Modeling and Control of Electromagnetic Damper
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Abstract— In this paper, we propose a model for electromagnetic damper using permanent magnets and electromagnets. The changes in position of the damper with respect to the base with varying the current in the coils of electromagnets are studied with experimental validation. Iron core with copper windings is used as electromagnets and carbon magnets are used as permanent magnets.

Key words: Electromagnetic Damper, permanent magnets, electromagnets

I. INTRODUCTION

Damper is used to damp out the oscillations. So when the body, whose oscillations are to be damped out, comes in contact with a damper, it comes to rest quickly.

When the current is passed through a solenoid, it acts as a magnet, the magnet so formed is called an electromagnet. Fig. 1 shows a simple electromagnet.

The combination of a damper and an electromagnet forms an electromagnetic damper.

II. DESIGN IDEAS

A. Mainly a damper can be designed in two ways:
1) Hanging type
Fig. 2 shows the hanging type of levitation system.

2) Uplifting type
Fig. 3 shows the uplifting type of levitation system.

Uplifting type of levitation systems are relatively more stable compared to the hanging type of levitation systems, since in uplifting type of levitation systems the

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Coil of insulated wire
Iron Nail
BATTERY

Fig. 1

SIMPLE ELECTROMAGNET

Levitation is phenomenon in which a body is suspended, without physical contacts, against gravity. In case of magnetic levitation, the object is suspended with no mechanical support other than by the force provided by magnetic fields. Magnetic force is used to counteract the effects of gravitational and any other accelerations.

A. Depending on the physical forces used to counteract the effects of the gravitational and any other accelerations, levitation system can be classified into two categories:

1) Levitation systems using attractive forces to counteract the effects of the gravitational and any other accelerations.
2) Levitation systems using repulsive forces to counteract the effects of the gravitational and any other accelerations.

B. Further these systems are classified into three categories on basis of type of magnets used for levitation purpose:

1) Levitation systems using attractive forces to counteract the effects of the gravitational and any other accelerations:
   (1) North (south) pole of permanent magnet facing south (north) pole of permanent magnet.

2) Levitation systems using repulsive forces to counteract the effects of the gravitational and any other accelerations:
   (1) North (south) pole of permanent magnet facing south (north) pole of electromagnet.
   (2) North (south) pole of permanent magnet facing north (south) pole of electromagnet.
   (3) North (south) pole of electromagnet facing north (south) pole of electromagnet.

3) Further these systems are sub-divided on basis of type of current flowing in the coils of electromagnets:
   (1) AC current in both electromagnets.
   (2) DC current in both electromagnets.
   (3) AC current in one electromagnet and DC current in another electromagnet.
center of gravity of whole system is higher compared to that of uplifting type of levitation systems.

B. **Hanging type of levitation systems (using repulsive forces to counteract the effects of the gravitational and any other accelerations):**

In this type, the damper is left to hang from the top (ceiling of model). The electromagnets are placed one below the damper and another at the end of the rod via which the damper is hanging. Electromagnets are placed such that their like poles face each other.

C. **Hanging type (using attractive forces to counteract the effects of the gravitational and any other accelerations):**

In this type, the damper is left hanging from the top (ceiling of model). The electromagnets are placed one below the damper and another at the end of the rod via which the damper is hanging. Electromagnets are placed such that their unlike poles face each other.

D. **Lifting type (Using repulsive forces to counteract the effects of the gravitational and any other accelerations):**

In this type the damper is not suspended but is allowed to float under the influence of magnetic field. One electromagnet is placed on the base of the damper and another is placed over the rod or support over which the damper is floating. Electromagnets are placed such that like poles face each other.

III. **DEMONSTRATION SYSTEM**

A. **System layout**

![Fig. 4: Base of Demonstration System](image)

Fig. 4 shows the schematic view of the base of the demonstration system. A wooden ply board is used as a base. Three electromagnets are stuck in vertical position. Next to each electromagnet a PVC pipe has been stuck, with a permanent magnet on its top. All the permanent magnets have the same pole facing upward. The structure of the damper needs to be such that it has minimal weight so that it can be lifted easily without unnecessary complications in the experiment and is heavy enough to be laterally stable under the repulsive levitation forces. There are many materials available that could be used to provide the basic structure. In our experiment we used a sun board. The damper has three supporting rods protruding downwards from it. The supporting rods have a permanent magnet stuck to its end. The pole of the magnets is opposite that of the magnets on the base. These carbon magnets are used to provide certain initial levitation before switching on the current to the coils. On the base of the damper, three smaller magnets are stuck such that each magnet is right above one vertical electromagnet. When current is passed through the electromagnet, magnetic poles are formed. The magnets thus placed are such that opposite poles face each other when the electromagnets are switched on.

The cumulative weight of whole system so formed is 605 gm. Fig. 5 shows the schematic view of electromagnet used. Iron core with copper windings with 1200 turns is used as electromagnet. Fig. 6 shows the final demonstration system.

![Fig. 5: Electromagnet](image)

![Fig. 6: Base of the Demonstration System](image)
B. Power Source

The experiment is conducted in two stages:

1) Stage 1:
All the three electromagnets are given voltage at same level. In this stage all the three electromagnets are given supply from same source. An auto-transformer is used to regulate the voltage and hence the current in the coils of electromagnets. Current in the coils of electromagnets is gradually increased. Meanwhile the position of damper with respect to the base is also recorded. The readings so obtained are then tabulated. Based on the readings obtained a curve between the current in coils and height of damper with respect to the base is plotted. Also a curve between the voltage given and the height of damper with respect to the base is obtained. Fig. 7 shows the block diagram for circuitry used in stage 1 of the experiment.

2) Stage 2:
The three electromagnets are given different voltages. In this stage voltage and current in the three electromagnets is regulated as per the alignment of the damper. Power from mains is fed to an auto-transformer which regulates the voltage and current supplied. Here in this stage the supply from auto-transformer is divided into three parts. A rheostat is used in each branch to further regulate the currents in coils of the three electromagnets. Initially all the coils were fed same level of current and the position of damper with respect to the base is recorder and tabulated.

Then using rheostat of individual branches, current in coils of three electromagnets is varied and the position of the damper with respect to the base is recorded. Three different curves for three electromagnets between the current in coils of electromagnets and height of damper with respect to the base is plotted. Also three different curves, for the three electromagnets, between the voltage supplied to coils of electromagnets and height of damper with respect to the base is plotted. Fig. 8 shows the block diagram of the circuitry used in stage 2 of the experiment.

IV. Calculations

A. Formula

Let \( i \) be the current flowing through coil, \( n \) be the no. of turns, \( B \) be the magnetic field due to electromagnet, \( f_p \) be the repulsive forces due to all permanent magnets used and ‘w’ be the weight of the damper

Then,

The force due to electromagnet \( f_e \) is given by

\[
    f_e = nBiL
\]

Where \( L \) is the distance of damper from electromagnet.

In this stage voltage and current in the three electromagnets is regulated as per the alignment of the damper. Power from mains is fed to an auto-transformer which regulates the voltage and current supplied. Here in this stage the supply from auto-transformer is divided into three parts. A rheostat is used in each branch to further regulate the currents in coils of the three electromagnets. Initially all the coils were fed same level of current and the position of damper with respect to the base is recorder and tabulated.

Then using rheostat of individual branches, current in coils of three electromagnets is varied and the position of the damper with respect to the base is recorded. Three different curves for three electromagnets between the current in coils of electromagnets and height of damper with respect to the base is plotted. Also three different curves, for the three electromagnets, between the voltage supplied to coils of electromagnets and height of damper with respect to the base is plotted. Fig. 8 shows the block diagram of the circuitry used in stage 2 of the experiment.
V. RESULTS

A. Stage 1

All the three electromagnets are given voltage from same source.

Table 1 shows the tabulated form of readings recorded in stage 1 of experiment.

Graph 1 shows the curve between the voltage given and the height of damper with respect to the base. Graph 2 shows the curve between the current in coils and height of damper with respect to the base.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Voltage(V)</th>
<th>Current(A)</th>
<th>Height from base</th>
<th>Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>12.5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0.6</td>
<td>12.6</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>1.3</td>
<td>12.7</td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>1.85</td>
<td>12.8</td>
<td>0.3</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>2.52</td>
<td>12.9</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 1: Readings recorded in stage 1 of experiment

B. Stage 2

The three electromagnets were given voltages from three different ways.

1) For electromagnet 1:

Table 2 shows the tabulated form of readings taken for electromagnet 1 during stage 2 of the experiment. Graph 3 shows a curve between the voltage given and the height of damper with respect to the base for electromagnet 1 during stage 2 of the experiment. Graph 4 shows a curve between the current in coils and height of damper with respect to the base for electromagnet 1 during stage 2 of the experiment.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Voltage(V) (volts)</th>
<th>Current(A) (ampere)</th>
<th>Height from base(cm)</th>
<th>Displacement(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>12.5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0.6</td>
<td>12.6</td>
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<td>15</td>
<td>1.85</td>
<td>12.8</td>
<td>0.3</td>
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<tr>
<td>5</td>
<td>20</td>
<td>2.52</td>
<td>12.9</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 2: Readings recorded for electromagnet 1 during stage 2 of the experiment

Graph 3: Plot between the voltage given and the height of damper with respect to the base for electromagnet 1 during stage 2 of the experiment

Graph 4: Plot between the current in coils and height of damper with respect to the base for electromagnet 1 during stage 2 of the experiment

2) For electromagnet 2:

Table 3 shows the tabulated form of readings taken for electromagnet 2 during stage 2 of the experiment. Graph 5 shows a curve between the voltage given and the height of damper with respect to the base for electromagnet 2 during stage 2 of the experiment. Graph 6 shows a curve between the current in coils and height of damper with respect to the base for electromagnet 2 during stage 2 of the experiment.
Modeling and Control of Electromagnetic Damper

Table 3: Readings recorded for electromagnet 2 during stage 2 of the experiment

<table>
<thead>
<tr>
<th>S. No</th>
<th>Voltage(V) (volts)</th>
<th>Current(A) (ampere)</th>
<th>Heigth from base(cm)</th>
<th>Displacement(cm)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td>2</td>
<td>5</td>
<td>0.54</td>
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<td>.15</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>1.36</td>
<td>12.70</td>
<td>.20</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>1.80</td>
<td>12.70</td>
<td>.20</td>
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<tr>
<td>5</td>
<td>20</td>
<td>2.51</td>
<td>12.85</td>
<td>.35</td>
</tr>
</tbody>
</table>

Table 4: Readings taken for electromagnet 3 during stage 2 of the experiment

<table>
<thead>
<tr>
<th>S. No</th>
<th>Voltage(V) (volts)</th>
<th>Current(A) (ampere)</th>
<th>Heigth from base(cm)</th>
<th>Displacement(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>15</td>
<td>1.70</td>
<td>12.8</td>
<td>.3</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>2.32</td>
<td>12.85</td>
<td>.35</td>
</tr>
</tbody>
</table>

Graph 5: Plot between the voltage given to electromagnet and the height of damper with respect to the base for electromagnet 2 during stage 2 of the experiment

Graph 6: Plot between the current in coils and height of damper with respect to the base for electromagnet 2 during stage 2 of the experiment

Graph 7: Plot between the voltage given to electromagnet and the height of damper with respect to the base for electromagnet 3 during stage 2 of the experiment

Graph 8: Plot between the current in coils and height of damper with respect to the base for electromagnet 3 during stage 2 of the experiment

VI. CONCLUSION

In this paper a model for electromagnetic damper is proposed. The change in position of the damper with change in current in the coils of electromagnets is studied and hence a curve is plotted.

REFERENCES

