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Performance of Eddy Current Retarder for Two Paramagnetic Moving Conducting Materials

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Abstract- Our work is related to the experimental study of working of eddy current retarder and how it is useful as a supplementary brake set i.e. they can be used in order to assist the primary brakes which increase the life span of primary brakes. Present Work is related to the study the behaviour of aluminium and copper when used as a brake disc in the experimental set up. We use permanent Magnets to fulfil our task. Our study observe that copper is better to be used as a retarding disc in ECR and this can be justified by experimental readings which are taken from optical tachometer, theoretical values and also by standard values.

Index Terms - Eddy current retarder; Supplementary brake set; Primary brakes; Aluminium; Copper; Permanent Magnets; Optical Tachometer

1. INTRODUCTION

Nowadays mainly disc and drum brake are used in automobiles but they have certain limitation like material wear tear, affect of friction material on environment, rust, noise, high thermal conductivity etc, due to this limitation including safety and environment regulations, there is a increasing demand for velocity retarders which can assist the primary friction brakes.

When these retarders are used as supplementary retarding equipment, the friction brakes can be used less frequently and therefore never reach higher temperatures. The brake lining can have a longer span and potential brake fade can be avoided.

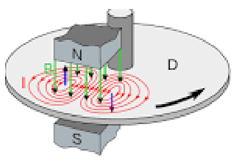
In some countries like Japan, Australia, North America and etc there is a growing trend of using this type of retarders for heavy duty vehicles. Among the several retarders, eddy current retarders are preferred to their fast response time and they require small installation space [1].

When magnetic flux linked with a metallic conductor changes, induced current are set up in a conductor in the form of closed loop called eddy current. They used as a braking system because this currents can be dissipated as a heat and the force will die out [2].

Eddy current retarder can be classified in to two types, drum and disk which are depending on the types of rotor shapes as used in friction brake. This type of retarder can also be classified in to permanent magnet and electromagnet, their difference depend upon the sources of flux supply. In permanent magnets we only use magnet nears the moving disc, which alters the polarity between adjacent magnets i.e. this type of retarder, require no external source. In case of electromagnet we controlled the magnetic flux by a coil current. The permanent magnet can be made electromagnet by winding a copper wire and supplying current to it. The use of electromagnet in ECR is better than permanent magnet because they are free from leakage [1].

2. THEORY

The eddy current retarder is basically based on Lenz's law, and it says that eddy current creates a magnetic field that opposes the magnetic that created it, and thus eddy currents react back on the source of the magnetic field. A nearby magnet will exert a drag force on a moving conducting surface which opposes its motion, due to the eddy current induced in the surface by a moving surface [2, 3]. This concept is used as a brake, which is used to stop the heavy rotating wheels when they are turned off.



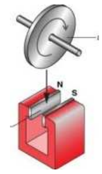


Figure1, Closed Loop Figure2, Conceptual Model
(Reference taken from Google Images)

In eddy current retarders, without using friction it transforms the kinetic energy of the moving body in to heat energy that is dissipated through the eddy current in the conductor. However the retarder will only work when there is relative motion between them [2, 4].

As by the definition, eddy current is develop in closed loop therefore the moving object should be solid or have such design so that there is no leakage of flux.

Consider an example, three types of discs of same material having dissimilarities in structure.

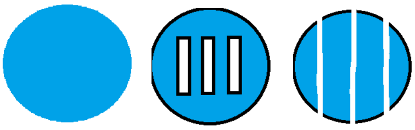


Figure3, three discs having different structure

We observe that 1st is solid in shape and therefore eddy current developed is in the form of closed loop and it's because of negligible leakage of magnetic flux. Thus in result we obtain maximum retarding performance.
In 2nd disc, there are air vents, so there will be some leakage of flux is observed. In result we obtain the retarding performance less than that of 1st disc
In 3rd disc there are vents but doesn't form the closed circular disc and there will be maximum leakage of flux is observed. Hence, there will be least or negligible retarding performance [5].

3. EXPERIMENTAL SETUP

In our experimental setup of eddy current experiment we use,

- Permanent Magnet,
- 1000rpm 12v DC motor, used to rotate the discs
- Power supply source i.e. battery,
- Two Discs of aluminium & copper (1mm thick and 150mm diameter)
- Optical Tachometer used to measure the angular speed of discs.

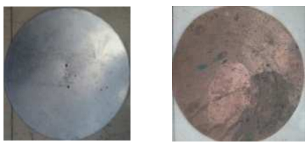


Figure4, two different discs of Al &Cu materials

Figure5, Rear view

Figure6, Front view

Figure 5 and Figure 6 shows the Rear and Front View of our Experimental Setup. Two 1000rpm DC motor is mounted on wooden bar, one for copper and one for aluminium and both the disc are attached directly to the motor shaft. Two wooden handle bars are used on which permanent magnets are mounted. This whole experiment set up is supported by wooden block.
When permanent magnets are brought near the rotating conducting disc, retardations are observed for aluminium and copper and those retardations are noted down for considerably period of time. Those readings are shown in tabular as well as in graph form in order to make the proper comparison between aluminium and copper.

4. THEORETICAL CALCULATION

In this experiment we theoretically calculate the following terms,

4.1 Flux Density , same for both the materials because area is same for both the materials
Flux density can be define as,

$$B = \mu \times H \qquad \text{Eq. (1)}$$

Where,
μ = permeability constant= 0.63
H = Magnetic field strength =1480gauss or 0.148tesla
Therefore,

$$B = 0.0932 \text{ Weber per m}^2$$

4.2 Flux , which is also same for both the materials
Flux can be define as,

$$\emptyset = B \times A \qquad \text{Eq. (2)}$$

Therefore,

$$\emptyset = 0.00658 \text{ Weber}$$

4.3 Braking Torque of Aluminium & Copper

The Braking torque of conducting materials can be define as [6],

$$\tau_{al} = N \times \frac{\pi\sigma}{4} \times t^2 \times d \times B^2 \times R^2 \times \omega \quad \text{Eq. (3)}$$

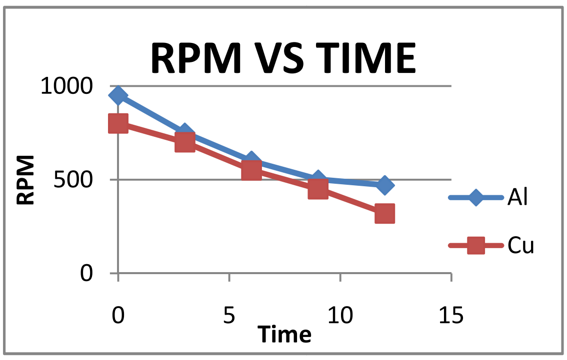
Where,
N = no. of magnets, t = diameter of magnet core, σ_{al} = specific conductivity, 35.5 × 10^6 [Sm^{-1}] d = disc thickness, 1mm or 0.001m, R = disc radius, 150mm or 0.15m
Therefore,

$$\tau_{al} = 0.4560 \text{ N/m}$$

Similarly, Braking torque for copper when all the values are same except specific conductivity (σ), i.e. 58.0×10^6 [Sm^{-1}]
Therefore, τ_{cu}= 0.7450 N/m

5. RESULTS & DISCUSSION

After analysing our experiment setup, experimental results are shown in Graphical & Tabular form as below,

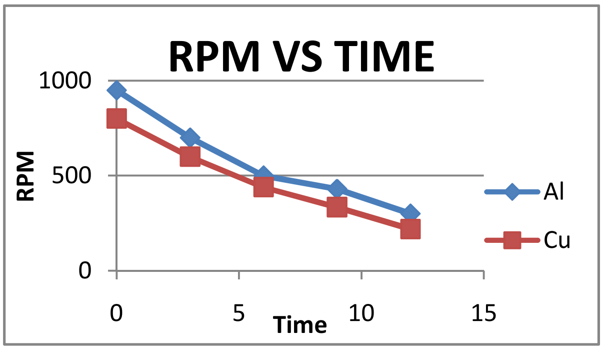


Graph 1 Retardation of Al & Cu discs with 1 set of magnet

Table-1 Retardation of Al & Cu discs with time

Sl.No	Time(x-axis)	Rpm(y-axis) Aluminium	Rpm(y-axis) Copper
1	0	950	800
2	3	750	680

3	6	600	520
4	9	500	440
5	12	470	400



Graph 2 Retardation of Al & Cu discs with 2 set of magnet

Table-2, Retardation of Al & Cu discs with time

Sl.No	Time(x-axis)	Rpm(y-axis) Aluminium	Rpm(y-axis) Copper
1	0	950	800
2	3	700	600
3	6	500	440
4	9	430	335
5	12	300	220

Thus, from these experimental values we observe that copper has a better retarding time than aluminium.

We can justify our results by observing the following points,

1. From the graphs we observe that copper show the greater decrement of speed with time than aluminium
2. From the theoretical calculation braking torque of copper is greater than aluminium
3. Increase in conductivity more will be eddy current and greater will be the retarding force. Since copper has higher conductivity than aluminium therefore more retarding force will be observed in copper.
4. Copper is denser than aluminium hence more speed retardation will be observe in copper than aluminium.

5. CONCLUSION

During our research, we explain the concept of ECR type of velocity retarder and how it is useful in using with primary brakes. We calculate the magnetic flux density as well as magnetic flux for aluminium and copper in order to show that retarding time doesn't depend upon the flux and flux density. They are same for aluminium and copper and only depend upon the magnetic field and area of moving objects.

In this paper we also calculate the theoretical braking torque which is different for both the materials and made our first comparison which material is better in this technology.

In order to prove our result we calculate the values experimentally from our experimental setup and plot a graph to show the considerably retard in speed with time and proving our result both theoretically and experimentally.

In this paper we find out the experimental values for both the disc with one set of magnet and two set of magnet.

This shows that ECR helps in retarding but is not effective as our primary brakes. They require high induced current in order to make this retarder to work more effectively.

Thus, this can be the limitation of ECR technology.

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