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EDDY CURRENT BRAKE FOR FOR HIGH SPEED TRAIN

Analysis Of Eddy Current Brake

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Abstract —*An eddy current brake, like a conventional friction brake, is responsible for slowing an object, such as a train or a roller coaster. However, unlike electro-mechanical brakes, which apply mechanical pressure on two separate objects, eddy current brakes slow an object by creating eddy currents through electromagnetic induction which create resistance, and in turn either heat or electricity. When the primary magnetic field and the secondary conductor of the eddy current brakes has relative motion ,the eddy currents will appear in the conductor and the braking force will be produced by the interaction of the eddy currents and the primary magnetic field. Due to the internal resistance of the conductor, the eddy current will dissipate into heat and the force will vanish. The force is dependent on the velocity of the change in magnetic flux and resists the change in flux. The brakes based on this principle have been found in many applications. For example, vibration suppression, vehicle suspension systems, high speed train braking systems, transmission systems, haptic interfaces, space docking mechanisms, loading systems and so on.*

Keywords-*Braking force analysis, design method, eddy current brake, experimental study, hybrid excitation.*

I. INTRODUCTION

Many of the ordinary brakes, which are being used nowadays stop the vehicle by means of mechanical blocking. This causes skidding and wear and tear of the vehicle. And if the speed of the vehicle is very high, the brake cannot provide that much high braking force and it will cause problems. These drawbacks of ordinary brakes can be overcome by a simple and effective mechanism of braking system 'The eddy current brake'. It is an abrasion-free method for braking of vehicles including trains. It makes use of the opposing tendency of eddy current.

This is an electric braking system which works on the principle that eddy current produced in it opposes the driving torque. This opposing torque is used to brake the automobiles. Mainly this system is purely based on Faraday's laws of electromagnetic induction and Lenz's law. For operating this a control switch is provided on the steering column in a position for easy manual. The skidding and complexity of mechanical braking system can be minimized by this system. Also the wear and tear of the vehicles can be reduced.

Eddy current is the swirling current produced in a conductor, which is subjected to a change in magnetic field. Because of the tendency of eddy currents to oppose, eddy currents cause energy to be lost. More accurately, eddy currents transform more useful forms of energy such as kinetic energy into heat, which is much less useful. In many applications, the loss of useful energy is not particularly desirable. But there are some practical applications. Such an application is the eddy current brake.

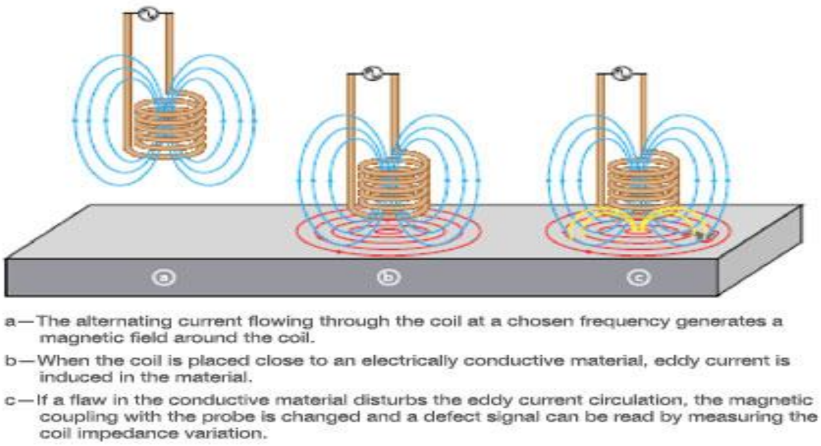


Figure 1. Eddy current produced in a conductor

The above Figure 1 shows how the eddy currents produced in conductor due to change in a magnetic field. In the eddy current brakes, the field source can be produced by winding systems or by permanent magnets. According to the difference of primary flux sources, the eddy current brakes could be divided into three types: electric excitation eddy current brakes, permanent magnet eddy current brakes, and hybrid excitation eddy current brakes. For the electric excitation eddy current brakes, the amplitude of air gap flux density could be adjustable, but the force density is low. Moreover, the additional power supply is needed as the dissipation is very large. Permanent magnet eddy current brakes allows for eliminating the electrical supply system to simplify the brake structure and has higher efficiency due to no power loss and high force density. Adversely, field modulation is not allowed . The hybrid excitation eddy current brakes combine advantages of the permanent magnet eddy current brakes and the electric excitation eddy current brakes. Therefore, the amplitude of air gap flux density is large, adjustable, and efficient.

II. PRINCIPLE OF OPERATION

Eddy current brake works according to Faraday's law of electromagnetic induction. According to this law, whenever a conductor cuts magnetic lines of forces, an emf is induced in the conductor, the magnitude of which is proportional to the strength of magnetic field and the speed of the conductor. If the conductor is a disc, there will be circulatory currents i.e. eddy currents in the disc. According to Lenz's law, the direction of the current is in such a way as to oppose the cause, i.e. movement of the disc.

A. CONSTRUCTION

The hybrid excitation linear eddy current brake includes a primary and the secondary. Its three dimensional view and top and front view are shown in Figure. 2, and Figure.3 respectively. The primary is consisted of excitation windings, primary core, and permanent magnets. The permanent magnets are polarized parallel to the direction of movement and they are placed in notches with alternate polarity. The direction of excitation current is opposite to that in the adjacent slot. The secondary comprises a low resistivity conductor plate on a back iron.

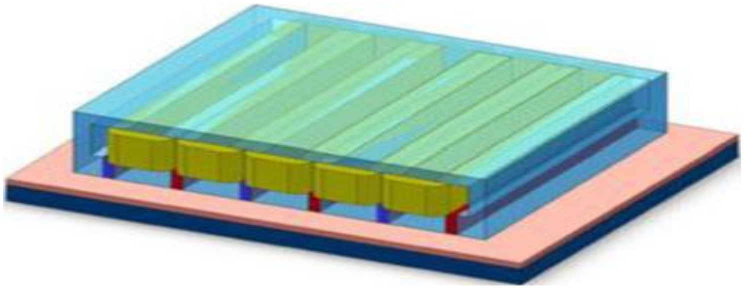


Figure 2. Three dimensional view of eddy current brake.

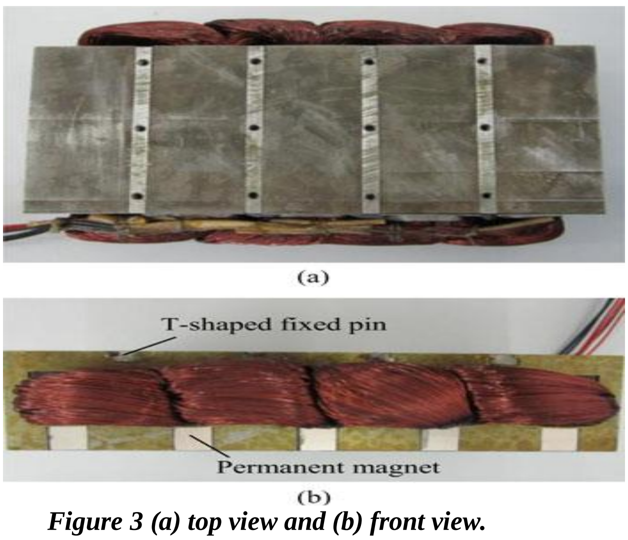


Figure 3 (a) top view and (b) front view.

B. WORKING

When the excitation windings without excitation current, the flux generated by the permanent magnets will form a magnetic short-circuit ring in the primary iron core, while it does not pass through the air gap, as shown in Figure.4. When excitation current flows through the excitation windings, there are two magnetic paths as shown in Figure.5 . One is produced by excitation windings; another is produced by permanent magnets. The two magnetic circuits are shunt-wound and are added in the air gap. The red line 1 represents the flux produced by permanent magnets, the yellow line 2 represents the flux produced by excitation windings, and the green line 3 represents the flux produced by permanent magnets and excitation windings.

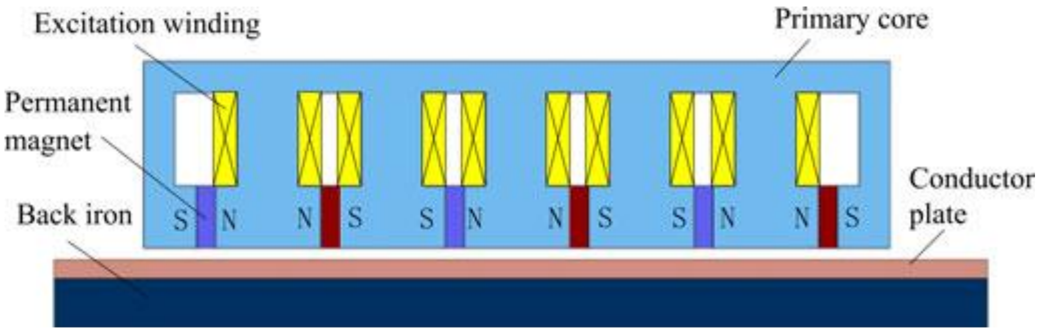
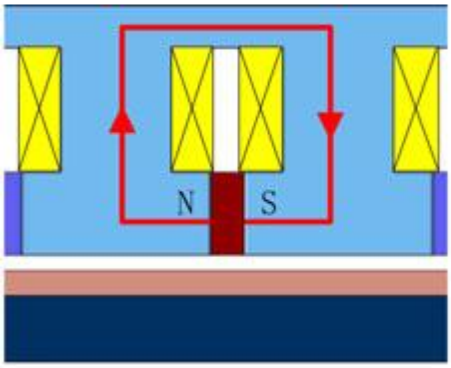
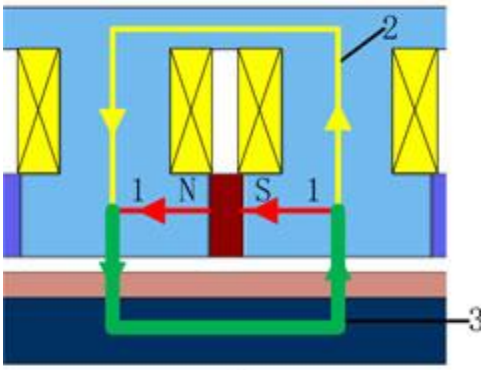


Figure 4. Side view of hybrid excitation linear eddy current brake.



(a)



(b)

Figure 5. Flux flow: (a) excitation windings without excitation current and (b) excitation windings with excitation current.

According to the law of electromagnetic induction, the relative movement of the primary and the secondary conductor plate causes eddy currents in the conductor plate. Due to the circulation of eddy currents, a magnetic field is generated that interacts with the magnetic flux generated by the permanent magnets and the excitation windings, which results in a braking force between the primary and the secondary conductor. The hybrid excitation linear eddy current brake proposed has some advantages as follows.

1) Using the hybrid excitation scheme has many advantages, such as controllability, energy saving, and large force density.

2) Using parallel magnetic path scheme, the flux of electric excitation does not pass through the permanent magnets. Therefore, the magnetic circuit is short and the additional air gap is small, and thus has high efficiency. Moreover, because of magnet congregate effect, the power density is high .

3) Using the multilayer conductor plate scheme, it has good conductivity and good permeability at the same time, therefore better braking performance can be achieved.

III. ADVANTAGES

Simple device structure and working principle, convenient control, High reliability, nonpolluting, high force density and,Low loss, Long life, Less strain to the operation, Less maintenance, Smooth retardation, which cuts down, the tire wears, Loading force can be continuously adjusted virtually eliminating the fluctuations of the loading force, therefore improving the accuracy of the system., No mechanical contact, small noise, high thermal stability, and vacuum compatibility ., The eddy current braking is very much useful for working without overheating.

III. APPLICATION

- For additional safety on long decants in mountain areas.
- For high speed passenger and goods vehicle eddy current brakes are best substitutes for ordinary brakes, which are being used nowadays in road vehicles even in trains, because of jerk free operation.
- It also be used to slow down the trolleys of faster roller coasters.
- In mountain areas where continuous braking force is needed , for a long time.

V. CONCLUSION

Eddy current brakes are the best choice when demands for reliability and safety are the highest. They work even in the toughest environmental conditions. Even the strike of lightning will not result in the loss of the braking force. Eddy current braking system is not popular nowa days. But we hope that the eddy current braking system which is simpler and more effective will take the place of the ordinary braking system and we can do expect it to be the norm one in few years of time.

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