Identification and Analysis of different parameters for Eddy Current Braking System along with its applications

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Abstract— Eddy current braking has more advantages as compared to mechanical braking. This research showcases the mechanism behind Eddy current braking system, its torque-speed characteristics along with other structure parameters which affects its performance.

Keywords— air-gap length; torque-speed characteristics

I. INTRODUCTION

We know automobiles these days use mechanical or frictional brakes to provide braking. But these conventional frictional brakes have some certain drawbacks like low response time, wear and tear of rotor pads, weakening of braking torque due to elevated temperature. In the following research, multiple applications of Eddy current braking system have been discussed in correspondence to the dimensional factors affecting it.

II. EDDY CURRENT BRAKING SYSTEM IN BRIEF

The principle behind Eddy current braking system is solely based on Faraday’s law of Electromagnetic induction. As stated by Faraday, electromotive force is generated in a moving conductor when it is placed in a stationary magnetic field. The magnitude of this emf completely depends upon the speed of the moving conductor and the magnetic field strength. Now the Lenz’s law comes into picture. Because of which the sole cause behind the above phenomenon needs to be opposed i.e. the motion of the conductor. Basically, an Eddy current braking system has two parts. One is the stator and the other is rotor. Both are placed near each other. In case of disc type ECB when the brake is applied, the electromagnet is excited. As the disc rotates, it interacts with the field lines of the electromagnet, circulating currents are produced in the disc. Due to this circulating current another magnetic field is created which opposes the external field. This results in the braking action of an ECB.

III. APPLICATIONS OF EDDY CURRENT BRAKING SYSTEM

3.1. In Railways
Mostly ECBs are used in high speed trains as its very difficult to control the speed of such trains using normal frictional brakes. Moreover, ECBs cannot be used independently as they have a major drawback i.e. they can lower the speed up to a certain nominal value. When the speed of the train reduces below the nominal speed then the operation of the ECBS decreases significantly. To overcome this drawback, ECBs are used in conjunction with customary mechanical brakes. This method is called as brake blend.
The ECBS used in trains consists of two parts. First is the dc energized magnetic poles that are placed under the bogie in between the rails and the second is the control system which controls the amount the dc excitation required to produce the desired braking force. This control system is powered by the train’s power system.

One of the advantages of ECBS in this application is that it is independent of any contact between rails and wheels of the train. And one disadvantage is the heating of the rails as the kinetic energy of the train is converted into Eddy current loss in the rails.

Electrical conductivity of the rail, pole pitch, air gap length, pole width is some of the parameters which if varied can affect the braking performance of the ECBS.
3.2. In Automobiles

As we know frictional brakes use brake pads which leads to wearing of the vehicles. Not only that the brake debris created is also a potential risk to the environment as it may cause air pollution. To tackle this problem, Embedded Eddy current brakes are used in automobiles which even have faster reaction time than conventional frictional brakes. The disc or the rotator in this kind of brake is generally made up of Aluminum, but in this an extra layer of copper is used so that more current can be channeled through the disc. The above process can improve the produced braking torque without expending more power. Moreover, Aluminum do not get attracted to the external magnetic field and its conductivity is also very good. In eddy current brakes used in automobiles, the disc thickness is an important parameter because the braking torque produced is directly dependent on it. Along with disc thickness, one more factor can be taken into consideration i.e. temperature of the rotating disc. Because as the temperature of the disc rises the braking torque produced reduces.

3.3. In dampers

When currents flow in the moving conducting material due to induction, heat energy is released from the system and this entire system acts like a viscous damper.
One advantage of the Eddy current damping is that the damping is carried out without even making any contact with the structure unlike other methods of damping. Additionally, the structures using Eddy current damping are less likely to face any kind of degradation in performance. Lesser air gap results in more compelling damping by the Eddy current damper. Electromagnetic dampers based on permanent magnet are least sensitive to factors like ageing and temperature. An analysis has been done regarding the impact of thickness of conductor and number of magnetic poles on the execution of Eddy current dampers. Number of pole pairs and thickness of conductor are the major parameters that affects the exhibition of dampers. To achieve maximum torque, the number of poles should be varied for a fixed value of relative speed and conductor thickness.

3.4. As couplers
Basic functioning of Eddy current coupling (ECC) is to control the rotating speed of the load shaft by changing the magnitude of the magnetic field. ECC generally has two parts that are a conductive surface and a magnetic part. The conductive surface remains in contact with the motor and rotates with the speed of the motor. Coming to the magnetic portion which usually consists of electromagnets or permanent magnets is coupled to the load. ECC is again categorized into two types i.e. radial coupling and axial coupling.
In radial coupling, the use of cylindrical configuration results in positioning of the magnetic field to be at right angles to the shaft. Where as in axial coupling, two circular discs are separated by an air gap and the magnetic field is positioned along the axis of the shaft.
The magnitude or strength of the magnetic field as well as the current in the conductor depends on the difference in speed of the motor and the shaft. This is known as slip speed. Higher shaft torque is a result of higher slip speed. The torque keeps increasing with increasing slip speed but after a certain value it starts decreasing if slip speed is further increased. Moreover, there are many advantages of ECC like long service life, minimal noise during operation, and even with slight axial and angular misalignment they can perform satisfactorily.

IV. SIMULATION RESULTS
Simulations are carried out to study the impact of various parameters on the braking torque. As per the transportation laws, in many interstates, the speed of a business vehicle is constrained to 80 km/h. Simulations on the braking torque of ECB were done at the speed from 0 to 2500 rpm along with the applied current which was set from 0 to 20A, and the temperature of rotator circle was set from 0 to 800°C with the parameters utilized in the simulation were recorded in Table 1. Below is the torque equation on which the simulations are based.

\[
T_b = \pi r^2 a^2 d \left( \frac{N\mu_0}{l_d\rho_0^2 (1 + \alpha t)^2 + adr\omega\rho_0 (1 + \alpha t)} \right)^2 \cdot t^2 \omega.
\]
Table 1: Model parameters of ECB.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
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<td>mm</td>
</tr>
<tr>
<td>$d$</td>
<td>3</td>
<td>mm</td>
</tr>
<tr>
<td>$r$</td>
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<td>mm</td>
</tr>
<tr>
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<td>720</td>
<td>turns</td>
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<tr>
<td>$l_g$</td>
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<td>mm</td>
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<td>H/m</td>
</tr>
<tr>
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<td>$1.75 \times 10^{-8}$</td>
<td>$\Omega$m</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>$4.1 \times 10^{-3}$</td>
<td>$1^\circ$C</td>
</tr>
</tbody>
</table>

Fig. 6. Torque-speed property of ECB as per simulation

Fig. 7. Brake torque characteristics (rotating speed and applied current) as per specified parameters
Fig.8. Brake torque characteristics (rotating speed and applied current) as per specified parameters

V. CONCLUSION

Nowadays, Eddy current brakes are a common braking phenomenon that are used in heavy-duty vehicles as they can control high speeds with utmost stability. Eddy current brakes were initially originated to counter the problems faced by high-speed vehicles using frictional brakes like skidding, wear and tear, high maintenance costs, low reliability, etc. But later, the concept of Eddy current began widely popular for other applications like braking in automobiles, design of air bearing system in aircrafts, as dampers, couplers, etc. This is all due to the benefits Eddy current system has over other systems like eco-friendly, minimal maintenance costs, less noise and less wear and tear. Finally, after the establishment of Eddy current system, developments were made to improve their performance. This was done by varying the values of certain parameters on which the braking torque depends. This review was strictly based on parameter identification of ECBS along with the various applications related to it.

REFERENCES


