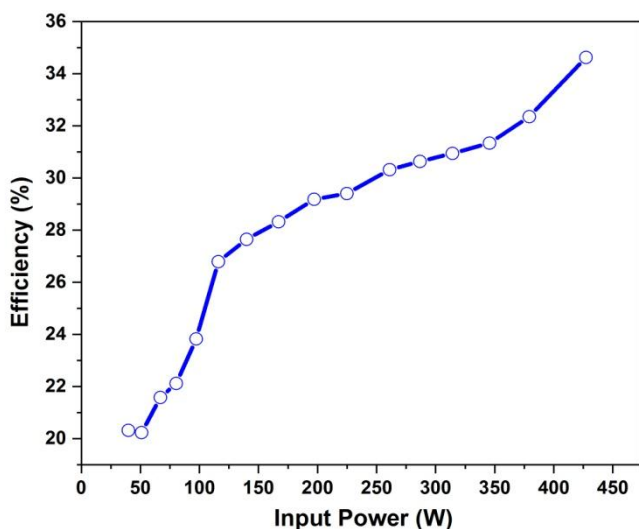


Fig -31: Variation of efficiency with input power.

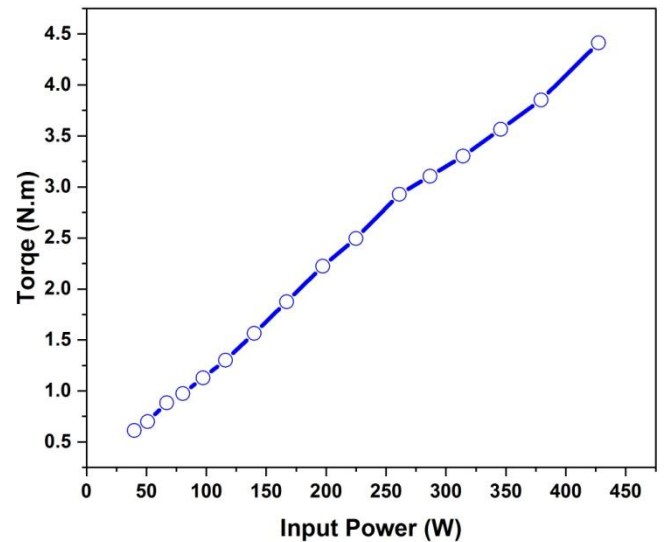


Fig -32: Variation of torque with input power.

## 6. CONCLUSIONS

The dual electromagnetic engine uses the battery completely for its operation. The usage of rechargeable battery helps in charging the battery from discharging. There is no usage of fuel for its operation, thus it is free from pollution. The noise produced is comparatively less than internal combustion engines. It produces smooth running performance, thus enhancing the comfort of the vehicle driver.

The design of dual electromagnetic engine was successfully implemented. The CAD models were designed and printed with highest precision. The materials obtained from printing could withstand high opposing forces. The experimental analysis of the model was carefully carried out. The piston was carefully gathered after printing to avoid the breakage. The generated output was as expected but with small uncertainty error. The engine was environment friendly and produced less amount of noise.

## ACKNOWLEDGEMENT

The authors thank the project guide Ganesh V.N for the valuable suggestions and guidance to complete this research work. Also, thank Mr. Padma Prasada, Sr. Asst. Professor MITE, Moodbidri and Mr. Rohith P. S., faculty member, PG department of physics, FMKMC College, Madikeri, for their support throughout the research work.

## REFERENCES

- [1] T. Selvakumar, S. Karthik, S. Arun Kumar, "Modern Electric Engine for Future Cars", International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), IEEE, 2018.
- [2] A. Manoj Anto, K. Muruges, M. Ibrahim John Basha, J. Dinesh Kumar, A. Thangarasu, "Design and Fabrication of Electromagnetic Engine", IRJET, ISSN (PRINT):2393-8374, (ONLINE): 2394-0697, Volume-5, Issue-4, 2018.
- [3] Rananavare Shrikant, Jadhav Nikhil, Borade Sagar, Gawande Mukund, Jagdale Hanumant, "Electromagnetic Engine", Volume-7, Issue-1, 2018.
- [4] Avinash N Fulbaria, Chirag R Fulbaria, Sagar K Solanki, Chirag D Ajudiya, Parag G Paija, "Modification and Fabrication of Electromagnetic Engine", JETIR, Volume-5, Issue 7, July 2018.
- [5] Gaurav S. Chavan, Nilesh C. Dukre, Akshay A. Musmade, Rahul B. Gaikwad, Dr. A.D. Dongare, "Electromagnetic Engine", IARJSET, Volume-4, Issue 2, February 2017.
- [6] Abil Joseph Eapen, Aby Eshow Varughese, Arun T.P, Athul T.N, "Electromagnetic Engine", IRJET, Volume-3, Issue 6, June 2014.
- [7] Amarnath Jayaprakash, Balaji, G. Bala Subramanian and N. Naveen, "Studies on Electromagnetic Engine", IJDR, Volume-4, Issue 3, pp. 519-524, March 2014.
- [8] P. Parthasaradhy, S.V.Ranganayakulu, "Hysteresis and eddy current losses of magnetic material by Epstein frame method-novel approach", IJES, pp. 85-93, 2014.
- [9] Vishal Abasaheb Misal, Umesh Dattatray Hajare and Arshad Ashak Atar, "Electromagnetic engine", IJTARME, ISSN: 2319 - 3182, Volume-2, Issue 4, 2013.
- [10] Syed Zaimal Abidin, Syed Kamarul Bahrin, Ungku Anisa, Ungku Amiruldin, "Design and development of a new electromagnetic prime mover", IEEE International conference on Control System, Computing and Engineering, 2012.
- [11] Syed Zainal Abidin, Syed Kamarul Bahrin, Noor Miza Muhamad Razali, Thahirah Syed Jalal, Ungku Anisa, Ungku Amirulddin, "Evaluating the Potential of Solenoid Motion System for Electric Vehicle - Challenging the Conventional Usage of Electric Motor", 2nd IEEE International Conference on Power and Energy, 2008.
- [12] Syed Suhel, Chetan Baseganni, Naveen Dinakar, "Design and Fabrication of Electromagnetic Engine", IJCESR, Volume-4, Issue-9, 2017.
- [13] Raj Solanki, Sushil Thakkar, Khushali Sheth and Harsh Sheth, "Fabrication of Electromagnetic Engine using Pull Force", IJAR, DOI:10.21474/IJAR01/6838.
- [14] Lutz-Christoph Schöning and Yun Li, "Review Electromagnetic Field Ignition System for Internal Combustion Engine", Proc. of 17th International Conference on Automation & Computing, University of Huddersfield, Huddersfield, UK, 10 September 2011.
- [15] Jaewon Lim, Chang-Hyun Kim, Jong-Min Lee, Hyung-suk Han, Doh-Young Park, "Design of Magnetic Levitation Electromagnet for High Speed Maglev Train", International Conference on Electrical Machines and Systems, Busan, Korea, IEEE, 2013.
- [16] Bo-Ha Lee, Chong-Won Lee, "Model based feed-forward control of electromagnetic type active control engine-mount system", Journal of sound and vibration, DOI:10.1016/j.jsv.2009.01.033, February 2009.
- [17] Lv Feng, Zhao Hua, Du Wenxia, Jin Huilong, "Electromagnetic Interference and Electromagnetic Compatibility Test Technology", International Conference on Machine Vision and Human-machine Interface, DOI 10.1109/MVHI.2010.36, IEEE, 2010.
- [18] S. J. Sampreeth, "Implementation of transistor rectifiers and comparison with diode rectifiers" International Journal in IT & Engineering (IJITE), Volume-8, Issue 5, pp. 01-15, May 2020.
- [19] Weijie Xu, Nana Duan, Shuhong Wang, Youguang Guo, Jianguo Zhu, "Modeling and Measurement of Magnetic Hysteresis of Soft Magnetic Composite Materials under Different Magnetizations", DOI:10.1109/TIE.2016.2606361, IEEE, 2016.