A REVIEW ON EDDY CURRENT BRAKING SYSTEM

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Abstract : When operating any machinery the basic safety system that is put into use is the braking system. The transformation of kinetic energy to heat energy due to formation of friction forms the basic design of a braking system. The friction is developed by the rubbing between two surfaces. There are several problems posed by these. To overcome these problems, a magnetic brake has been developed. The concept involves magnets that generate eddy currents which are conducted by the discs. This brake has no wear as it is contactless, it is less responsive to temperature than the commonly used frictional brakes, it also has a quick and simple actuation, and has a reduced response to wheel-locking. This is obtained by the creation of a braking force due to a magnetic field across the moving conductor that induces eddy currents which creates a perpendicular magnetic field. The wide range of applications of these brakes firmly infer the viability and simplicity of this activity. The braking Power can be changed to control considerably higher torque loads by changing the number of turns of the coil or by even increasing the voltage. This gives flexibility of operation of the system and makes it reliable also in changing load patterns

Keywords – *Aluminum, Braking, Copper, Eddy Current, Electromagnetic*

I. INTRODUCTION

Types Of E.C.B

Various types of Eddy Current Braking Systems are as follows.

Circular Eddy Current Brakes

Electromagnetic brakes are similar to electrical motors; non-magnetic metallic discs which are the rotors that are connected to a rotating coil and this creates a magnetic field between the coil and the rotor that in turn results in formation of resistance which is used to produce electric current or heat. With the passage of current through electromagnets a braking force is created. When a metal moves through a magnetic field created by the electromagnets an eddy current is formed on the discs, that generate a magnetic field in the opposite direction that resists the motion of the discs. This opposing force produced creates a breaking action on the discs.

Linear Eddy Current Brakes

Linear type of eddy current brakes comprises of a magnetic yoke with electrical coils placed along the Railway track, which are magnetized as alternating magnetic poles. There is a constant air gap maintained of about 7mm between the rails and the magnets.

A non stationary magnetic field is created at the head of the rail as the magnet moves along the rails, this in turn generates electrical tension that forms eddy currents. The so formed eddy currents disrupt the magnetic flux so as to divert the magnetic forces in opposite directions of its movement. Thus generating a horizontal force component that neutralize the movement of the magnets.

Effect of various parameters on Eddy Current Brakes:

The design of an Eddy Current Brake was reduced to five optimization problems which are discussed in the following sections.

Rotor Disc Clearance

The rotor disc clearance must be optimized to maximize braking torque when the brake is on and to increase reversibility when the brake is off. This optimization will be largely conducted experimentally.

Rotor Disc Thickness

The thickness of the rotor cycle, d must be optimized to limit the time constant, τ and to minimize the disc's moment of inertia, I. The time consistent does not depend on the plate thickness. The improvement issue decreases to limiting the disc thickness while maintaining enough structural rigidity.

Induced Current

By Faraday's law the current induced is directly responsible for the strength of the magnetic field. This in turn raises the effort applied in braking the disc. The current value must be varied along a range of value to get an optimal range of operation. As per Ohm's Law the increase in resistance of a circuit leads to the decrease in the current supply.

Electromagnet Turns

As per Lorentz's principle the attractive field generated by an electromagnet is legitimately relative to the quantity of turns. This helps in developing a relation between the braking torque and the quantity of turns in the curl. The diameter of the wire is kept constant and can be calculated by the amount of heat dissipated by the electric heating effect.

II. LITERATURE REVIEW

The following are summaries of research papers and patents cited for the project

An experiment was conducted using permanent magnets as a radial disc to create an array of magnetic fields, when the brake is applied this field is brought closer to a ferromagnetic wheel which causes the braking action. From the experiment conducted it was concluded that the disadvantages of permanent magnets was their high leakage of flux and the inefficiency of mechanism to apply the brakes. He suggested the use of electro magnets[1].

A researcher listed the use of permanent magnets in Eddy Current braking mechanisms. The Application of a radial arrangement of permanent type of magnets in pairs in order to create a set of interchanging North Pole and South Pole. A magnetic tube rotates within this arrangement and as brake is applied the flux from both magnets interfere and create a braking force. The two possible positions of the tubes are (1) the polarities of magnets facing each other are same (2) the polarities are different[2].

A researcher designed and simulated the key characteristics on a scaled model of permanent magnet electrodynamic brakes. The model employs the use of Neodymium magnets and generates design guidelines and scaling laws for magnetic, cost and mechanical scaling of the brakes. A comparison of braking torque with variation in air gap and magnetic flux density was carried out and graph was plotted. The results collected were compared with maglev braking system and linear induction motor and good results were found for Permanent Magnets Brakes at an analytical and test point of view[3].

A researcher worked with use of permanent magnet Linear brakes and is more particularly directed towards eddy current brake systems for vehicles. It was found that there is no frictional wear as there is no contact made with the rail when braking so Linear eddy current brakes would be a better replacement for frictional brakes[4].

A researcher designed a contactless eddy Current brake for vehicles which introduces a magnetic field to a copper disc brake, thus inducing an eddy current in the disc, and applies a contactless braking torque to the disc because of a relative action between the eddy current and the magnetic field formed by an electric magnet ,which provides a slip ratio. A couple of cores are arranged around the edge of a brake disc and are spaced apart from one another at a right angles in the brake. To form an electrical magnet a coil is wound on each core . Around the axle a speed sensor is attached, therefore detecting the revolutions of the wheel. A control unit is used to analyse a DC or AC control current in correspondence to a speed signal output from the sensor, consequently providing an suitable output control current value to the coils. The coils of the cores receive a control current that is provided by an amplifier of current from a control unit or brake pedal. At high speeds DC current is supplied to the coils by the control unit while AC current is supplied to the coils when the vehicle moves at lower speeds or is halted on a slope. In this situation the DC current is variable with respect to a pedalling force, while the AC current is variable in the frequency with respect to the pedalling force[5].

A researcher proposed a contactless method by using magnetic drag force in order to design the braking systems to make improvements over the existent conventional or normal frictional braking systems. This project established that the air gap has a momentous effect on the magnetic flux density from FEM model. The tentative exploration shows good correlation between designed and measured values of magnetic flux density[6].

A researcher proposed that with the relative motion between a magnet and a conductor there would be a formation of Eddy current. The current induces a reverse magnetic Flux which leads to the deceleration of movement[7].

An experiment was conducted to study the action of three varying types of materials like aluminium, zinc and copper to be used as brake discs. On experimenting with the various materials it was concluded that aluminium is the best material since it reacted better and quicker as compared to the other two materials. The findings of this experiment also showed that the increment of current into the electromagnets would increase the drag force which in turn slowed down the material discs more effectively[8].

Another researcher focused on two series of aluminium namely Al6061 and Al7075 as the brake disc, and a comparison was carried out between both the series of aluminium with a few varied parameters like air gap, number of turns and brake disc thickness. From the comparison it was concluded that Al6061 was the best material to be selected as the brake disc material since it has a higher electrical conductivity compared to Al7075 which generated the influence of greater braking torque[9].

A researcher considered a metal disc of thickness (s), conductivity (σ) and width (2d) and compiled mathematical models using Maxwell equations and developed differential equations of the magnetic field with acceptable accuracy. He quotes that the Ritz process has high computational requirements but is very effective and can be applied to boundary value problems of greater complexity compared to the one solved in the paper. Namely the field intensity is obtained as a finite series and its square appears in the formula of loss, thus a two variable numerical integration is necessary[10].

A comparative study was conducted between three mathematical models namely Smythe's model, Schieber's model and Wouterse's model. A brief description of each model with their advantages and limitations were highlighted in this report. These models were simulated with varying wheel slip values, different road conditions and magnetic flux within an estimate error of 1%[11].

Schieber's Approach

A experiment was conducted where a rotating disc was placed between an electromagnetic pole pieces having a significant air gap between the disc and pole pieces. Due to a specific distance of air gap a better experimental curves were obtained resulting in an effective braking . From this experiment a braking torque equation was found.

Smythe's Approach

A experiment was conducted wherein a thin conducting disc rotates between the electromagnet or permanent magnet pole pieces. From the comparison of experimental curves it was found that this model was good at low speeds but for high speeds , braking torque decreases at a faster rate.

Wouterse Approach

Based on Schieber's and Smythe's approach, Wouterse tried to find the overall solution for the torque in both the high-speed region and the low speed region. The Following were the results obtained:-

1. At very low speeds, the field differs only slightly from the field at zero speed.
2. At the speed at which the maximum dragging force is exerted, the mean induction under the pole is already significantly less than B0.
3. At higher speeds, the magnetic induction tends to further decrease

An experiment was conducted for the working of ECB as a speed retarder. In this electromagnets were positioned radially with a spacing in between and the switching was controlled by operating signal. A detailed experimental setup of the operation of the signal supplied to the device was given for the performance of braking action[12] .

A researcher presented the statistical analysis used to define optimized parameter for Electromagnetic braking. Parameters such as air gap, no of electromagnet turns, current induced and disc thickness were varied and their effect in the reduction of RPM were calculated. A fully nested ANOVA was used to determine the two most significant factors in the Eddy Current Braking System, then two-way ANOVA was applied to clarify the most significant factors to be used as the controlling parameters in this study[13].

A Mathematical model was built for the purpose of calculation of the torque of the eddy current brake system and hydraulic brake system and to analyse the braking force distribution between the two. Experiments on dry and wet asphalt road were conducted and the result indicated that the response of hybrid brake system was better than that of traditional hydraulic braking system which enhanced about 0.3 s more than hydraulic braking system[14].

The use of an eddy current braking system was later integrated into wind turbines. The mechanism was specifically made for its use in wind turbine generation system where it was positioned within the generator. The blower and the eddy current brake are used in such a way that the rotating plate of the blower works as the rotating plate on the eddy current braking system[15].

A study was conducted to show the behaviour caused by the vibration generated in a bearing cage structure when a7 electromagnetic braking is applied . This study showed the analysis of behaviour caused by vibrations . It was seen that smaller air gap produced a high magnetic flux which increased the damping force generated by the bearing cage structure, it also showed that air gap has a distinguished effect on the structures vibration when electromagnetic braking was applied[16].

A researcher concluded that when the gap between two plates goes on increasing the braking force between the two plates also reduces and hence the speed of wind turbine shaft increases. It was concluded that the failure of turbine at high speed can be avoided by maintaining a suitable gap between plates according to the speed requirement and available wind intensity at that point[17].

III. CONCLUSION

The various papers surveyed have tested the operating parameters for the increased optimization of ECB. Many have laid the guidelines for research and implementation of ECB for various industrial and automotive applications.

Max Baermann's patent highlights the advantages of electromagnets over permanent Magnets. P. Hanyecz provides mathematical models for calculation of the braking torque. P. Kachroo provides validation of those mathematical models. Kyi Hwan Park and Kap Jin Lee issued a patent in which they designed an eddy current braking system for automobiles. M.Z. Baharom and G. Priyandoko compared aluminium, copper and zinc for the best disc material in which they concluded that aluminium is the best disc material. An analysis of variance of various parameters such as: air gap, coil turns, disc thickness, initial speed rotation, etc. was performed.

From above papers, the various parameters of the Eddy Current Brake were decided. Based on this research the use of aluminium as disc material and the use of mathematical models for calculation of braking torque were justified.

The objective of this study was to research the various papers previously published by the respective researchers and compare the various studies to find the optimal configuration for an Eddy Current Brake. Different arrangements of magnets and magnets of high flux density and their effects are discussed. A magnet of high magnetic flux density can be used to reduce braking time. Magnets can be arranged at different positions around the disc in a radial arrangement to get effective braking torque distribution.

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