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DESIGN AND FABRICATION OF MAGNETIC REGENERATIVE SHOCK ABSORBER ATTACHMENT

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ABSTRACT

In today's vehicles, several energies are not being harnessed. One such important energy is the vibrational energy of the vehicle suspension under the excitation of road irregularity and vehicle acceleration or deceleration. A regenerative shock absorber is a type of shock absorber that converts intermittent linear motion and vibration into electricity. A magnetic regenerator was developed that can be attached to the front shock absorber of a two-wheeler. A small prototype was fabricated to test the working principle and then the actual component was fabricated and tested.

1. INTRODUCTION

The magnetic induction principle states that voltage will be developed across the ends of a conductor in a magnetic field if there exists a relative motion between the conductor and the magnetic field. The regenerative shock absorber attachment shown in Figure 1 consists of a magnet assembly and a coil assembly. The magnet assembly is made of disc-shaped permanent magnets and disc-shaped high magnetically permeable spacers stacked in an Aluminum tube. The coil assembly is made of copper coils wound on an Aluminum tube. As the copper coils move inside the magnetic field, a voltage will be generated.

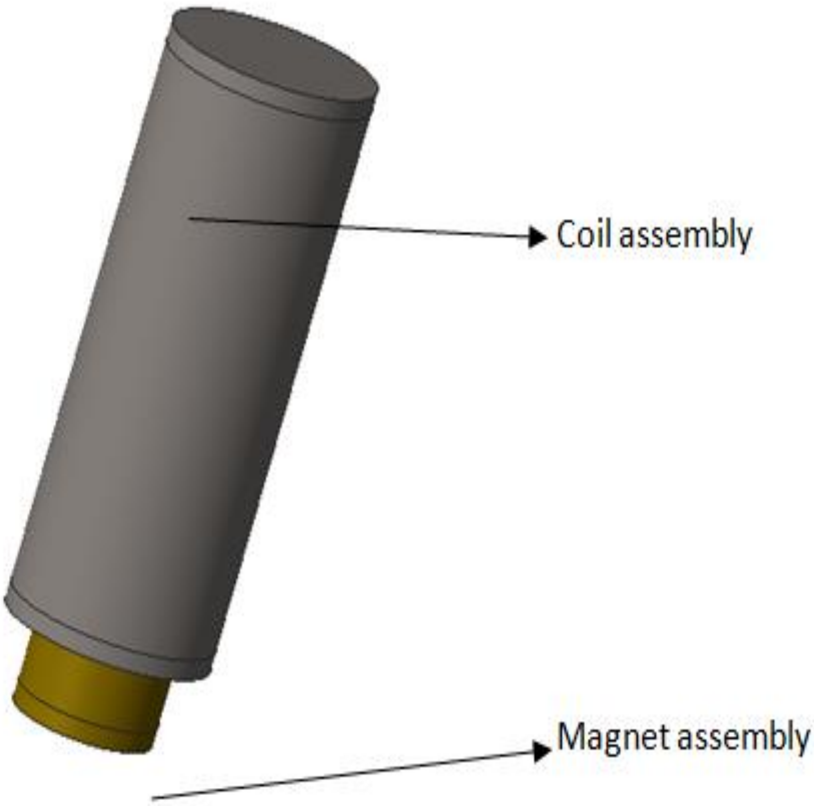

Figure 1 Model of the regenerative shock absorber attachment

2. PROBLEM DEFINITION AND OBJECTIVE

Electric vehicles are considered to be a clean and effective solution concerning the fossil fuel crisis and excessive emissions of carbon dioxide. But the usage of electric vehicles has been long obstructed due to some problems like less number of recharge stations, short driving range, low speed and long recharge time. Researchers have been trying to improve the distance travelled per full charge of electric vehicles by using regenerative technologies. In the past decade, regenerative braking systems have become increasingly popular, recovering energy that would otherwise be lost through braking. The objective of the project is to develop a magnetic regenerator that can be used as an attachment to the front shock absorber of a two-wheeler to generate electricity from road shocks and vibrations.

3. METHODOLOGY

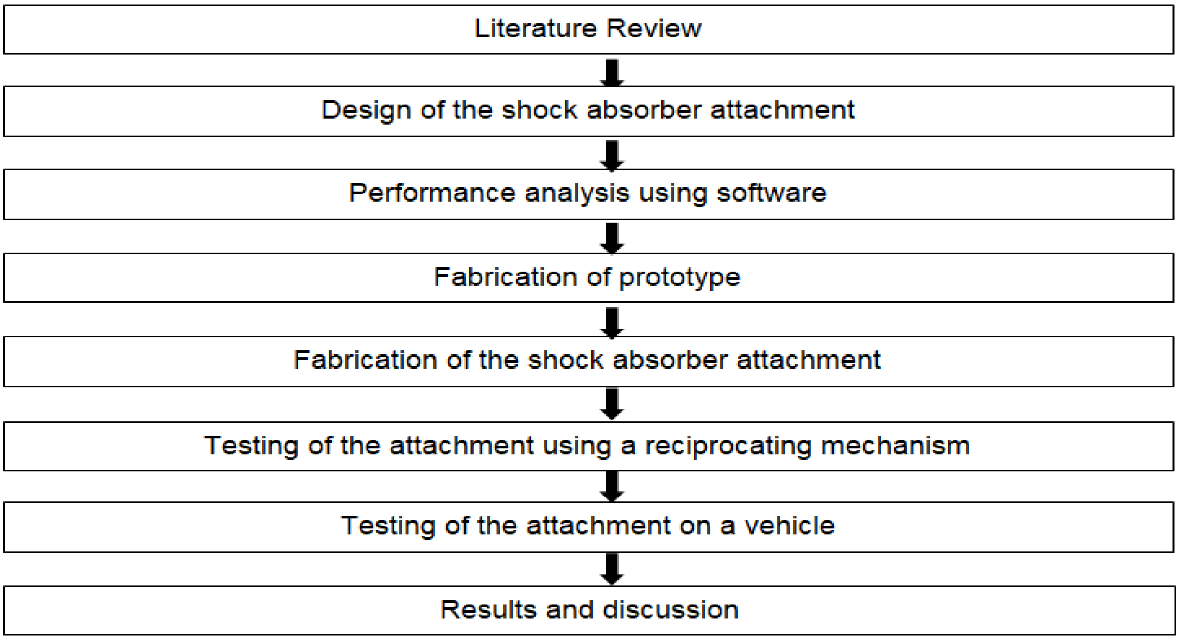

Figure 2 Methodology

4. DESIGN OF THE MAGNETIC REGENERATIVE ATTACHMENT

The attachment consists of a magnet and spacer assembly stacked in a casing and a coil assembly wound on a support tube. Around the coil assembly, there is an outer casing to enclose the whole assembly.

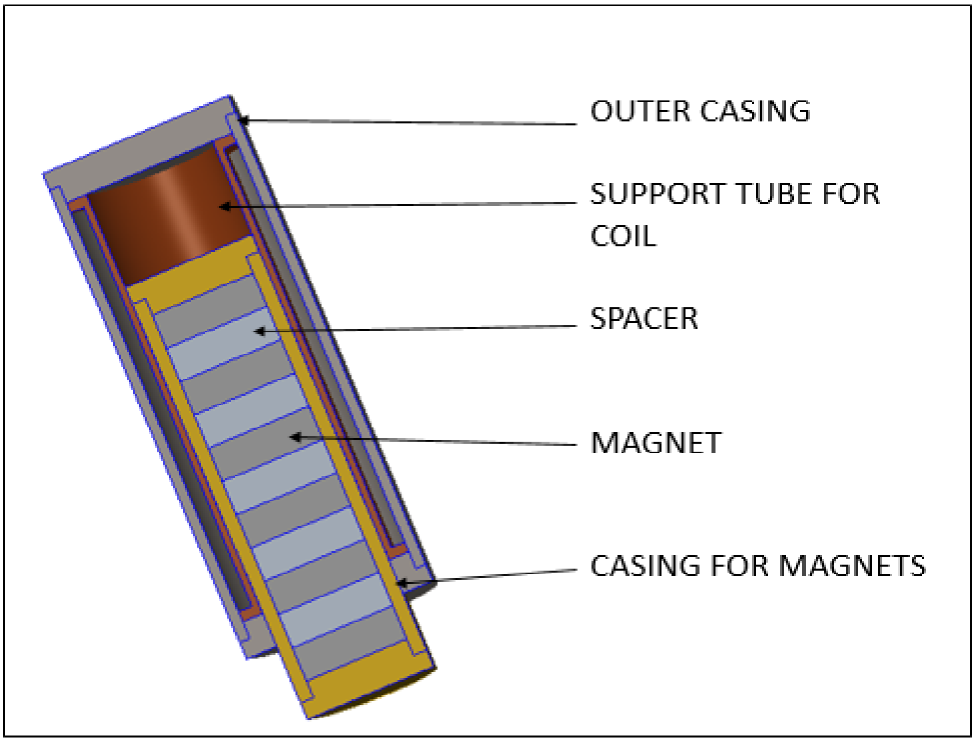

Figure 3 Construction of the shock absorber attachment

The materials for the magnet casing, support tube and outer casing should be selected such that more magnetic flux can reach the coils. The material for the magnet casing and support tube must have high reluctance such that the magnetic flux will not be retained in them. The use of a high magnetically permeable material for the outer cylinder will effectively pull the flux towards the coils and increase the radial flux density.

The effect of various materials with different magnetic permeability was analyzed using static magnetic field analysis on a 2D axisymmetric model using FEMM 4.2 software. The initial design used Low Carbon Steel as depicted in Figure 3 for the magnet casing, support tube and outer casing. From the results obtained, we found that most of the magnetic flux is retained in the magnet casing without reaching the coils. By changing the materials of the magnet casing and support tube to Aluminum and using Low Carbon Steel for the outer casing, we found that more magnetic flux can reach the coils and this can be referred to in Figure 4. The maximum value of magnetic flux at the coils was found to be 0.164 T.

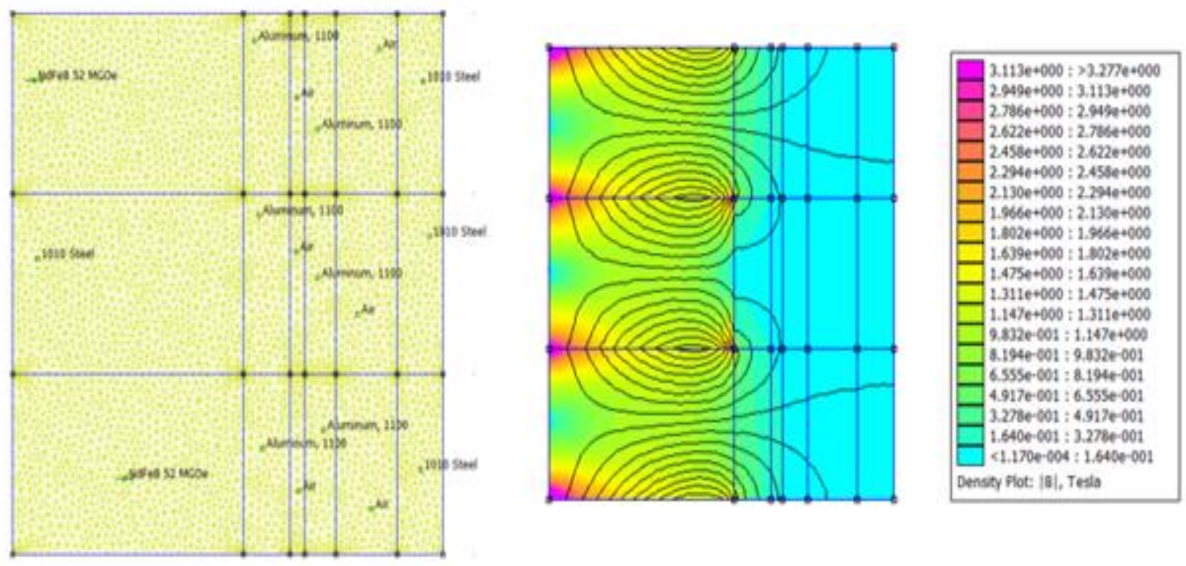

Figure 4 Axisymmetric cut section model and magnetic density plot for the final design

Based on the static magnetic analysis, Aluminium was selected for the magnet casing and support tube and Mild Steel was selected for the outer casing. The rare-earth permanent magnets FeNdB grade N52 have been selected due to their high magnetic density. To reduce the effects of air in decreasing the radial flux in the coil conductor, high magnetically permeable steel spacers are inserted between each magnet.

The magnet assembly consists of permanent magnets and spacers stacked alternatively in a casing. The permanent magnets and the steel spacers have a diameter of 30 mm and a thickness of 10 mm as shown in Figure 5. The number of magnets and steel spacers is 6 and 5 respectively. The casing for magnets has an inner diameter of 30.2 mm, outer diameter of 38 mm and length of 120 mm as shown in Figure 6 and is made of Aluminium. The tube is closed on both sides utilizing Aluminium bushes which are shown in Figure 7.

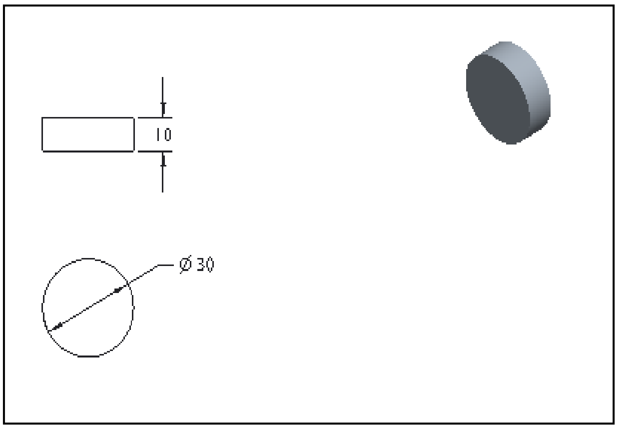

Figure 5 Magnets and spacers

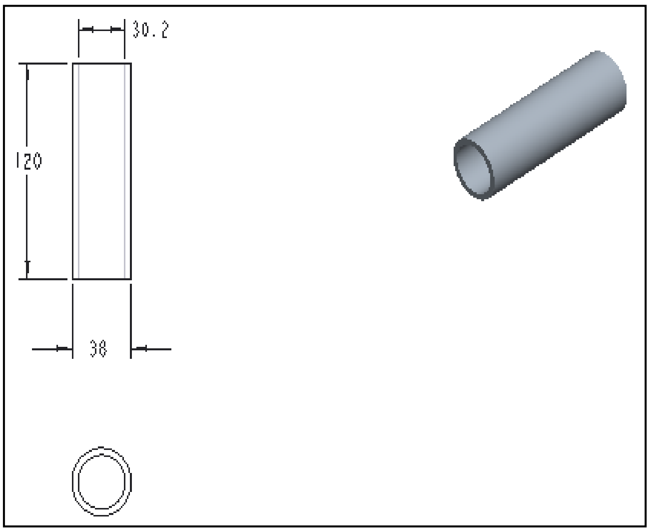

Figure 6 Magnet Casing

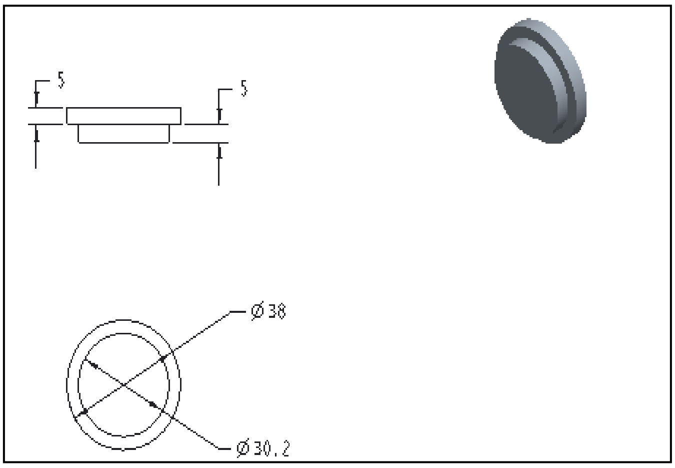

Figure 7 Bushes for closing the magnet casing

The coil assembly consists of a support tube and multiple coil windings. The coils are wound on a support tube shown in Figure 8 and the material for the support tube is Aluminium.

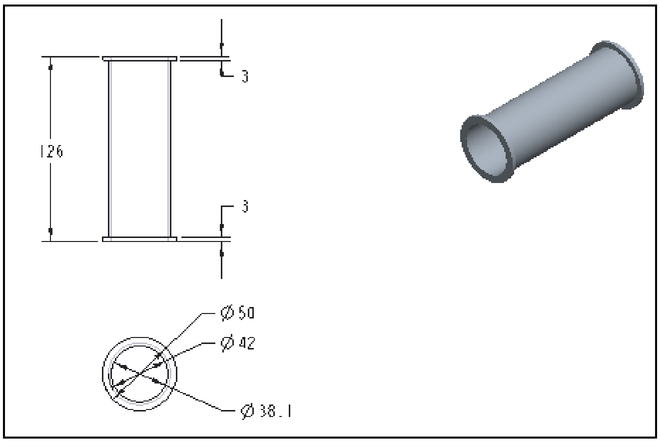

Figure 8 Support tube for coils

A copper coil of 30 SWG (0.315 mm) has been selected for the coil windings. The entire assembly is enclosed by an outer casing made of Mild Steel. The outer casing has an inner diameter of 50 mm, an outer diameter of 56 mm and a length of 136 mm. The outer casing is closed by a Mild Steel bush at the top and a Nylon bush at the bottom. Nylon was used for the lower bush to reduce friction between the bush and the magnet casing during motion and also to avoid magnetic attraction between the bush and the magnets.

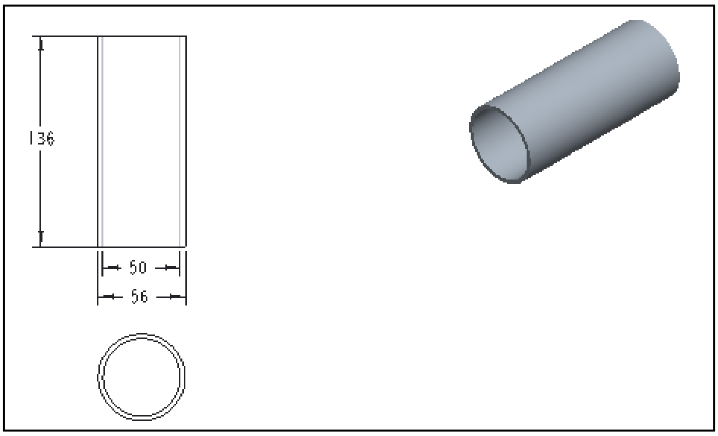

Figure 9 Outer casing

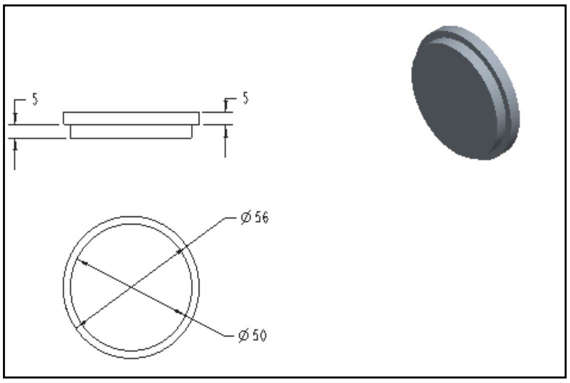

Figure 10 Bush for closing the upper part of the outer casing

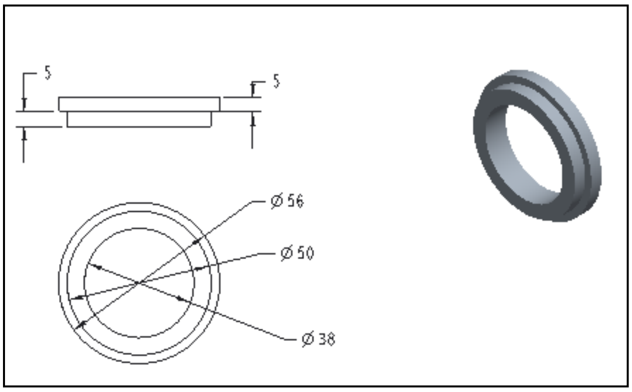

Figure 11 Bush for closing the lower part of the outer casing

5. FABRICATION OF THE MAGNETIC REGENERATIVE ATTACHMENT

All the components of the assembly have been fabricated individually with independent machining processes. Several processes like turning, boring, parting, step turning and drilling have been used to make the components of the assembly like the magnet casing, bushes, support tube for coil and outer casing. All these fabricated components have been assembled to make the final model.

5.1. MAGNET CASING

An aluminium pipe of outer diameter 40 mm and inner diameter 28 mm was taken and turned to an outer diameter of 38mm followed by boring to increase the inner diameter to 30.2 mm. The 0.2 mm clearance was given for the smooth insertion of the magnets and the spacers. The pipe was then parted at 120 mm to obtain the required length of the component. The magnet casing was closed at both ends utilizing bush made of aluminium by step turning of diameters 30.2 mm and 38 mm and parted at 10 mm.

5.2. SUPPORT TUBE FOR COILS

An aluminium pipe of outer diameter 50.9 mm and inner diameter of 36 mm was chosen. The pipe was turned to an outer diameter of 50 mm for a length of 3 mm at the top and bottom to form the support flanges. The central 120 mm length was turned to a diameter of 42 mm and the inner diameter was bored to 38.3 mm. The 0.3 mm clearance was given for the smooth movement of the magnet casing through the support tube.

5.3. OUTER CASING

A mild steel pipe of outer diameter 60 mm and inner diameter 50 mm was chosen and machined to an outer diameter of 56 mm and inner diameter of 50.1 mm. The pipe was then parted at 136 mm to obtain the required length of the component. The top of the pipe was closed with a mild steel bush and a nylon bush with a bore of 38 mm was used for the bottom. The bush to close the outer casing on the upper side is made from a mild steel rod. The rod is step turned to get a 5 mm portion of 56 mm diameter and another 5 mm of 50.1 mm diameter and then finally parted to get a part of 10 mm.

5.4. COIL WINDING

Seven coils of thickness 20mm, 20mm, 15mm, 15mm, 15mm, 10mm and 10mm have been wound on the support tube. The coils with higher thickness are at the bottom portion of the support tube which will always be in the magnetic field irrespective of the position of the magnet casing. The coils with lower thickness are at the top portion which will have the magnetic field only at high displacement in the shock absorber. These coils have been connected in series to get the output voltage.

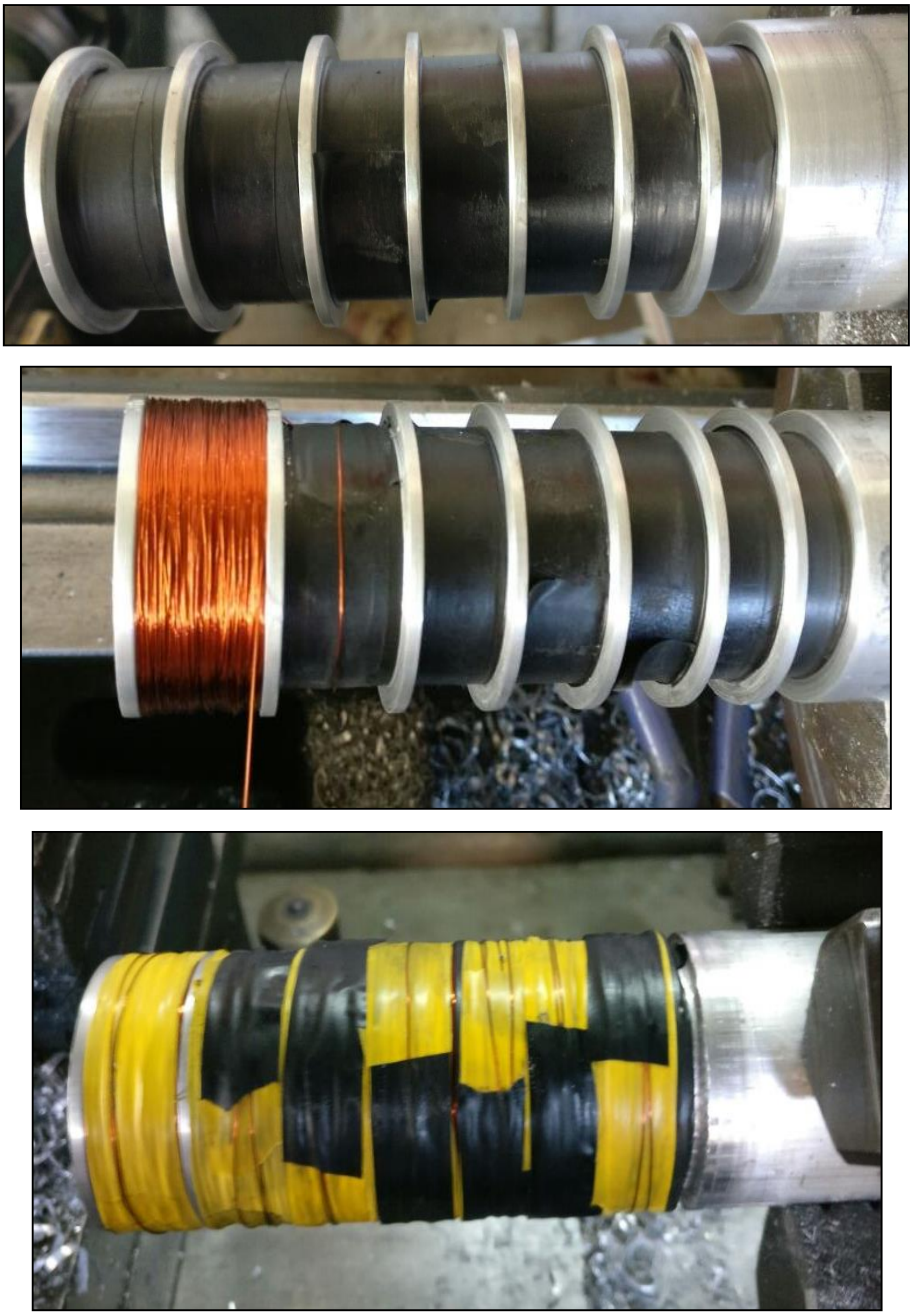

Figure 12 Coil Winding

5.5. FABRICATED MODEL

Figure 13 Fabricated Model

6. TESTING OF THE MAGNETIC REGENERATIVE ATTACHMENT

6.1. EXPERIMENTAL SETUP FOR TESTING

A variable amplitude reciprocating mechanism has been designed to simulate the road conditions, where the amplitude can be varied from 0 mm to 70 mm. The experimental setup consists of a 3 phase, 440 V, 180 W motor which has a speed of 89 rpm.

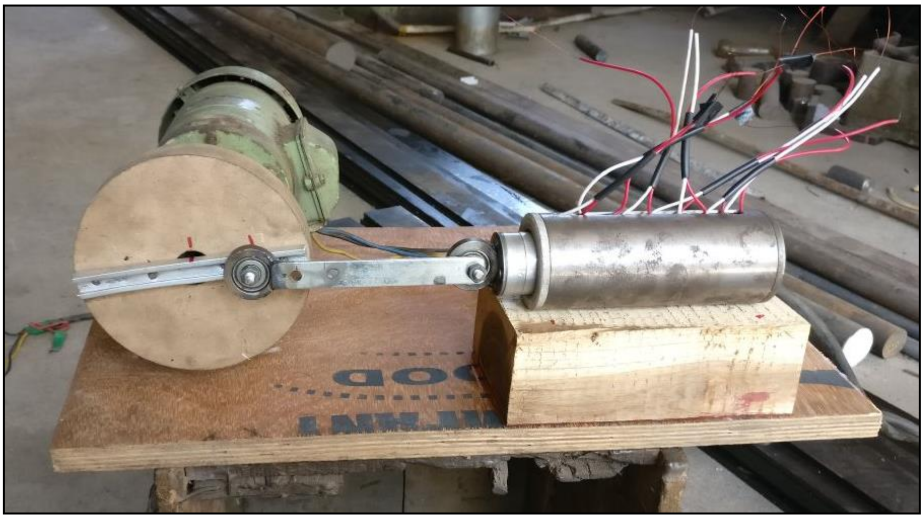

Figure 14 Experimental setup for testing

The regenerative shock absorber was tested at different amplitudes of 5 mm, 10 mm and 30 mm. All the seven coils have been connected in series and the output voltage was measured using a multimeter. The measured output was fluctuating DC voltage from 0 volt to 0.5 volts. The reason for the low voltage is that the coils of 10 mm thickness won't be in the magnetic field constantly. So the voltage generated by the coils of 10 mm is very less, thereby adding more resistance and reducing the overall voltage. Since the lower coils of thickness 20 mm, 20 mm and 15 mm will always be in the magnetic field irrespective of the position of the magnet casing, the three coils have been connected in series and the output voltage was observed to be fluctuating from 0 V to 2.5 V. A step-up chopper circuit shown in Figure 15 was used to get a constant stepped-up voltage.

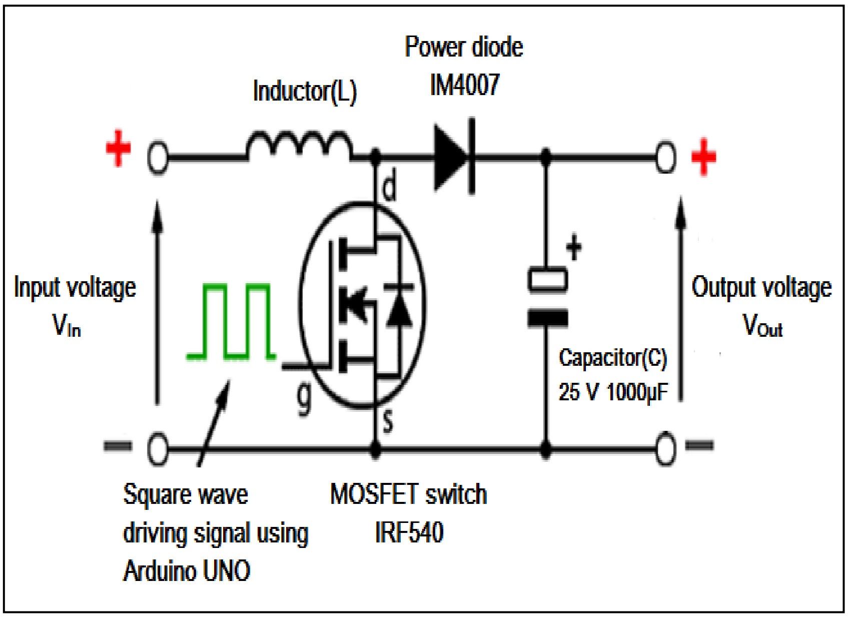

Figure 15 Step-up chopper circuit

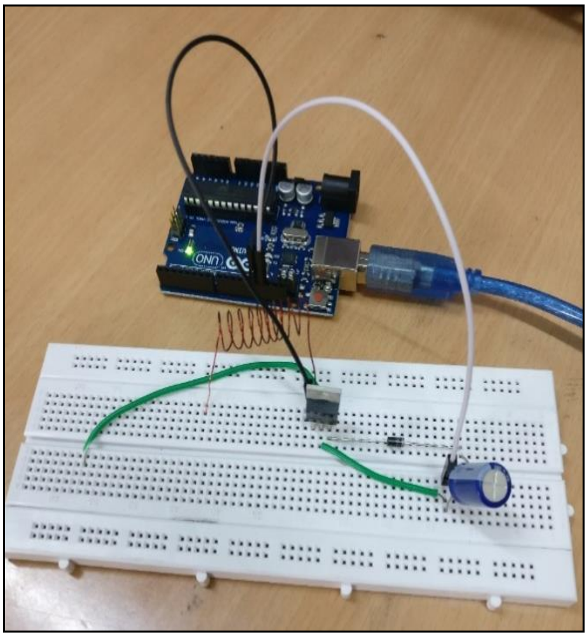

Figure 16 Components of the Circuit

6.2. STEP-UP CHOPPER CIRCUIT

The circuit consists of an inductor of inductance 0.0200285 H, a diode IM4007, a MOSFET switch IRF540 and a 25 V, 1000 μF capacitor. An Arduino UNO microcontroller was used to provide a square wave driving signal to the gate of the MOSFET switch. The components of the circuit have been connected as shown in Figure 16.

The regenerative shock absorber was tested using the experimental setup at different amplitudes. The output voltages for different amplitudes were recorded using a multimeter and tabulated as shown in table.

Displacement	*5 mm*	*10 mm*	*30 mm*
Maximum Voltage	*13.2 V*	*13.15 V*	*12.19 V*
Minimum Voltage	*12.15 V*	*12.07 V*	*12.02 V*
Average Voltage	*12.68 V*	*12.61 V*	*12.10 V*

6.3. TESTING OF THE MAGNETIC REGENERATOR ON A VEHICLE

The regenerative shock absorber attachment was connected to the front shock absorber of a bike using U-clamps. Figure 17 shows the image of the regenerative shock absorber attachment connected to the vehicle.

Figure 17 Shock absorber attached to the vehicle

The regenerative shock absorber attachment was tested on different types of roads and the output voltage was observed to be more than 12 volts, which is sufficient to charge a 12 V battery.

7. CONCLUSIONS

- The magnetic regenerative shock absorber attachment was designed by considering the dimensions of a conventional shock absorber.
- The effect of various materials on the magnetic field acting at the coils was analyzed using static magnetic field analysis on a 2D axisymmetric model using FEMM 4.2 software.
- A small prototype was fabricated to test the working principle.
- The actual component was fabricated and tested using an experimental setup and on a vehicle.
- The voltage generated was found to be around 12 V, which is sufficient to charge a 12 V battery.

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