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Experimental investigation of Eddy current based braking system

Padhye Mandar S

Assistant Professor, Mechanical Engineering, Finolex Academy of Management and Technology,Ratnagiri. Maharashtra, India

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Abstract - *Brakes are responsible for stopping any mechanical system. The brake is very crucial part of any automobile or any moving system. It was observed that adhesive wear and thermal degradation are the main sources of ageing or fading of mechanical friction brakes. The degradation of friction surfaces ultimately results in less braking and reduced safety. Also there are chances of leakage of brake fluid in conventional hydraulic brakes which results into brake failure. In order to overcome these limitations, Eddy current generation phenomenon can be implemented in the braking system. Eddy currents gets developed when a conducting and non-ferromagnetic material is moved in the constant magnetic field and oppose the motion of the conductor. In this kind of brakes braking effect depends on the speed of a conductor. An experimental set up is developed to study braking system using eddy current. It was found that braking torque increases with increase in magnetic field and is directly proportional to the angular velocity of the wheel. System stopping time decreases as the current value goes on increasing. At higher speeds stopping time reduces drastically. Reduction in RPM from initial speed is higher at higher speed. For higher values of current braking torque increases drastically. Maximum value of braking torque achieved was about -0.2054 N-m at 1200 RPM when current was 5.23 Amp.*

Key Words: **Braking system, Eddy current, Magnetic field, Braking torque, solenoid.**

1.INTRODUCTION

A brake is a mechanical device which resists motion, slowing or stopping a moving object or preventing its motion. Brakes are generally applied to rotating axles or wheels. Role of mechanical braking or frictional braking is very crucial in industries and automobile sectors. Mechanical braking system include drum brakes, disc brakes, hydraulic brakes etc. In all the types the braking is dependent on the frictional force between mating surfaces Friction brakes convert the kinetic energy of a moving body into heat and dissipate it into the atmosphere. In general, there are no coolants to absorb this heat so all heat is given out by natural or forced convection only. This is one of the reasons for degradation of the brakes and the brake fade effect.

In automobiles the wheels are the main components which give motion to the vehicle and then keeps it in that state. So for stopping the vehicle the motion of the wheels is inhibited and the vehicle is made to stop. It is very essential to reduce the speed of vehicle during turning or when some object comes into the path of vehicle. The braking is required to be uniform not sudden in order to avoid skidding of the vehicle. Antilock Braking System was developed for the same soul reason. The brakes have utmost importance when safety of vehicle is considered. They are designed to stop the vehicle in a shortest possible distance without locking the wheels.

Existing mechanical friction brakes have wide applications in every field of motion and power absorption. Many of the ordinary brakes, which are being used now a days to stop the vehicle by means of mechanical friction. This causes wear and tear of the frictional surface. Also at higher speed of the vehicle, the frictional brake cannot provide sufficient braking torque. Hydraulic braking system can also fail due to leakage of brake fluid. The heat generation and frictional wear results into reduction in braking effect with time and compromisation with safety.

In order to make frictionless brakes to inhibit motion of wheel Eddy currents can be used for providing resistance to motion. An eddy current brake, like a conventional friction brake, is used to slow or stop a moving object by dissipating its kinetic energy as heat. In this process magnetic field acts as actuator for production of eddy currents in case of Eddy current brakes. However, unlike electro-mechanical brakes, in which the drag force is used to stop the moving object is provided by friction between two surfaces pressed together, in an eddy current brake the resistive force is an electromagnetic force between a magnet and a nearby conductive object in relative motion. By this way we can use one smart option as an innovative application.

As per the Faraday's law of induction conductive surface moving past a stationary magnet will have circular electric currents called eddy currents induced in it. By Lenz's law, the circulating currents will create their own magnetic field which opposes the magnetic field developed by stationary magnet. Therefor moving conductor will experience a resistive force from the magnet that opposes its motion, which is proportional to its velocity. The electrical energy of the eddy currents is dissipated as heat due to the electrical resistance of the conductor.

The objective of the current study is to investigate the braking system based on eddy current braking. An experimental set up is developed to test the eddy current braking system. 6 Solenoids are used which are going to act as permanent magnet. Disk made up of aluminium acts as brake disk where eddy currents are developed. Braking effect is analysed at different speed of rotation and also by varying magnetic field intensity by changing current flowing through the solenoids. Operational characteristics and performance test results are explained below.

2. Literature Review

Qian M. and KachrooP. [1] worked on modeling and control of electromagnetic brakes for enhanced braking capabilities for automated highway systems. In his study he prepared mathematical simulation for robust sliding mode controller to maintain wheel slip. Simulation show that the design is capable of controlling the vehicle with parameter deviations and disturbances. Sodano H. A. [2] used the eddy current excitation method in vibration testing. He revealed that system functions by the generating a force which is proportional to a velocity between a magnet and structure. Razmayslov V. A. et. al.[3] gave methods to calculate eddy current brake force in railway cart retarder. They further explained how the poles of the magnetic field & how poles of the coil should be placed to get an efficient braking. Adly A. A. and v Abd-El-Hafiz S.K. [4] have worked on speed range based optimization of non linear electromagnetic brakes. They have various outcomes on the non linearity of the braking using electromagnetic coil. So this factor should be considered while designing the eddy current brake.

Ren H. et. al. [5] have worked on the brake performance analysis of ABS for eddy current brakes and electro-hydraulic hybrid brakes. They concluded that the contactless braking gives less abrasion, noise, friction, dust & risk of thermal failure which is less as compared to conventional braking system. Lezhi Y. et. al.[6] developed permanent magnet retarder. They concluded that an eddy current retarder generates much heat when it continuously works which may lead to serious decline in braking torque. They suggested about how heat dissipation could be minimized in design of eddy current brakes. Jae S. C. et. al.[7] put their focus on the significance of microstructure in design of eddy current brakes. They revealed that a stacked composite composed of a thin magnetic membrane which is sandwiched between paramagnetic material is proposed to enhance braking force. Anwar S. and Stevenson R. C . 8] have studied about torque characteristics for optimal design of copper layered eddy current brakes. They suggest that the braking torque is directly proportional to eddy currents produced and eddy currents produced is directly proportional to rotational speed. Padhye M. [9] have carried out experimentation using eddy current and cocluded that braking effect is proportional to angular velocity of wheel and it is necessary to combine it with conventional brakes for low speed application. Liu C.Y. et. al.[10] took the efforts to use eddy current brakes in automobiles. They came up with conclusion that the brake torque drops approximately 40% after the temperature in rotor reaches its maximum value. Hence certain actions must be taken to limit the temperature rise. Gonzalez M. I. [11] has performed experiments with eddy current brakes. His study suggests that the material used for the disc should have less resistivity value as it is inversely proportional to braking torque. So Aluminium, Copper, Brass are the materials which could be used for making disc.

3. Design and development of Eddy current braking system

3.1 Concept of Eddy Current

A magnetic eddy current brake capitalizes on the magnetic field anomaly called an 'eddy current'. The eddy current around a magnetic field create their own swirling effects and their own magnetic field. Those eddy currents can be used to create a braking effect by using the resistance of these eddy currents to oppose the rotational motion of the wheel.

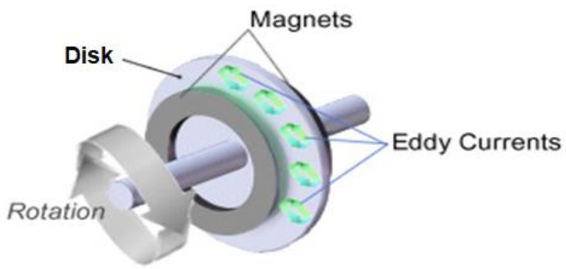

Fig – 1: Concept of Eddy Current

A conductive surface having relative motion with respect to stationary magnet will have circular electric currents called eddy currents induced in it by the magnetic field as shown in Fig. 1. These circulating currents will generate their own magnetic field opposite to the field of stationary magnet. Due to this the moving conductor experiences a drag force from the magnet that opposes its motion. The electrical energy of the eddy currents is dissipated as heat due to the electrical resistance of the conductor.

The eddy currents that are generated are normal to the direction of rotation of disk. In case of eddy current brakes, the metal disk is exposed to a magnetic field from an electromagnet, creating eddy currents in the disk. The eddy currents meet resistance as charges flow through the disk, and this acts to slow down the rotation of the disk. Faster the disk is spinning the stronger the effect, which results in extremely smooth transitions between resistance levels.

3.2 Experimental setup

Whole experimental set up is mounted on rigid base frame.Base frame is prepared by MS C-section of size 2cm × 2cm. In order to provide motion electric motor is used. 0.5 Hp DC motor is used having rated speed of 1440 rpm. DC motor speed is easily controlled by monitoring the input voltage supplied to motor through dimmerstat. Motor is coupled to input shaft by means of small dog clutch. Mild steel disc gives a moment of inertia to the assembly. The disc has diameter 300 mm and thickness of 15 mm. Aluminium disk of 260 mm diameter and 15 mm thickness is used as brake disk for development of eddy current. Digital tachometer was used to measure rotating speed of shaft.Experimental set up is as shown in Fig. 2.

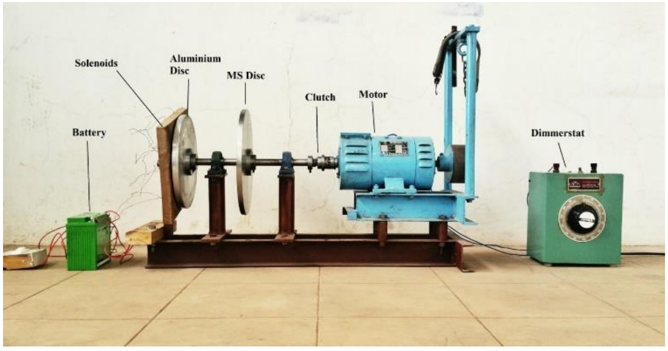

Fig - 2 : Experimental Setup

6 solenoids each made by wounding 260 turns of insulated copper wire on milld stel bar acts as permanent magnet. Wire used for solenoid is of gauge 22. Mild steel bar is used as core for solenoid is having 1.4cm diameter and 3 cm length. Wooden board is used for mounting 6 solenoids as shown in Fig 3. 12V battery and ON/OFF switch is used to power solenoid coil.

Fig - 3: Solenoid coil

4. Result and Discussion

Initially DC motor speed was calibrated with different input voltages through dimmerstat. Then the solenoids are kept at distance of 5mm from the Aluminium plate. Battery circuit is connected to power solenoid coil. Assembly was driven with the help of motor at different speeds of rotation. When required speed was reached the motor was switched off and the assembly was allowed to rotate free. The magnetic field was applied at same moment. The time taken by assembly to come to rest was measured using stopwatch. The reduction in speed for initial short period was also measured in order to find out instantaneous retardation. From the obtained retardation time period deceleration was calculated and using the value of retardation the braking torque was estimated. During experimentation, observations were tabulated and analysed.

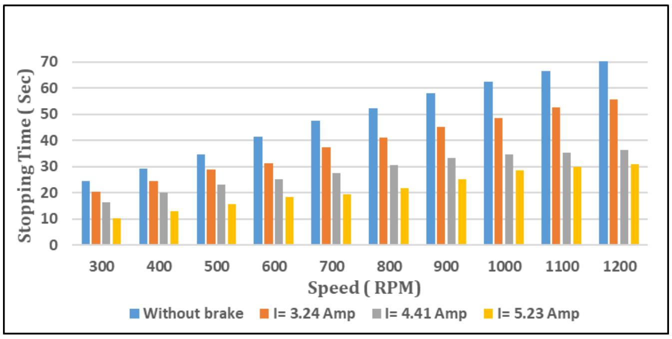

Chart -1: Stopping time v/s speed

Variation of stopping time with speed and current is shown in chart 1. Stopping time decreases as current through solenoid coil increases, this reduction in stopping time is increasing with increase in speed. Effect of speed and current on braking torque is given by chart 2. Braking torque is very low at low speed which is drawback however, appreciable increase in braking torque is observed at higher speed and for a current value 5.23 Amp.

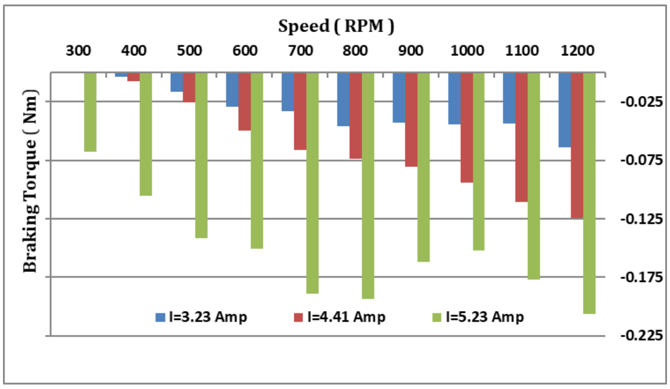

Chart -2: Braking torque v/s speed

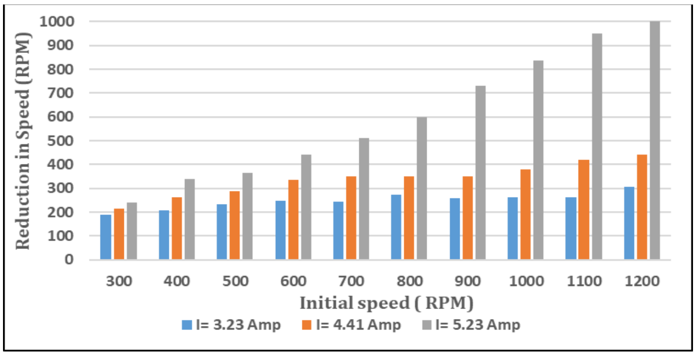

Chart -3: Reduction in speed v/s Initial speed

Reduction in speed of the assembly due to application of brake from initial speed after 10 sec. is recorded. Charts 3 shows that almost 80% speed reduction takes place in just

10 sec. At higher speed this reduction increases further which highlightes the effectiveness of eddy current braking at higher speed.

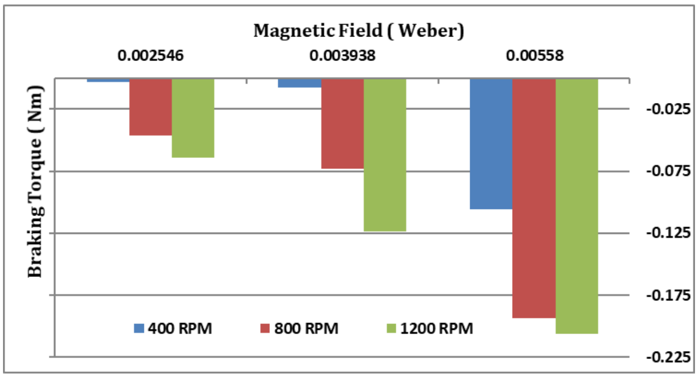

Chart -4: Braking torque v/s Magnetic field

Effect of magnetic field developed by the solenoid on braking torque is shown in Chart 4. It is obvious that with increase in magnetic field braking torque increases and braking torque is very low at low speed. At a speed of 1200 RPM with magnetic field of 0.00558 weber braking torue is -0.2064 Nm. This clearly indicates that eddy current braking is effective for high speed application.

5. CONCLUSIONS

In the present work an innovative idea of implementing eddy current brakes is discussed and same is analyzed through experimentation. Experimental set up consisting aluminium disk and 6 solenoids is used to study eddy current braking effect. Effect of speed and magnetic field intensity on braking torque and stopping time is investigated. Eddy current braking observed to be more effective at higher speed as about 80% of the speed reduction is obtained within 10 sec. Further, braking torque is directly proportional to speed and magnetic field intensity. Braking torque of -0.2054 Nm is obtained at a speed of 1200 RPM with magnetic field of 0.00558 weber.

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BIOGRAPHIES

Mandar S. Padhye
Assistant Professor
Mechanical Engg. Department
Finolex Academy of Management and Technology, Ratnagiri, India.