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Contactlesss Eddy Current Braking System in Automobiles

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Abstract:- In mechanical type braking system which are being used now days to stop or retard the automobile by means of artificial frictional resistance. This causes skidding and wear & tear of the vehicle which may cause serious problems. If the speed of the vehicle is very high, then it will not provide high braking torque, which may cause less frictional resistance during braking action and it will cause problems like accidents. These drawbacks of mechanical type brakes can be overcome by a simple, effective and efficient mechanism of braking system which is called as "**The Non contactless braking system or Eddy current braking System**". It is a non contact type braking system then it is an abrasion-free method for braking in automobiles. It makes use of the opposing tendency of Eddy current. Eddy current are the loops of or swirling electric current produced in a conductor,by changing the magnetic field .The change of magnetic field is required for generating flux by the principle of faraday law. In eddy currents braking energy such as kinetic energy transform into heat, which is an unused energy. In some applications, the useful energy is lost i.e not particularly desirable. But there are some practical applications such an application is the eddy current brake.[1]This paper report explores the working principle of eddy current brake mechanism. In eddy current braking, like a conventional friction brake, which is responsible for slowing an object, such as a train or a roller coaster etc. In the friction braking, the pressure is applied on two separate objects, but in eddy current braking an object is stopped by creating eddy currents through electromagnetic induction which creates resistance, and in turn either heat or electricity. For such a breaker, we give analytical formulas considering end effects for its magnetic field, eddy current distribution, forces according to the secondary relative permeability, and conductivity. The results given here are purely analytic.[2]The principle of braking in road vehicles involved the conversion of kinetic energy into heat. This heat energy conversion therefore demands and appropriate rate of heat dissipation if a reasonable temperature and performance stability are to be maintained. The electromagnetic brakes works in relatively cool condition thus it avoid problem that friction brake face by using a totally different working principle and installation location. By using electromagnetic braking as substitute retardation equipment, the friction braking may be used less as compared and therefore practically never reach high temperature. Thus by eddy current braking brakes have a longer life , and potential "brake fade" problem can be avoided, it is apparent that the electromagnetic brake is an essential compliment to the safe breaking of vehicles.[3]

***Keywords**- Eddy current, Braking system*

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1: INTRODUCTION

Eddy currents are electric currents induced in conductors when they exposed to fluctuating magnetic field,due to relative motion of field source and conductor or due to variation of field with time.

As the friction brakes uses the force that stops the moving objects motion by friction between between two surfaces pressed together, although the force in an eddy current brakes 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.[4]

EDDY CURRENT BRAKING is just like other friction brakes which are responsible for slowing or retards the object's motion by producing circulating eddy's currents in the conductors.The brakes use opposing tendency of eddy currents.

The shortcomings of friction brakes which use mechanical stopping technique can be eliminated by use of simple and effective process known as eddy current brakes.

Essentially the eddy current brake consists of two parts,a stationary magnetic field system and a solid rotating part,which includes metal parts.These two system are seprated by short air gap,as they aren't having any contact from each other thus the system haven't wear and tear as compared to friction brakes.

During braking,the metal disc is exposed to a magnetic field from an electromagnet, genrating eddy's current in disc.The magnetic interation between applied field and the eddy currents slow down the rotating disc.Thus the wheels of vehicle also slows down since the wheels are directly coupled to disc of the eddy current brake,thus producing smooth stopping motion.

2. REVIEW OF LITERATURE

Eddy currents are electric currents induced in a conductor when it is exposed to a changing magnetic field either due to the relative motion of the field source and conductor or due to the variations of field with time.[8] These eddy currents circulate inside the body of the conductor. These circulating eddies of current induce magnetic field ofpolarity opposite to the applied magnetic field. Due to the internal resistance of the conductive material, eddy currents will be dissipated into heat and energy will bere moved from the system, producing a damping effect. The generated eddy currents can be potentially used for many interesting dynamic applications. The concept of using eddy current for damping purposes has been known for a long time.The majority of research in eddy current damping has taken place in the area of magnetic braking. When the conducting disc rotates with the rotor, eddy current damping can only be effectively used in the subcritical range..[10] The eddy current damper consisted of a flexible linkage with two permanent magnets and a fixed copper plate attached to the end of the cantilever beam.The relative motion between the permanent magnets and the copper plate produced eddy currents.

3. Methdology Flow

Essentially, in eddy current braking system consists of two different members, a stator(it is a stationary magnetic field system) and a rotor(it is a solid rotary member) , generally of mild steel, which is always called as secondary because the eddy currents are induced in it (Rotor) and the primary is called as stator. These two members are separated by the short air gap generally in millimetre , they're being no contact between the two for the purpose of torque transmission. Consequently there is no wear and tear as in friction brake.Stator or stationary field system consists of pole core, pole shoe, and field winding. The field winding is wounded on the pole core. Pole core and pole shoes are made of east steel laminations and fixed to the state of frames by means of screw or bolts. . This system consists of two parts.[12]

1. Primary Member (Stator)

2. Secondary Member (Rotor)

As the wheels starts rotating.the disc which is coupled to the wheels of the vehicle produced eddy current in it, as close proximity to stationary magnetic poles. When we want to brake the vehicle, a control switch is put on which is placed on the steering column in a position for easy operation.

As the control switch is operated, thus current flows from a battery to the field winding connected to the poles, thus energizing the magnet. Then the rotating disc will cut the magnetic field. When the disc cuts the magnetic field, rate of flux changes occur in the disc which is proportional to the strength of the magnetic field. The current will flow back to the zero field areas of the disc and thus it create a closed current loop like a swhirling or eddy. A flow of current always means there is a magnetic field as well. Due to Lenz's law, the magnetic field produced by the eddy currents oppose the movement direction.Thus instead of mechanical friction, a magnetic friction is created. In results, the disc will experience a "opposive" or the braking effect, and thus the disc stops rotating. Faster the wheels are spinning, stronger the effect, meaning that as the vehicle slows,thus the braking force is reduced by producing a smooth stopping action. [12]

4.Design andOptimazation of Eddy current braking on Assembly

The design of an eddy current brake reduced to some optimization problems which are discussed in the proceeding sections.

1. **Rotor Disc Clearance :-**The rotor disc space must be gained to maximize torque when the brake is on and maximize back drivability when the brake is off. This optimization are: maximum torque requires minimum clearances while maximum back drivability may have a clearance threshold where within the eddy currents cannot be eliminated due to the parabolic shape of the magnetic field lines in the off case. This optimization will be largely conducted experimentally.[13]

2. **Rotor Material :-** The material of the rotor disc must also be optimized in order to minimize the time constant, τ and minimize the disc's moment of inertia, *I*. There are two strong candidates in our selection of material which are copper and aluminum. This evaluation is based on the qualitative result of Equation given. In order to

minimize the time constant, we must choose the smallest ratio of density, ρ to conductivity, σ from all the materials available. We have evaluated the ratios for a number of possible commercial materials. We find that copper and aluminum rank top. The ratio for copper is calculated to be 1.5*10^-4 kgm2/S and for aluminum is 0.76*10^-4 kgm2/S. Therefore, we plan to use aluminum as the material for our rotating disk in the prototype in order to achieve better brake performance.[13]

NOTE:-

1. THE SELECTION OF MATERIAL IS ALUMINUM .
2. THICKNESS OF DISK 4.3 MM.
3. WEIGHT = 550 GM
4. DIAMETER OF PLATE = 230MM/23CM.

1. **Stator Air Gap**

2. Values of observationsare results for this experimental set are presented in Table 1. The varied observations are highlighted for clarity. When the Eddy current Braking is – On then the co-officient damping is decreased when air gap is increases. The observation for good braking strength with air gaps up to 2.5 Milimeters.

3. The built-in frictional damping of the physical prototype was determined by removing the stator magnets in order to eliminate any eddy current effects. This value was found to be small compared to the damping in the ECB-ON case, but significant in the ECB-OFF case. Further, frictional damping will be eliminated in the final design by use of roller bearings instead of plain bearings.[13]

Quantity of Stator Magnets, *Q*	Magnetic Array Radius, *R* (mm)	Phase Angle, θ (degrees)	Air Gap, *s* (mm)	Weight, *W* (N)
	8 1	***1 0***	***0 . 2***	***5 1 . 2 1 5 2***
	8 1	***1 0***	***0 . 2***	***5 1 . 2 1 5 2***
	8 1	***1 0***	***0 . 2***	***5 1 . 2 1 5 2***
	8 1	***1 0***	***0 . 2***	***5 1 . 2 1 5 2***
	8 1	***1 0***	***0 . 2***	***5 1 . 2 1 5 2***
	8 1	***1 0***	***0 . 2***	***5 1 . 2 1 5 2***
	8 1	***1 0***	***0 . 2***	***5 1 . 2 1 5 2***
	8 1	***1 0***	***0 . 2***	***5 1 . 2 1 5 2***

Rotor Disc Thickness

The thickness of the rotor disc, *d*, must also be optimized in order to minimize the time constant, τ and minimize the disc's moment of inertia, *I*. The inertia of the disc is linearly proportional to the thickness , so minimizing the disk radius minimizes the disk inertia. The time constant does not depend on the disc thickness . Thus, the optimization problem reduces to minimizing disc thickness while maintaining enough structural rigidity.[13]

4.1Control Design

Stator Air Gap Values of parameters and damping coefficient results for this experimental set are presented in Table 3. The varied parameter is highlighted for clarity. The coefficient of damping of the ECB-ON decreases as the air gap increases The physical prototype demonstrated good braking strength with air gaps up[13] to 2.5mm.

S . N o	Moment Arm, *r* (m)	Time (s)	Torque, τ (Nm)	Rotor Angular Velocity, ω (rad/s)
1	0 . 0 4	3 3	0 . 7 0 6	0 . 0 2 1 3
2	0 . 0 4	2 6	0 . 7 0 6	0 . 0 2 7 1
3	0 . 0 4	2 0	0 . 7 0 6	0 . 0 3 6 1
4	0 . 0 4	1 5	0 . 7 0 6	0 . 0 4 8 1
5	0 . 0 4	7	0 . 7 0 6	0 . 1 0 3 2

4.2Formula

4. Calculation of Magnetic Field

5. Calculation of Current Density

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$J = \sigma(R\dot{\theta} \times B)$

6. Calculation of Braking Torque

7. **4.4Result & Calculation**

Calculation :- Calculation of megnetic field on plate = B

$^{\mu}{}_{0}$ For electrical conductivity=4 * 10^{-7}

n (no. of turns) = 700

I = 4 Amp.

L_g (Air Gap) = $2.5/10^{-3}$

$$B = \frac{\mu_0 ni}{L_g}$$

$$= \frac{4\pi \times 700 \times 16 \times 4 \times 10^{-3}}{2.5 \times 10^{7}}$$

= 22.51 T

Current Density

$J = \sigma (R\theta \times B)$

$J = 2.7 (0.0025 \times 0.0213 \times 2.2518\times10^{-5})$

$J = 3.2375\times10^{-9}$

Calculation of Power Dissipation

$P_d = \sigma \times R^2 \times S \times d \times \theta^2 \times B^2$

$= 2.7 \times 0.00000625 \times 0.0004523 \times 0.0043 \times 0.004536 \times (2.2518\times10^{-5})^2$

Calculation of Braking Torque

$T_b = P_d / \theta^{'}$

$= 3.5439\times10^{-22}$

Or

$T_b = \sigma \times R^2 \times S \times d \times \theta^{'} (\mu_0 n / L_g) i^2$

$= 2.7 \times 0.00000625 \times 0.0004523 \times 0.0043 \times 0.0213 \times 506.97$

$\mathbf{T_b = 7.604\times10^2}$ **N-m**

8. **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. Adjustable brake force.
7. High brake force at high speeds.
8. No contacts,therefore no wear and tear.
9. No noise or smell during braking.
10. Low maintenance and light weight.**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.**[14**

3.It can’t be used in low speed vehicle or vehicle running at low speed.

5 Conclusion

From this study, it can be concluded that thicker disc will generate high torque which will approach the motor torque in order to stop the disc rotation which in this study disc of 4.3 mm is better than 5 or 6 mm of thickness. Smaller air-gap will produce high braking torque required to stop and give better performance to the electromagnetic braking which air-gap of 2.5 mm shows the best result compared to 3 mm and 3.5 mm gap. Aluminum which shows great performance of braking torque produced in this study.

5.2Applications of Eddy Current Brakes

Eddy current braking is a state of the art braking technology that has both economic and risk management advantages. This unique braking system takes the simple function of magnetic and non-magnetic forces and turns it into a high tech masterpiece. Using these forces as a braking mechanism stems from the purposeful generation of eddy currents in order to slow a movement. Eddy currents are formed when a conductor moves through a magnetic field, which generates opposing forces that swirl within the conductor. This reaction between forces provides the perfect conditions for smooth deceleration. If you’re interested in reading more about the science behind eddy current technology, then you can click here to learn more. Here are 5 familiar applications of the eddy current brake.[15]

1. Gym Equipment
2. Industrial Equipment
3. Recreation Equipment
4. Rides and Roller Coasters
5. High Speed Electric Trains

.5.3Future Scope

The future of braking systems focuses on making the process of braking more energy efficient . Here we discuss some methods , Aerodynamic braking , regenerative braking and Contactless Braking System. While aerodynamic braking is aircraft technology which is now being used in some supercars ,whileregenerative braking is the method of recovering the heat thatis lost from brake pads. Contactless braking is the technology that aims to replace direct use of pneumatic , mechanical, hydraulic systems by electronics system, it is a part of a larger drive by wire technology revolution.

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