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Effects of Rotor Material on Eddy Current Brake Performance

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Abstract

The eddy current brake(ECB) is built by corresponding motion between a coil and a metallic material. The eddy current and coil creates reverse magnetic fields w produces braking force and dissipated heat due to resistivity of rotor material. In this paper, an ECB system is offered and different rotor materials are investigated with respect to generated braking torque.

Keywords: eddy current, magnetic field, braking torque,ECB.

1. INTRODUCTION

If a metallic object stays in a magnetic field, electric currents called as eddy currents are generated. They move in a circular path at the reverse of the polarity of the applied field. While applied magnetic field and eddy current's magnetic field interface, braking force occurs. Consequently, because of the metallic resistance, generated currents are dissipated as heat. The eddy current brake is built by corresponding motion between a coil and a metallic material. The eddy current and coil creates reverse magnetic fields with produces braking force and dissipated heat due to resistivity of rotor material.

Eddy current brakes/retardes are invastigated on this paper. ECB's are used widely on industry such as air bearing, vibration damping and heavy truck braking system. ECB on heavy trucks(magnetic retarders) are designed to decrease the load on friction based brakes. This system is also used on engine and chassis dynamometers.

ECB has many advantages such as contactless braking, silent operation, easy to imitate ABS. But the most distinctive advantage is having zero friction. With that feature, mechanic part lives increases dramatically. At the other hand, ECB braking capacity decreases at low speeds and also demagnization and skin effects at higher speeds which reduces braking performance.

There are many extensive studies on literature about ECB. Wiederick and et al offers a formula for force occurs on circular plate moving on a magnetic field between 10 and 150 mT and this formula brings a linear relationship between speed of plate and dragging force. Also that formula shows geometric and physical parameters affecting the dragging force parameters. Simeu and Georges gives a relationship between dragging force at low speeds and high speeds seperately. Gosline designed a haptic interface which includes an eddy current brake. Coils are placed so that it can work as linear damper. His study shows that it can be used also for robotic applications. Karakoc proposed time varying magnetic fields for eddy current brakes. Higher torque values achived with time varying magnetic field (Sinusodal and triangular) but with vibration problem. Sodano proposed a test rig which consists of two magnets and one cantilever beam. Eddy current braking effect used as a damper for residual vibration. He tested with one magnet and also two magnets and illustrates the performance difference. Magnet gap difference effect also investigated with respect to damping ratio.

2. MATERIAL METHOD

2.1 Material

2.1.1 Mechanical System

Authors Mechanical system of the experiment rig consist of a DC motor, its bed and rotor. DC motor is with reductor and suitable with high torque applications. The bed has a roller bearing between the body and DC motor, with that way, the generated torque by DC motor will not transferred to the body, only to torque sensor.

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Table 1 DC Motor Properties

Property	
Speed	200 rpm
Voltage	12 V
Power	18 W
Diameter	40 mm

Rotors have a 2-mm thickness and 100 mm diameter and connected to DC motor shaft. Three different are materials are used which are aluminum alloy steel, Chrome alloy steel and low carbon steel. Two identical coils are fixed to the ground and placed 45 mm outside of the center of rotor. Their properties are shown on table 1.

Table 2 ECB Properties

Property	
Rotor Diameter	100 mm
Rotor Thickness	2 mm
Air Gap	0.9 mm
Coil Current	3*2 A
Coil Diameter	26 mm

2.2.2 Load Cell

Figure Load cell is a transducer that is used to generate an electrical signal proportional to the force which is exerted on it. The used load cell consists of 4 straingages which their resistance changes with respect to deflection, are placed in the wheatstone bridge configuration. Output signal of the wheatstone bridge is amplified and filtered by opamp circuit show in figure. In our experiment, beam type loadcell with 500 gr of maximum capacity is used.

2.2.3 Microcontroller and Serial Communication Software(Teraterm)

PIC16F877A microcontroller is chosen for data collecting from load cell since it has 10 bit ADC and RS-232 serial communication hardware.

Teraterm software is used to connect the PC and microcontroller and establish a data transfer. Microcontroller calibrate the signal and converts it to N.cm. Teraterm is suitable for such systems which gathers data from USB ports and record it on an excel file.

2.1 Method

In this experiment rig,shaft speed is constant at 200 rpm and air gap between rotor and coils are 0.9 mm. A load cell is used as a torque sensor. The output of the load cell send to microcontroller. PC and microcontroller connects each other via USB and transfer torque data.

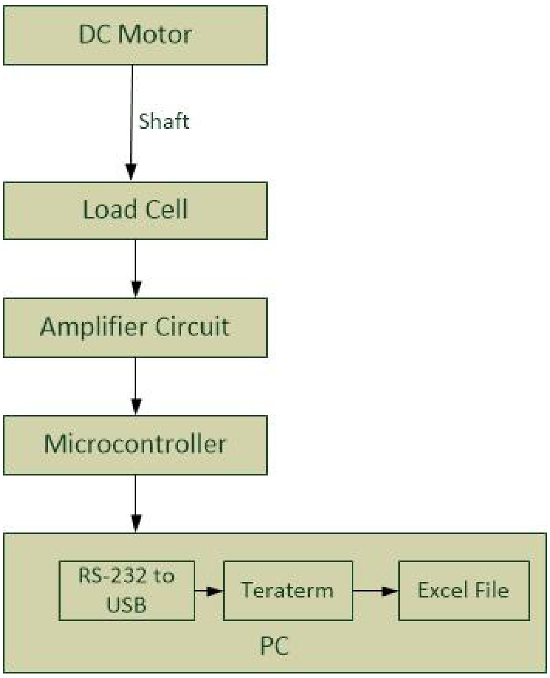

Figure 1. Flowchart of ECB

The braking torque is determined by placing known weighs on loadcell and measure the output signal by multimeter. The procedure is repeated 5 times to achieve sensitive calibration. Finally, the values are turned into torque values with microcontroller software. Sample time of the experiment was 0.1s.

3. RESULTS AND DISCUSSION

Maxwell's equations are used to state the electric and magnetic fields emerging from charge motion or simply current and evaluate how those fields change in time. Maxwell equations can be described as follows:

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t} \tag{1}$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J} + \frac{\partial \boldsymbol{D}}{\partial t} \tag{2}$$

$$\nabla . \boldsymbol{D} = \rho \tag{3}$$

$$\nabla . \boldsymbol{B} = 0 \tag{4}$$

where **E** is the electric field, **B** is the magnetic flux density, **H** is the magnetic field intensity, **J** is the current density, ρ is the charge density and **D** is the displacement flux density. From constitutive equations **H** and **D** can be written as follows:

$$\boldsymbol{H} = \frac{1}{\mu} \boldsymbol{B} \tag{5}$$

$$\mathbf{D} = \epsilon \mathbf{E} \tag{6}$$

where μ the magnetic permeability and ϵ is the electric permittivity of the medium. According to Faraday's Law (Eq.1) changing magnetic field induces electric field. In an ECB system; when a disk rotates, eddy currents are generated on the surface of the disk due to Faraday's Law. Hence we have an external magnetic field and electric field generated by eddy currents. According to the Lorentz force law a force is exerted on a charged particle moving with velocity v through a medium involved with a magnetic and an electric field. Using Lorentz force law the eddy currents can be given as follows: [5]

$$\boldsymbol{J} = \sigma \left(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B} \right)$$

Here σ is the conductivity of the rotating disk. Hence, changing in the conductivity of the disk can change the magnitude of generated eddy currents in the disk. E. Simeu and D. Georges [2] state that the magnitude of induced current density in the conductor is:

$$|\boldsymbol{J}| = \sigma\, R\, \dot{\theta} |\boldsymbol{B}|$$

where $\dot{\theta}$, σ, and R are the angular velocity, conductivity, and the effective radius of the material used, respectively. If we integrate the currents over the cylindrical volume of the disk the total power dissipated (P_d) is found as:

$$P_d = \frac{\pi \sigma}{4} D^2 d\, B^2 R^2 \dot{\theta}^2$$

where D and d are the diameter of the circle of the magnet pole and disk radius, respectively. The braking torque can be given as:

$$\tau_{brake} = \frac{\pi \sigma}{4} D^2 d\, B^2 R^2 \dot{\theta}^2$$

It is well known that conductivity (σ) is the reverse of resistivity (σ=ρ-1) and due to the resistivity of the material used, the induced eddy-current will dissipated into heat. Hence material selection of a disk prominently affects the braking torque of the ECB system. In this regard, we have used three different materials namely galvanized Zn steel (Zn-alloy), chromium alloy steel (Cr-alloy), and st35 steel. We have measured torque values in each 30 seconds and calculate average values presented in Fig.2. Calculated average torque values of Cr-alloy, Zn-alloy, and st35 steel are 0.077, 0.203 and 0.223 N.cm respectively. The conductivity of the elemental chromium is around 7.9x106 S/m which is quite lower than elemental iron and resistivity of Cr-alloy steel alloy is higher than st35 steel. Increasing in the resistivity means higher heat dissipation and lower brake torque. By the same manner, the small differences in the torque values for Zn-alloy and st35 steel can be attributed to small resistivity increases after galvanization process.

Fig.3. Average Torque values of the Cr-alloy, Zn-alloy, and st35 steel

4. CONCLUSION

An experiment rig is built and torque performance of different rotor materials on eddy current brake. These materials are low carbon steel, Cr alloy steel and Zinc galvanized steel. Experiments are done at 200 rpm with 0.9 mm air gap between rotor and coils. Results shows that Low carbon steel has the most generated torque and galvanized steel has the lowest generated torque.

REFERENCES

[1] Wiederick H. D., (1987), Magnetic braking Simple theory and experiment,American Association of Physics Teachers, 55(6), 500-502

[2] SIMEU E., GEORGES D., 1996, Modeling and control of an eddy current brake, Control Engineering Practice, 4(1), 19-26

[3] SADANO H., 2006, Improved Concept and Model of EddyCurrent Damper, Journal of VibrationandAcoustics, 128,295-302

[4] ANDREW H. ,GOSLİNE C., 2007, Eddy Current Brakes for Haptic Interfaces: Design, Identification, and Control, Transactıons On Mechatronics,13(6),669-677

[5] KARAKOC K., J. PARK E. *, SULEMAN A., 2008, Design considerations for an automotive magnetorheological brake, Mechatronics, 18(8), 434–447