EDDY CURRENT BRAKING SYSTEM AND ITS EFFECT IN REDUCING FRICTIONAL LOSS

DESIGN PROJECT REPORT

In

B.Tech in Mechanical Engineering

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ABSTRACT

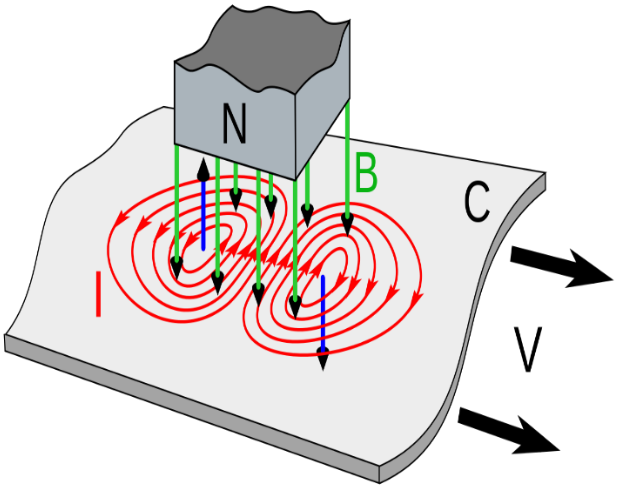
An electromagnetic brake is a new and revolutionary concept. Electromagnetic braking system is a modern technology braking system used in light motor & heavy motor vehicles. This system is a combination of electro-mechanical concepts. The frequency of accidents is now-a-days increasing due to inefficient braking system. It is apparent that the electromagnetic brake is an essential complement to the safe braking of heavy vehicles. It aims to minimize the brake failure to avoid the road accidents. It also reduces the maintenance of braking system. An advantage of this system is that it can be used on any vehicle with minor modifications to the transmission and electrical systems. An Electromagnetic Braking system uses Magnetic force to engage the brake, but the power required for braking is transmitted manually. The disc is connected to a shaft and the electromagnet is mounted on the frame .When electricity is applied to the coil a magnetic field is developed across the armature because of the current flowing across the coil and causes armature to get attracted towards the coil. As a result, it develops a torque and eventually the vehicle comes to rest.

Electromagnetic brakes are the brakes working on the electric power &magnetic power. They work on the principle of electromagnetism. The working principle of this system is that when the magnetic flux passes through and perpendicular to the rotating wheel the eddy current flows opposite to the rotating wheel/rotor direction. This eddy current trying to stop the rotating wheel or rotor. This results in the rotating wheel or rotor comes to rest/ neutral. These are totally **friction less**. Due to this, they are more **durable & have longer life span**.This project aims at studying and comparing the use of eddy current brake system over conventional mechanical brake(disc or drum brake).

INTRODUCTION

A brake is a device, which inhibits motion.Most commonly, brakes use friction to convert kinetic energy into heat.The disc brake or disk brake is a device for slowing or stopping the rotation of a wheel. A brake disc usually made of cast iron or ceramic composites is connected to the wheel and the axle. To stop the wheel, friction material in the form of brake pads is forced   mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. This leads to a great component of energy to waste, on the contrary eddy current braking system can reduce this friction loss and help in improving the overall efficiency of the automobile.

Unlike electro-mechanical brakes, in which the drag force used to stop the moving object is provided by friction between two surfaces pressed together, the drag force in an eddy current brake is an electromagnetic force between a magnet and a nearby conductive object in relative motion, due to eddy currents induced in the conductor through electromagnetic induction.A conductive surface moving past a stationary magnet will have circular electric currents called eddy currents induced in it by the magnetic field, as described by Faraday's law of induction. By Lenz's law, the circulating currents will create their own magnetic field which opposes the field of the magnet. Thus the moving conductor will experience a drag force from the magnet that opposes its motion, proportional to its velocity. The electrical energy of the eddy currents is dissipated as heat due to the electrical resistance of the conductor.



<u>Purpose of the Project</u>

The purpose of the project is to propose a much better and efficient braking system then mechanical braking i.e disc or drum braking. Electromagnetic magnetic braking can be a prominent alternative to conventional braking systems.To Design and analyze eddy current braking system and its effect in reducing frictional losses.

To have a comparative study between the eddy current braking system and conventional braking system interms of –

- Obtained output
- Cost
- Power utilisation

<u>Scope for the Project</u>

Eddy current braking system has find its wide application in present Indian railway braking system which is capable of stopping and handling enormous load which cannot be handled with mechanical braking using friction.

Eddy current generates more efficient output as compared to conventional braking system and thus its application in present automobile industry will definitely prove fruitful.

Use of eddy current braking system has following advantages over conventional braking system-

- These are non-mechanical, no moving parts hence no friction.
- Fully resettable, no parts need to be replaced
- Can be activated at will via electrical signal
- Low maintenance cost
- Operates at any rotational speed.

ELECTROMAGNETIC-BRAKE VS CONVENTIONAL BRAKING

- CONVENTIONAL FRICTION BRAKE
  The conventional friction brake system is composed of the following basic components: the “master cylinder” which is located under the hood is directly connected to the brake pedal, and converts the drivers’ foot pressure into hydraulic pressure. Steel “brake hoses” connect the master cylinder to the “slave cylinders” located at each wheel. Brake fluid, specially designed to work in extreme temperature conditions, fills the system. “Shoes” or “pads” are pushed by the slave cylinders to contact the “drums” or “rotors”, thus causing drag, which slows the car. Two major kinds of friction brakes are disc brakes and drum brakes. Disc brakes use a clamping action to produce friction between the “rotor” and the “pads” mount in the “caliper” attached to the suspension member’s Disc brakes work using the same basic principle as the brakes on a bicycle: as the caliper pinches the wheel with pads on both sides, it slows the vehicle.

Drum brakes consist of a heavy flat-topped cylinder, which is sandwiched between the wheel rim and the wheel hub. The inside surface of the drum is acted upon by the linings of the brake shoes. When the brakes are applied, the brake shoes are forced into contact with the inside surface of the brake drum to slow the rotation of the wheels.

Air brakes use standard hydraulic brake system components such as braking lines, wheel cylinders and a slave cylinder similar to a master cylinder to transmit the air -pressureproduced braking energy to the wheel brakes. Air brakes are used frequently when greater braking capacity is required.

The main reasons why conventional friction brakes fail to dissipate heat rapidly are as follows:

- poor ventilation due to encapsulation in the road wheels,
- diameter restriction due to tire dimensions,
- width restrictions imposed by the vehicle spring designer,
- Problems of drum distortion at widely varying temperatures.

It is common for friction-brake drums to exceed 500 °C surface temperatures when subject to heavy braking demands, and at temperatures of this order, a reduction in the coefficient of friction ('break fade') suddenly occurs. The potential hazard of tire deterioration and bursts is perhaps also serious due to the close proximity of overheated brake drums to the inner diameter of the tire.

- ELECTROMAGNETIC BRAKE

The construction of the electromagnetic braking system is very simple. The parts needed for the construction are electro magnets, rheostat, sensors, and magnetic insulator. A cylindrical ring shaped electro magnet with winding is placed parallel to rotating wheel disc/ rotor. The electro magnet is fixed, like as stator and coils are wounded along the electromagnet. These coils are connected with electrical circuit containing one rheostat, which is connected with brake pedal. In addition, the rheostat is used to control the electric current flowing in the coils, which are wounded on the electro magnet, and a magnetic insulator is used to focus and control the magnetic flux. In addition, it is used to prevent the magnetization of other parts like those that axle and it act as a support frame for the electromagnet. The sensors used to indicate the disconnection in the whole circuit. If there is any error, it gives an alert, so we can avoid accident.

The parts of Electromagnetic Disc Brake are:

- AC Motor
- Disc
- Frame
- Electromagnet
- Circuit Board
- Pulleys & Belt
- Shaft

WORKING PRINCIPLE

If a piece of copper wire was wound, around the nail and then connected to a battery, it would create an electro magnet. The magnetic field that is generated in the wire, from the current, is known as the "**right hand thumb rule**". The strength of the magnetic field can be changed by changing both wire size and the amount of wire (turns). The fields of EM brakes can be made to operate at almost any DC voltage and the torque produced by the brake will be the same as long as the correct operating voltage and current is used with the correct brake.

A constant current power supply is ideal for accurate and maximum torque from a brake. If a non-regulated power supply is used the magnetic flux will degrade as the resistance of the coil goes up. The hotter the coil gets the lower the torque will be produced by about an average of 8% for every 20°C. If the temperature is constant, and there is a question of enough service factor in the design for minor temperature fluctuation, by slightly over sizing the brake can compensate for degradation. This will allow the use of a rectified power supply, which is far less expensive than a constant current supply. Based on **V = I × R**, as resistance increases available current falls. An increase in resistance, often results from rising temperature as the coil heats up, according to:

Rf = Ri× [1 + aCu × (Tf - T)]

Where Rf = final resistance, Ri = initial resistance, aCu = copper wire's temperature coefficient of resistance, 0.0039 °C-1, Tf = final temperature, and Ti = initial temperature.

The working principle of the electric retarder is based on the creation of eddy currents within a metal disc rotating between two electromagnets, which set up a force opposing the rotation of the disc. If the electromagnet is not energized, the rotation of the disc is free and accelerates uniformly under the action of the weight to which its shaft is connected. When the electromagnet is energized, the rotation of the disc is retarded and the energy absorbed appears as heating of the disc. If a rheostat varies the current exciting the electromagnet, the braking torque varies in direct proportion to the value of the current.

The basic operation of magnetic field that is generated in the wire, from the current, is known as the "right hand thumb rule. This rule is known as faraday's law.

A. Electromagnetism is one of the four fundamental interactions in nature. The other three are the strong interaction, the weak interaction, and gravitation. Electromagnetism is the force that causes the interaction between electrically charged particles; the areas in which this happens are called electromagnetic fields

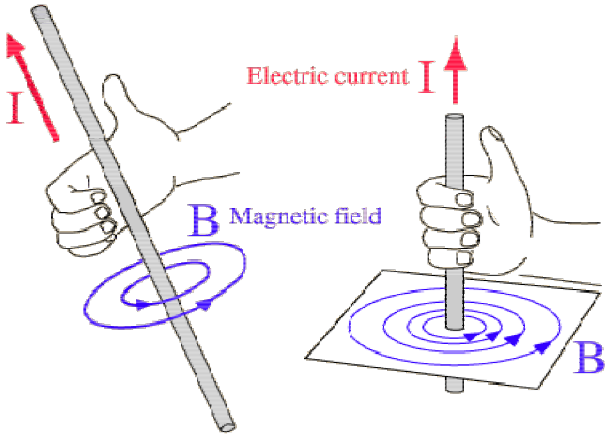


Figure-11.Right Hand Thumb Rule

A typical retarder consists of stator and rotor. The stator holds 16 induction coils, energized separately in groups of four. The coils are made up of varnished aluminum wire mounded in epoxy resin. . The rotor is made up of two discs, which provide the braking force. When subject to the electromagnetic influence when the coils are excited. Careful designs of the fins, which are integral to the disc, permit independent cooling of the arrangement.

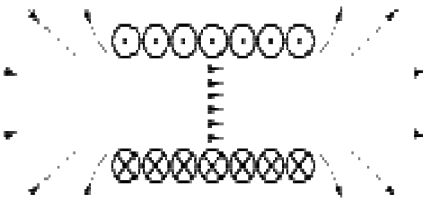


Figure-12.Magnetic Field Lines

At the initial stage, the brake pedal and rheostat are in rest. When we apply the brake through the brake pedal, the rheostat allows the current to flow through the circuit and this current energizes the electromagnet. The rheostat controls the amount of current flow. Depending on the current flow, different amount of magnetic flux can be obtained. By this varying

magnetic flux, different mode of brakes can be obtained. For example, if we want to suddenly stop the vehicle then press the brake pedal fully, then the rheostat allows maximum current, which is enough to stop the vehicle. Similarly, we can reduce the speed of the vehicle by applying the brake gradually.

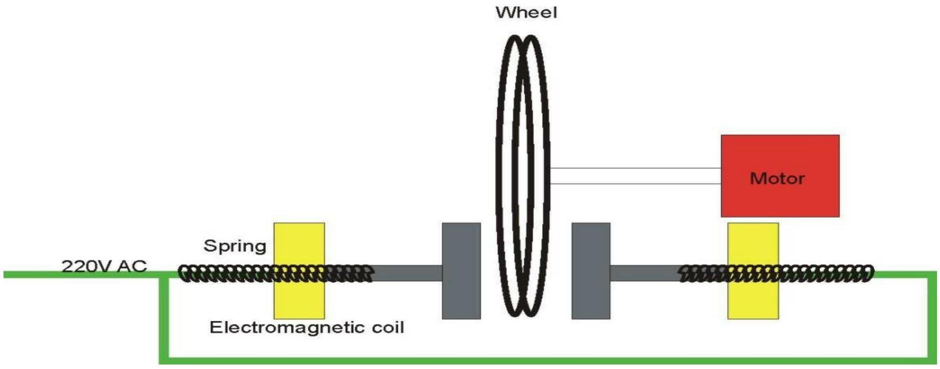
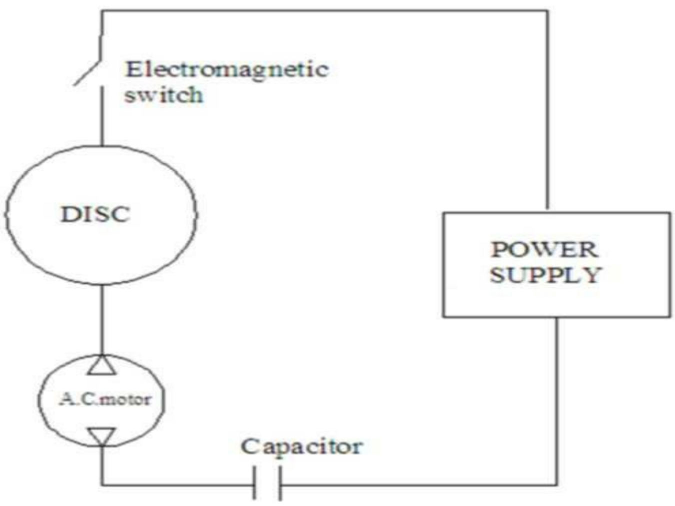


Figure-13. Arrangement of EM Brake

Working Of Electromagnetic Disc Brake

The electromagnet is energized by the AC supply where the magnetic field produced is used to provide the braking mechanism. When the electromagnet is not energized, the rotation of the disc is free and accelerates uniformly under the action of weight to which the shaft is connected. When the electromagnet is energized, magnetic field is produced thereby applying brake by retarding the rotation of the disc and the energy absorbed is appeared as heating of the disc. Therefore, when the armature is attracted to the field the stopping torque is transferred into the field housing and into the machine frame decelerating the load. The AC motor makes the disc to rotate through the shaft by means of pulleys connected to the
shaft.



Flowchart of Working of Electro Magnetic Disc Brake

CALCULATIONS

Figure 2 shows the dimension parameter of ECB in hybrid brake system; according to Lee and Park [7], the eddy current brake torque can be expressed as

$$T_{bc} = T_i i^2 \omega, \tag{1}$$

where T_{bc} is the eddy current brake torque, i is the current of the coil, and ω is the angular velocity of the disk. The braking torque coefficient T_i is

$$T_i = \sigma_0 R_b^2 \left(\frac{\mu_0 N}{L}\right) SD, \tag{2}$$

where σ_0, μ_0, N, L, S, D, and R_b represent the electric conductivity, permeability of air, number of coil turns, air gap distance, cross-sectioned area of the core, the disk thickness, and the brake torque radius of the disk. However, because of the flux leakage, heat influences the disk. The coefficient T_i should be modified. According to Simeu and Georges [11],

$$T_i = \alpha C \sigma_0 R_b^2 \left(\frac{\mu_0 N}{L}\right) SD, \tag{3}$$

where α and C are the modified factors:

$$\begin{gathered} \alpha = 1 - \frac{1}{2\pi}\left[4\tan(\psi) + \psi \ln\left(1 + \frac{1}{\psi^2}\right) - \frac{1}{\psi}\ln\left(1 + \psi^2\right)\right], \\ C = 0.5\left[1 - \frac{AB}{\pi(1 + R_b/R_w)^2 (R_w - R_b)^2}\right]. \end{gathered} \tag{4}$$

Here, A and B are the width and height of the iron cross-sectioned area and $\psi = B/A$.

$$\begin{gathered} T_{bc} = \frac{2\widehat{T}i}{\upsilon_k/\upsilon + \upsilon/\upsilon_k}, \\ \widehat{T} = \left(\sqrt{\left(\frac{c}{\zeta}\right)\frac{\pi}{4}R_b^2}\sqrt{\left(\frac{L}{R_b}\right)}\right)\frac{N}{L}, \\ \upsilon_k = \frac{2}{\mu_0}\sqrt{\left(\frac{1}{c\xi}\right)\frac{\rho}{D}}\sqrt{\frac{L}{R_b}}, \end{gathered} \tag{5}$$

where υ, υ_k, c, ξ, and ρ represent the speed of brake disk, critical speed, scale factor, scale coefficient, and resistivity of brake disk [13–15].

Since the ECB in the hybrid brake system has two brake disks, the eddy current brake torque should be as follows.

When $v < v_k$:

$$T_{bc} = 2\left\{1 - \frac{1}{2\pi}\left[4\tan(\psi) + \psi\ln\left(1 + \frac{1}{\psi^2}\right) - \frac{1}{\psi}\ln\left(1 + \psi^2\right)\right]\right\} \times \left(0.5\left[1 - \frac{AB}{\pi(1 + R_b/R_w)^2(R_w - R_b)^2}\right]\right) \times \sigma_0 R_b^2\left(\frac{\mu_0 N}{L}\right) SD\, I^2\omega. \tag{6}$$

When $v > v_k$:

$$T_{bc} = \frac{2}{v_k/v + v/v_k}\left(\sqrt{\left(\frac{c}{\zeta}\right)\frac{\pi}{4}R_b^2}\sqrt{\left(\frac{L}{R_b}\right)}\right)\frac{N}{L}. \tag{7}$$

2.2. Brake Disk Model

The brake disk model describes relationship between pressure of wheel cylinder and brake torque.

According to Chen et al. [16], the empirical model of brake torque and pressure can be expressed as

$$T_{bh} = \frac{p_w\mu}{k_\mu}, \qquad \mu = 0.3 + 0.12\exp\left[-(1.2492 - 0.0029v - 0.0814p_w)\right], \tag{8}$$

where T_{bh} is brake torque, p_w is brake pressure, μ is friction coefficient, k_μ is calculation coefficient (2.099), and v is vehicle speed.

2.3. Wheel Model

In order to analyze the performance of the hybrid brake system with varying torque characteristics, a vehicle wheel model is needed. It is assumed that vehicle lateral, vertical, roll, and yaw dynamics are negligible for the braking application. As shown in Figure 4, the wheel rotational dynamics are given by the following equation:

$$\sum M_y = T_{bi} - F_xR + F_{rr}R - T_d = -I_\omega\dot{\omega},$$

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ADVANTAGES AND DISADVANTAGES

ADVANTAGES

1. Problems of drum distortion at widely varying temperatures. Which is common for friction-brake drums to exceed 500 °C surface temperatures when subject to heavy braking demands, and at temperatures of this order, a reduction in the coefficient of friction ('brake fade') suddenly occurs.

2. This is reduced significantly in electromagnetic disk brake systems.

3. Potential hazard of tire deterioration and bursts due to friction is eliminated.

4. There is no need to change brake oils regularly.

5. There is no oil leakage.

6. The practical location of the retarder within the vehicle prevents the direct impingement of air on the retarder caused by the motion of the vehicle.

7. The retarders help to extend the life span of the regular brakes and keep the regular brakes cool for emergency situation.

8. The electromagnetic brakes have excellent heat dissipation efficiency owing to the high temperature of the surface of the disc which is being cooled.

9. Due to its special mounting location and heat dissipation mechanism, electromagnetic brakes have better thermal dynamic performance than regular friction brakes.

10. Burnishing is the wearing or mating of opposing surfaces .This is reduced significantly here.

11. Electromagnetic brake systems will reduce maintenance cost .

12. The problem of brake fluid vaporization and freezing is eliminated.

DISADVANTAGES

1. Dependence on battery power to energize the brake system drains down the battery much faster.

2. Due to residual magnetism present in electromagnets, the brake shoe takes time to come back to its original position.