Frictionless Braking System

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Abstract- *Most braking system runs on the principle that releases kinetic energy to heat energy. This method has its disadvantage and must be replaced with a more efficient braking system that responds quickly doesn't produce heat and is also maintenance-free. In the operation of any machinery, the primary safety system is the braking system. These brakes pose several problems i.e. significant wear, fading, complex and slow actuation, etc and this is only because of Frictional brakes that work by rubbing on two surfaces. This paper is an attempt to solve these problems, where a contactless magnetic brake has been developed by using a metal disc that will conduct eddy current generated by magnets and this is analyzed using an experimental setup.*

Keywords- Contactless magnetic braking, Eddy current brake, Electromagnetic induction, Ferrite magnet, Neodymium Iron Boron magnet and Wear-free.

I. INTRODUCTION

The developed brake is wear-free, less-sensitive to temperature than friction brakes, has fast and simple actuation, and has a reduced sensitivity to a wheel lock. This is achieved by the generation of braking torque by a magnetic field across a moving conductor which creates a perpendicular magnetic field by induced eddy currents. Contactless brakes can be applied to any machinery like automobiles, locomotives, roller coasters, hydraulic and turbomachinery, machine tools, elevators, etc. The wide range applicability of these brakes strongly implies the effectiveness and ease of operation. The braking force can be adjusted to control higher torque loads by increasing the number of magnets and surface area of magnets. This gives the flexibility of operation of the system and makes it reliable even in changing loading patterns. There are two ways to induce an eddy current in the rotor; they are strong permanent magnet and an electromagnet. Electromagnets are DC type which is powered by a battery. They have faster electrical actuation with lower losses. But in the case of battery discharge electromagnets pose significant problems and are not reliable. So here, an experimental study of a permanent magnet eddy current braking system is performed to find out the practical limits of ECBS.

Here, in our study, we are using two types of permanent magnets (NdFeB and Ferrite). The air gap between the disc and the permanent magnet will be adjusted by the brake lever mechanism. To rotate and control the speed of the disc, an AC motor is used. The drawbacks of the conventional braking system can be overcome by the eddy current braking system.

II. PRINCIPLE OF OPERATION OF BRAKE

"**Electromagnetic induction**" is the principle behind eddy current embedded conventional braking system. Eddy current brakes make use of the opposing tendency of eddy currents. Eddy current embedded conventional braking system is a merging of eddy current brake and conventional brake. These brakes have been used in trains and roller coasters successfully. So far, no ideas had been that effective in implementing the eddy current embedded conventional braking system in automobiles. "Eddy Current Embedded Conventional Braking System" is the only way to solve this.

Eddy current brakes use the drag force created by eddy currents as a brake to slow or stop moving objects. Since there is no contact with a brake shoe or drum, there is no mechanical wear. However, an eddy current brake cannot provide a **"holding"** torque and so may be used in combination with mechanical brakes. A diagrammatic view of the Eddy Current Braking system is shown in Figure 1.

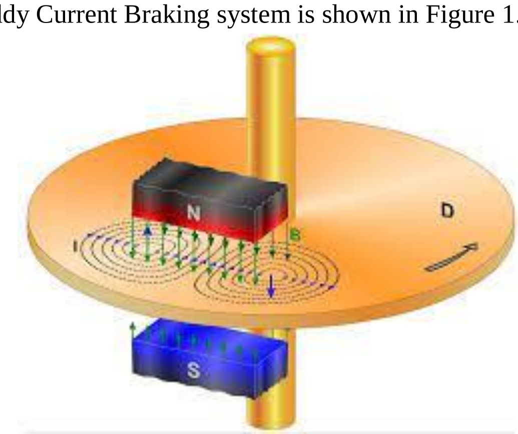


Fig 1. Eddy Current Brake

III. METHODOLOGY AND WORKING

Initially, a body frame is fabricated with hollow square steel pipes. A two-wheeler wheel is placed at the center of the body frame with two stainless steel rotor discs placed on both sides of the wheel. The wheel is attached to the tyre. A motor is placed in front of the wheel for the rotation of the wheel. Permanent magnets such as Neodymium Iron Boron magnets and Ferrite magnets are placed on the brake pads which are placed over the rotor disc for the application of the brake. By the application of the brake lever, the permanent magnet is brought near the rotating disc with a very small maintained air gap. Then eddy currents are induced in the rotor due to varying magnetic flux and these eddy currents oppose the rotation of the disc by the principle of Lenz law hence within a few seconds the disc comes to rest. The completed fabricated model of the Frictionless Braking System model is shown in Figure 2.

Lenz law: An eddy current is a current set up in a conductor in response to a changing magnetic field. **Lenz's law predicts that the current moves in such a way as to create a magnetic field opposing the change**; to do this in a conductor, electrons swirl in a plane perpendicular to the changing magnetic field.

3.1 COMPLETE FABRICATION AND METHODOLOGY OF THIS SYSTEM:

- Study the problems in the making of the magnetic braking system
- Designing the needed components. Selecting of needed materials.
- Buying the materials.
- Fabrication of the magnet's handle.

Fig 2. Fabricated model of Frictionless Braking System

The detailed considerations and specifications are in Table.1 Component includes a Motor, a Rotor disc, and Permanent magnets.

Components	Considerations	Specifications
Motor	The motor is chosen based on the load condition. Our project requires lower load conditions, so we have selected a motor that is used in a sewing machine.	Type: AC Single phase Speed: 3500 rpm Horsepower: 1 HP Voltage: 220 volts
Rotor disc	According to the journals copper, aluminium, stainless steel, and cast iron are the best materials for ECBS. We chose stainless steel as disc material for its better properties.	Stainless steel disc: Density: 8.96 g/cm3 Disc diameter: 294 mm Weight: 1.13 kg Thickness: 23 mm
Permanent magnets	There are 4 types of permanent magnets available 1) Neodymium Iron Boron (NdFeB) 2) Samarium Cobalt (SmCo) 3) Aluminum Nickel Cobalt (AlNiCo) 4) Ceramic (Ferrite) After the market survey, we got only 2 types neodymium iron boron magnet and ferrite magnet	Type 1: NdFeB Magnet diameter: 30 mm Thickness: 10mm Quantity: 6 Type 2: Ferrite Magnet dimension: 100 mm * 30 mm Thickness: 10mm Quantity: 2

Table 1 Description of materials

3.2 MATERIAL DESCRIPTION

3.2.1 BRAKE DISC

The material of the brake disc is Stainless Steel with high carbon content and good thermophysical characteristics. The critical performance requirements for a brake rotor include good thermal conductivity, low wear rate, long durability, low vibration, heat resistance, and high cooling rate. A picture of the Rotor disc is shown in Figure 3.

Number of discs used = 2
Diameter of a disc = 294 mm
Area of a disc = 67886.68 mm^2

Area of the disc affected by the Magnetic field = 51842 mm^2

Fig 3 Rotor disc

3.2.2 NEODYMIUM IRON BORON MAGNET

Neodymium magnets (also known as "NdFeB", "Neo" or "NIB" magnets) are permanent magnets made of neodymium, iron & boron. They are from the Rare-Earth magnet family and have the highest magnetic properties of all permanent magnets, stronger than Samarium Cobalt (SmCo), Alnico, and Ferrite.

Neodymium magnets are the strongest permanent magnets commercially available, anywhere in the world. They provide unparalleled levels of magnetism and resistance to demagnetization when compared to Ferrite, Alnico, and even Samarium Cobalt magnets.

The Neodymium atom can have a large magnetic dipole moment because it has 4 unpaired electrons in its electron structure as opposed to (on average) 3 in iron. In a magnet, it is the unpaired electrons, aligned so that their spin is in the same direction, which generates the magnetic field. A picture of Neodymium Iron Boron magnets is shown in Figure 4.

Number of magnets used = 6
Diameter of a magnet = 30 mm
Area of a magnet = 706.86 mm^2
Area of six magnets = 4241.16 mm^2

Fig 4 NdFeB Magnets

3.2.3 FERRITE MAGNET

The most important properties of ferrites include high magnetic permeability and high electrical resistance. High permeability to magnetic fields is particularly desirable in devices such as antennas. High resistance to electricity is desirable in the cores of transformers to reduce eddy currents.

A strong magnetic property, relatively low conductivity, low eddy current, dielectric losses, and high permeability are the important properties of ferrite materials.

Ferrite is a body-centered cubic (BCC) form of iron, in which a very small amount (a maximum of 0.02% at 1333°F / 723°C) of carbon is dissolved. This is far less carbon than can be dissolved in either austenite or martensite because the BCC structure has much less interstitial space than the FCC structure. A picture of a Ferrite magnet is shown in Figure 5.

Number of magnets used = 2
Dimension of a magnet = 100 mm * 30 mm
Area of a magnet = 3000 mm^2
Area of six magnets = 6000 mm^2

Fig 5 Ferrite Magnet

IV. ANALYSIS AND DISCUSSION

From the below tables, we can notice that the percentage of reduction in time gradually increases with an increase in rpm irrespective of to change in magnets and change in speed. And it was found that the maximum percentage of 84.64 attains only at 1000rpm in table 2 and it gradually decreases with a decrease in rpm and so the minimum percentage of reduction is 81.01 at 400rpm and this table is for NdFeB magnet at a maintained air gap of 8mm with and without magnet. And table 3 shows that the maximum percentage of reduction attains at 1000 rpm with a percentage of 73.48 for Ferrite magnet with a maintained air gap of 8mm with and without magnet and minimum attains at 400 rpm with a percentage of 67.52.

After changing the air gaps from 8mm to 12mm using the magnets NdFeB and Ferrite the percentage of reduction are calculated from the below tables, at the maintained air gap of 12mm the maximum percentage of reduction was 80.42 at 1000 rpm and the minimum was at 400 rpm with a percentage of 77.30 for NdFeB magnet and for Ferrite it was found to be 70.66 at 1000rpm and 61.41% at 400 rpm with and without magnets.

4.1 ANALYSING USING NDFEB MAGNET WITH A MAINTAINED AIR GAP OF 8MM

Table 2 Data for NdFeB at 8mm air gap

Speed (rpm)	Without magnet (sec)	With magnet (sec)	% of reduction
1000	18.95	5.56	70.66
800	13.01	4.30	66.95
600	9.98	3.96	60.32
400	8.50	3.28	61.41

The maximum percentage of reduction was 84.64 at 1000rpm and the minimum was 81.01 at 400rpm for the NdFeB magnet at a maintained air gap of 8mm.

4.2 ANALYSING USING FERRITE MAGNETS WITH A MAINTAINED AIR GAP OF 8MM

Speed (rpm)	Without magnet (sec)	With magnet (sec)	% of reduction
1000	18.70	4.96	73.48
800	12.09	3.98	67.08
600	10.55	3.57	66.16
400	8.96	2.91	67.52

Table 3 Data for Ferrite at 8mm air gap

The maximum percentage of reduction was found to be 73.48 at 1000 rpm and the minimum percentage of reduction was found to be 67.52 at 400rpm for Ferrite at an 8mm air gap.

4.3 ANALYSING USING NdFeB MAGNETS WITH A MAINTAINED AIR GAP OF 12MM

Speed (rpm)	Without magnet (sec)	With magnet (sec)	% of reduction
1000	18.90	3.70	80.42
800	13.60	2.99	78.01
600	10.01	2.25	77.52
400	8.90	2.02	77.30

Table 4 Data for NdFeB magnet at 12mm air gap

The maximum percentage of reduction was found to be 80.42at 1000 rpm and the minimum percentage of reduction was found to be 77.30 at 400rpm for NdFeB at a 12mm air gap.

4.4 ANALYSING USING FERRITE MAGNET WITH A MAINTAINED AIR GAP OF 12MM

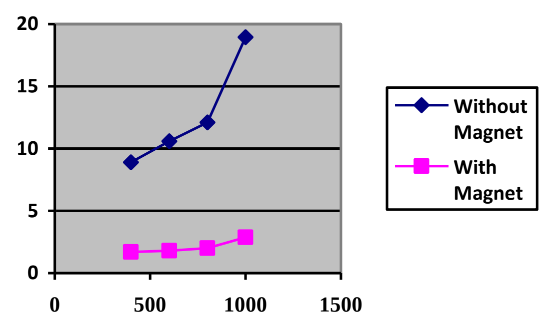
Table 5 Data for Ferrite magnet at 12mm air gap

Speed (rpm)	Without magnet (sec)	With magnet (sec)	% of reduction
1000	18.69	2.27	84.64
800	12.09	2.01	83.37
600	10.60	1.80	83.02
400	8.90	1.69	81.01

The maximum percentage of reduction was found to be 70.66 at 1000 rpm and the minimum percentage of reduction was found to be 61.41 at 400rpm for Ferrite at a 12mm air gap.

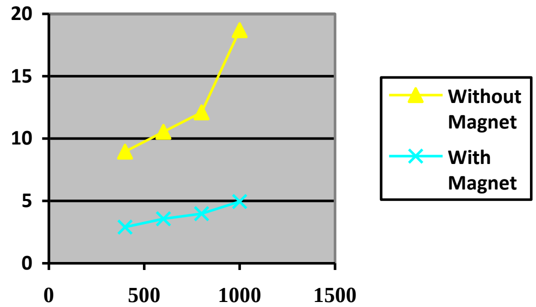
V. GRAPHICAL RESULTS

Graphs 1, 2, 3, and 4 show-stopping times in seconds of Rotor disc plotted on Y-axis against speed range in rpm on X-axis. The yellow and dark blue curves indicate the stopping time obtained without a magnet. The blue and pink curves indicate the stopping time obtained with the magnet respectfully.



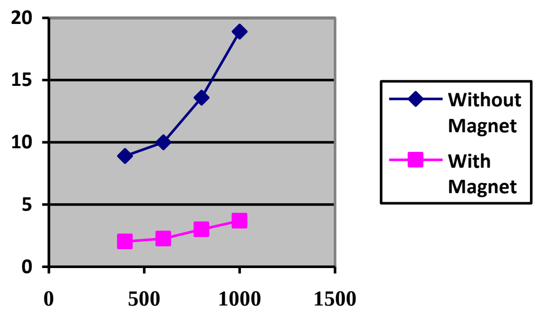
Graph 1 shows the data for NdFeB at an 8mm air gap

In Graph 1, the dark blue curve has points 8.90, 10.60, 12.09, and 18.69 seconds. The pink curve has points 1.69, 1.80, 2.01, and 2.87 seconds.



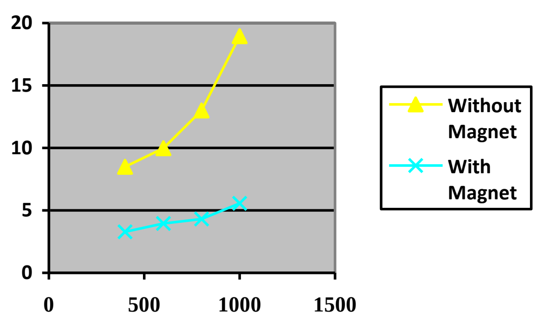
Graph 2 shows the data for Ferrite at an 8mm air gap

In Graph 2, the yellow curve has points 8.96, 10.55, 12.09, and 18.70 seconds. The blue curve has points of 2.91, 3.57, 3.98, and 4.96 seconds.



Graph 3 shows the data for NdFeB at a 12mm air gap

In Graph 3, the dark blue curve has points 8.90, 10.01, 13.60, and 18.90 seconds. The pink curve has points of 2.02, 2.25, 2.99, and 3.70 seconds.



Graph 4 shows the data for Ferrite at an 8mm air gap

In Graph 4, the yellow curve has points 8.50, 9.98, 13.01, and 18.95 seconds. The blue curve has points 3.28, 3.96, 4.30, and 5.56 seconds.

The disc does not get stopped immediately but it slows down the speed and brings it to rest after a certain time lag. Hence disc locking is eliminated and an antilock braking system is not needed and because there is no locking of the wheel, skidding is eliminated. The above data shows that the maximum braking torque occurs at a critical speed of 1000 rpm at an 8mm air gap in an NdFeB magnet. After passing over the critical speed the braking torque value reduces due to the impact of eddy current depths.

VI. RESULTS AND DISCUSSION

The speed is measured by a tachometer and time is measured by a stopwatch. The speed of the wheel reduced from 1000rpm to 0rpm within 2.27 seconds and this can be improved by increasing the surface area of the magnet (the greater the surface area greater will be the braking torque).

VII. NOMENCLATURE

Symbol	Meaning	Unit
D	Diameter	Mm
L	Length	Mm
B	Breadth	Mm
T	Thickness	Mm
N	Speed	Rpm
W	Weight	Kg
Hp	Power	W
P	Density	g/cm^3
V	Voltage	Volt

Table 6 Nomenclature

VIII. CONCLUSION

Frictionless braking produces effective braking with small wear and tear. The maintenance cost of this braking is small. This braking is a non-contact braking system and therefore there is no friction and minimum wear and tear. Thus, wreckage formed in braking is small and hence is eco-friendly. This braking is a more clean way of braking. Wheel skidding is eliminated as the wheel does not get locked. It is very suitable for high speed. It works on electricity and takes up a very little amount of power for a small period. It only Consumes small space hence installation is easy. It can be used effectively to replace typical braking systems.

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