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Construction & Comparison of Contactless and Contact Magnetic Braking System

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Abstract

Braking is an essential component of every automobile. The Eddy Current Braking System and the Electromagnetic Braking System are the two braking systems examined and contrasted in this article. Utilizing economical materials and resources to construct both systems further enhances the accessibility of advanced braking technology for students and learners. The experimental configuration is elaborate to analyse the structural distinctions between these systems comprehensively. Eddy current braking generates a resistive force that decelerates motion without physical contact by inducing circulating currents within a conductor travelling through a magnetic field. On the other hand, electromagnetic braking decelerates the vehicle by generating a frictional force via the interaction of a magnetic field generated by electromagnets with a metal disc or drum. Graphical analysis was employed to compare performance and illustrate the distinctions between the contactless and contact braking systems. The impact of fluctuations in air gap and angular velocity on the operation of the Eddy Current Braking System is also investigated. By the cost-effective construction system, this article created a potential to adopt this system in the maximum educational sector and other areas. Amidst the extensive discourse surrounding magnetic braking systems in the automotive industry, this article fills a void by conducting a comparative assessment of their construction and operational efficacy. The results provide significant knowledge regarding each system's comparative effectiveness and possible uses, thereby advancing automotive braking technology and facilitating greater accessibility for learners and students due to their economical construction.

Keywords: magnetism, electromagnet, eddy current, braking system, contactless braking, automobile

1. Introduction

The braking system is the most critical safety feature while using any equipment. The brake system is also developing as the world is getting more advanced daily. Different types of braking systems involve various mechanisms. Some brakes are contactless; sometimes, two surfaces connect to create the braking system. A metal disk is at the heart of the eddy current braking system, carrying the eddy current produced by magnets. This brake can be applied quickly and easily, doesn't wear out, and doesn't lock up wheels like friction brakes do when the temperature changes. This is accomplished using a magnetic field across a moving conductor to generate braking torque, which induces eddy currents to produce a perpendicular magnetic field. The electromagnetic braking system is a new technology. In this technology, electromagnetism will stop the vehicle immediately when the brake is applied. To brief this system, the brake plate of this system will be metal, and a solenoidal magnet will be used to rub that rotating plate. When the brake is applied, electricity will be supplied to the solenoid, acting as a magnet. This solenoidal magnet will then attract the brake plate and hold it tight. This method will help the brake work in the automobile using electromagnetic theory.

2. Components

Eddy Current Braking System

I. **Rotor Disc:** Cast iron is commonly used to make the rotor; however, strengthened carbon-carbon or ceramic matrix composites may also be used in specific circumstances. This has a connection to both the axle and the wheel

II. **Shaft:** A shaft is a revolving machine component that transmits mechanical energy from one machine to another or from a power source to an end user. The cross-section of a shaft is typically round. It is

mounted with different parts, including pulleys and gears. Mild steel is the material used to make standard shafts.

III. **Permanent Magnet:** An electromagnet or a permanent magnet can generate the magnetic field of an eddy current brake, and the amount of braking force can be adjusted by varying the electric current through the electromagnet's windings.

Electromagnetic Braking System

I. **Wheel and Brake Plate:** A wheel is a spherical component mounted under a vehicle or other object that rotates on an axle to facilitate movement across uneven terrain.

II. **DC Motor:** A direct current (DC) motor is a device that converts energy. Popular genres rely heavily on appealing-field qualities. A motor turns a shaft using electrical energy. Inside the motor, the magnetic field created by the electric energy rotates the armature.

III. **Roller Chain:** A chain is a logical assembly of joined, related objects. Typically, it is constructed of metal. Its general personality is similar to that of a rope. But despite being straight, rigid, and load-bearing under tension, it is flexible and bendable under pressure.

3. Methodology

In the diagram below, a metal sheet (C) can be seen sliding to the right while being held by a magnet. The sheet permits the North Pole (N) magnetic field (B) to pass through. The magnetic flux across the sheet changes due to the metal's motion. This field causes the electric current (I) to flow counterclockwise through the sheet, by Faraday's law of induction. Herein lies the secret to Eddy Current's success. An eddy current flows clockwise when the magnetic field weakens across the sheet at the magnet's trailing edge (on the right side).

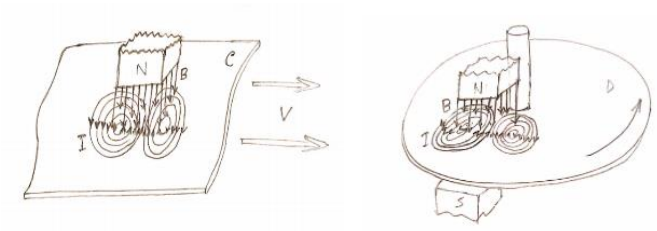


Fig. 1. Free body Diagram of Eddy Current Principle

In the case of electromagnetic braking systems, Magnetism and Electromagnetism are so related that sometimes it's hard to distinguish between them. Electromagnetism can be defined as the physical phenomenon in which two electrically charged particles attract or repulse each other when their electromagnetic field is forced to touch each other. When an electrically charged particle moves, a magnetic field is created. Positive/Negative electric change creates a Positive/Negative electromagnetic field. Two of the same types of electromagnetic fields repulse each other, and opposite fields attract each other. An electric conductor coil wraps an iron bar in the Solenoidal Magnetic Field. The bar is wrapped by wire by many turns. When the electricity is applied, an electromagnetic field is created. This magnetic field forces the charged particles of the iron bar to orient in a specific direction, creating a large amount of the magnetic field.

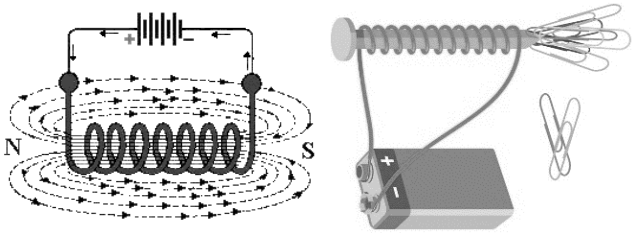


Fig. 2. Electromagnetism and Solenoidal Magnetic Field

Working Principles

An eddy current braking system attaches a disc to a steel shaft. The shaft is connected with a bearing and a roller chain. The other part of the chain is connected to the motor, which is connected to the power connection. A permanent magnet is set up in the middle with a spring and a paddle. After starting the motor, the shaft, as well as the disc, starts its rotation. After getting the proper speed, the paddle is pressed to get the magnet in front of the disc. The disc and the magnet get in a parallel way but do not get connected. The magnet creates the magnetic

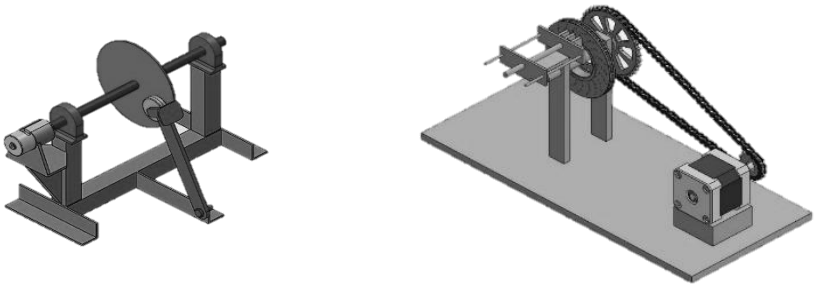
field, and the rotating disc together creates the eddy current, which prevents the disc's rotation speed. This whole system is more applicable in high-speed situations. The behaviour of an eddy current brake is analogous to viscous friction in a liquid, as the braking force is directly proportional to the velocity V. As the speed drops, the braking force also lowers. There is no interaction between the magnet and the conductor since the magnetic field is always the same when the conductive sheet is immobile. Therefore, an eddy current brake has no holding force. This is how the entire system operates.

In an electromagnetic braking system, a wheel with a brake plate will be motioned via a motor. The chain-Sprocket mechanism will transmit the rotational energy from the DC motor to the wheel. Conversely, a Solenoidal Magnetic Field will convert electrical energy from the source to a magnetic field. There will be two complete electrical circuits. The first will power up the DC motor, and the second will magnetise the iron bar. When the switch of the first circuit is turned ON, the DC motor will give motion to the wheel. When the switch of the second circuit is turned on, the electrical power from the source will be converted to the magnetic field.

When a magnetic field is generated, the iron bar is drawn to the brake plate and comes into contact with it. After that, friction goes against the wheel's rotation. Soon, both wheel velocity and rotational energy diminish.

CAD Model

Before construction, a simple CAD model of the two projects was created, which helped to give an idea of the setup for the whole construction process.

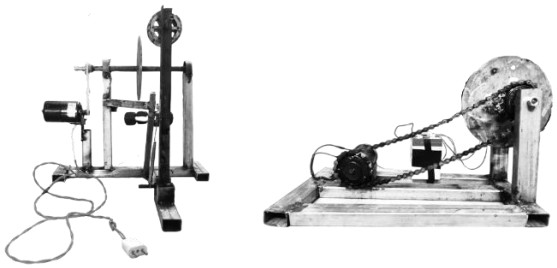


(a) (b)

Fig. 3. CAD model of (a) Eddy Current Braking System and (b) Electromagnetic Braking System

Experimental Setup

In the experimental setup, every material used is collected from the local market to reduce construction costs. The motor and battery are collected from different machines. The joints in the maximum sections are welded in both projects. Nut-and-bolt connections connect the other joints.



(a) (b)

Fig. 4. Experimental Setup of (a) Eddy Current Braking System and (b) Electromagnetic Braking System

The joint and the structure were polished very carefully to reduce friction. In both projects, the friction affected the rotation of the wheels less. The structure was rigid, as mild steel was used in both cases.

Experimental Procedure

Several experiments have been carried out to evaluate the two-braking system's performance. A tachometer was used to determine the vehicle's speed at this stage, and a stopwatch was used to assess the time required. Next, the brake performance test was carried out. The magnetic flux, the distance between the magnet and the disc, and the speed of the disc were the primary parameters that contributed to the variance in eddy current observed throughout this performance. The only two factors that generated the temporal variation in the experimental results were the

air gap and the speed. Both of these variables were constant since the magnetic flux was constant. The primary comparison has been completed once the performance test has been completed.

4. Experimental Data

After the construction procedure, both projects were used for their performance tests. Different variables were measured to test performance. Measurements were taken multiple times to ensure less error and clarity.

Table 1. The Experimental Data of Output Time

Observation No.	Eddy Current Braking System		Electromagnetic Braking System	
	Time (s) (with brake)	Time (s) (without brake)	Time (s) (With Brake)	Time (s) (Without Brake)
1	5.43	19.26	0.05	15.03
2	6.11	20.52	0.06	14.56
3	6.31	21.45	0.09	13.90
4	6.54	22.15	0.06	15.42
5	7.23	22.71	0.04	14.95

5. Conclusion

A comparison study was done between two constructed braking systems. In this study, five different angular velocities in the disc were gained. The data for braking time was taken for each angular velocity. Braking time for contact braking system, contactless braking system and without braking system were measured and plotted in a graph for comparison. The graph shows that the contact braking system takes less time, and no brake takes more time to stop the disc. At the same time, a contactless braking system takes more time than a contact brake and less time than a no brake. For obvious reasons, contact brakes generate friction, which resists the motion of the disc brake; that's why it takes the shortest time to stop the disc.

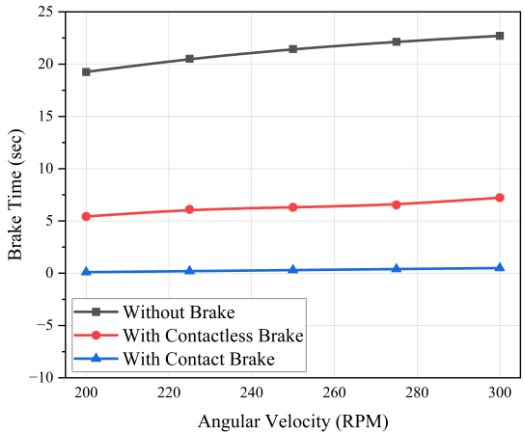


Fig. 5. Comparison of time required in eddy current and electromagnetic brakes, with or without using the braking system.

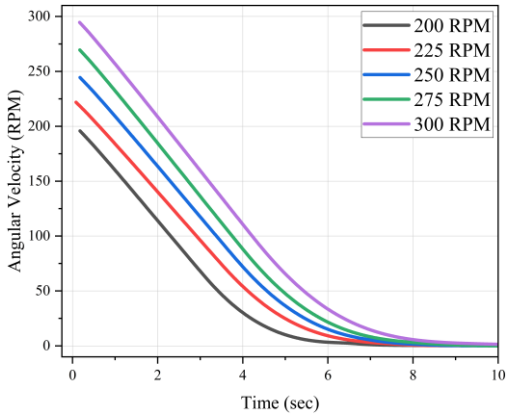


Fig. 6. Comparison of time required using eddy current brake when the air gap is constant.

A different investigation was conducted for contactless braking by altering the disc's starting angular velocity. In this instance, the air gap between the disc and the permanent magnet was maintained at 5mm. In this study, five different initial angular velocities of the disc were gained, and then contactless brakes were applied to measure the braking time for each velocity. Here, the braking time is shorter at lower speeds and higher at higher speeds.

A study was conducted on the contactless braking system by varying the air gap between the brake disc and the permanent magnet. This study was for three air gaps (2.5mm, 5mm, 10 mm). In this study, a constant angular velocity of 250 RPM was gained, and then a contactless brake was applied by varying its distance from the disc, and data for the brake time was measured. For a 10mm distance, it is seen that it takes more time to stop the disc. Meanwhile, 2.5mm takes less time. A 5mm air gap takes more time than a 2.5mm air gap but less time than a 10mm air gap to stop the disc in contactless braking. In conclusion to the study, the closer the magnet, the shorter the brake time for a contactless braking system. The magnet has more impact over the disc at a shorter distance than at a more significant distance.

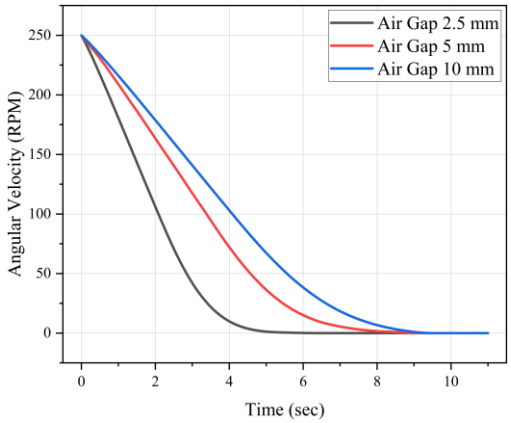


Fig. 7. Comparison of time required using eddy current brake when the angular velocity is constant, and the air gap is variable between 2.5 mm to 10mm.

In conclusion, this research contrasted the electromagnetic and eddy current braking systems. While electromagnetic brakes have more stopping strength, eddy current brakes are easy to use and effective. The decision is based on particular application requirements, weighing aspects like braking force and cost-effectiveness. This study offers tips for choosing the best braking system for various technical applications.

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