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DESIGN AND FABRICATION OF ELECTRO-MAGNETIC DISC BRAKING SYSTEM

Naresh Balram Bhandari[1], Akshay Nandu Darade[2], Sarika Madhav Sonawane[3], Vidya Krushna Sonar[4]

[1234]Mechanical Engineering, SIER Savitribai Phule Pune University, (India)

ABSTRACT

A brake is a device which is artificial frictional resistance applied on a moving disc or moving member, in order to reduced or stops the speed or motion of the machine. An Electromagnetic braking system uses the magnetic force to operate brakes and the power to be supplied electrically by the regulator switch. When electrical supply give to the electromagnet than the electromagnet produced highly effective magnetic field and these magnetic power used to be braking purpose. Dynamic calculation of electromagnetic system assisted is discussed for different masses and respect to the wheel RPM which shows the effect in braking control. It aims to minimize the brake failure, also minimize the maintenance of braking system. This primary result will leads to electromagnetic braking and its application.

Keywords: Braking System, Electromagnet, Electrical Supply, Frictional Resistance, Maintenance, Working

I. INTRODUCTION

Technical enhancement a lot of new technologies are arriving in the braking systems. The principle of braking is depend on the conversion of energy that is converted kinetic energy in to thermal energy i.e. heat. In two wheeler Disc brake and Drum brake are used in existing system, both braking are Contact type braking as well as the frictional resistance braking. Due to contact type braking losses are more like the wear and tear and so on. Also maintenance is required more like lubrication, replacement of auxiliary part due to wear and tear. These are few problems in the existing braking sy

Realize the importance of the new braking system that reduced common problems mentioned earlier, experiment will be conducted to study of electromagnetic braking system. In this electromagnet electrical supply converted into magnetic field which is act as magnetic force on the disc to be braked. In this braking system parameter influence to the braking force which are electrical current, air gap between the disc and the electromagnet etc. these are parameter will be design in this experiment. This type of braking system is more effective than the existing braking system. And all disadvantages of the existing braking system wiil be minimized in the electromagnetic braking system.

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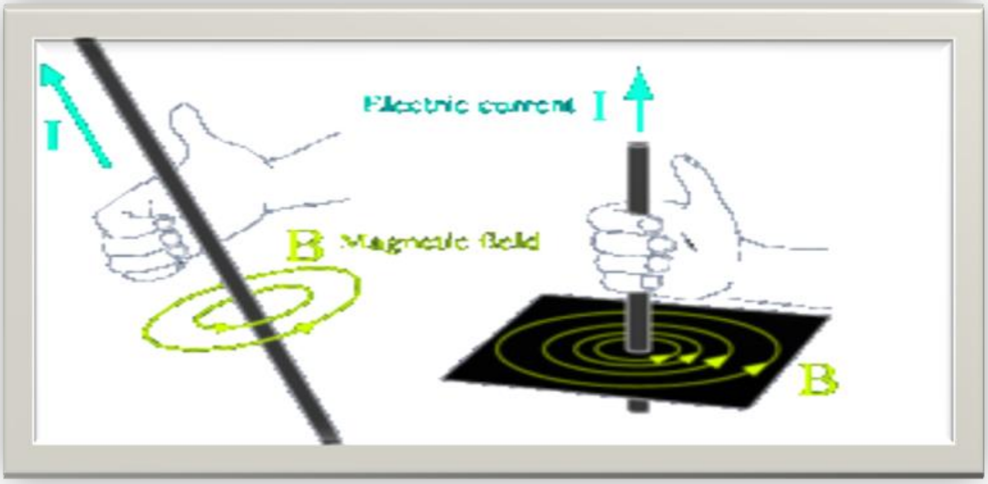
II. ELECTROMAGNETIC BRAKE

2.1 Principl

If a piece of copper wire was wound, around the nail (Bar) and then connected to the electrical supply, it would create an electro magnet. The magnetic field that is generated in the wire, from the current, is known as the "right hand thumb rule". The strength of the magnetic field can be changed by changing both wire size and the amount of wire (turns).



An electromagnet is type of temporary magnet in which the magnetic field is produced by a flow of electric current. The magnetic fields disappear when the current is lost. The wire produces loops of magnetic field lines around it, the current represents the movement of bar and resulting field line direction is the direction of turning. If a wire is wound into a coil, then the field lines add up in such a way as to produce a set of field lines surround the coil in a similar way to those that surrounds as a permanent bar magnet.

If further a piece of soft iron is placed inside the coil, they themselves serve as many little bar magnets in the iron, creating a strong bar magnet as long as the current is switch on.

2.2 Working

A soft-iron core that is magnetized by passing a current through a coil of wire wound on the core. Electromagnets are used to lift heavy masses of magnetic material and to attract movable magnetic parts like iron disc and ferrous material.

When electric supply given to the electromagnet then it act as a temporary magnet this magnetic field exerted the force on rotating disc in the direction of perpendicular to the disc.In an engineering sense the word electromagnet does not refer to the electromagnetic forces incidentally set up in all devices in which an electric current exists, but only to those devices in which the current is primarily designed to produce this force, as in solenoids, relay coils, electromagnetic brakes and clutches, and in attractive and lifting or holding magnets and magnetic chucks.

Electromagnets may be classified into two types: one is the traction magnets, in which the pull is to be exerted over a distance and work is done by reducing the air gap; and other is lifting or holding magnets, in which the material is initially placed in contact with the magnet. For Examples of the latter type are magnetic chucks and circular lifting magnets.

III. DESIGN CALCULATION AND EQUATION

3.1 Design Of Electromagnet

3.2 Electromagnet Specification.

- **Outer core:** 40mm X 40mm.
- **Inner Core:** 25mm X 25 mm.
- **No. of turns on electromagnet (N)** =800, (24 gauge wire)
- **Current & Voltage supplied (I/V)** = 7amp/230volts.
- **Length of electromagnet (L)** =25 mm.

  Let the plate,shaft & wheel assembly maximum weight is to be consider approx. 5kg. i.e. 49.05 N, so we know that,

  $$F = \frac{B^2 A}{2\mu_o}$$

3.3 Where

F is the force in Newton.

B is the magnetic field in teslas.

A is the area of the pole faces in square meters.

μ_o is the permeability of free space.

In the case of free space (air), $\mu_o = 4\pi \cdot 10^{-7}\,\mathrm{H}\cdot\mathrm{m}^{-1}$

49.05 $= \frac{B^2\ \{[(40 \times 40) - (25 \times 25)]X\ 10^{-3}\}}{2 \times 4\Pi \times 10^{-7}}$

B = 0.0112 wb/m^2.

Total magnetic flux in core:

Ø = B ×A

Ø = 0.0112×0.975

Ø = 0.0109 wb.

The magnetizing force

H = B/μ **= 0.0112/4π×10^-7 = 8912.67 AT/m.**

For air gap of 0.5 mm magnetic force is given by between magnet & plate.

AT = H×L

= 8912.67×25×10^-3

= 222.816 AT

Find the power of electromagnet

F$=\frac{(N \times I)^2\ \mu A}{(2 \times g)^2}$

g = air gap between electromagnet & plate

F$=\frac{(800 \times 7)^2\ 4\pi \times 10^{-7}\ \times 0.975}{(2 \times 0.5)^2}$

F = 38.423 N for each electromagnet

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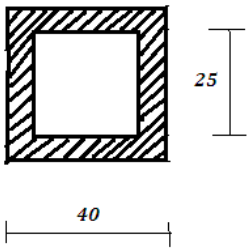

IV. MOTOR SELECTION

Thus selecting a motor of the following specifications,

- **Single phase AC motor.**
- **Power = 1/15hp=50 watt.**
- **Speed= 0-8600 rpm (variable).**

4.1 Motor Torque

$$P = \frac{2 \Pi N T}{60}$$

$$T = \frac{60 \times 50}{2 \Pi \times 8600}$$

T = 0.055 N-m

Note: All Calculations Are Taking At Full Speed Of Motor.

Power is transmitted from the motor shaft to the input shaft by means of an open rope drive,

Motor pulley diameter = 30 mm

IP _ shaft pulley diameter = 60 mm

Reduction ratio = 2

Coefficient of friction for lather circular rope = 0.23

Center distance = 380 mm

Pulley drove angle 2β= 38˚ **β=19˚**

Mass of belt per unit length m = 0.0186 kg/m

$\alpha = \sin^{-1}\frac{D-d}{2\,C} \quad = \sin^{-1}\frac{60-30}{2\,x\,380}$

α= 2.2622˚ (In degree)

α= 0.03948 (In radians)

ϴ = Angle of lap of belt

$\theta = \pi - (2\alpha)$

$= \pi - (2x0.03948)$

ϴ =3.062 (In radians)

ϴ =175.47˚ (In degree)

Now $\frac{F1}{F2} = e^\wedge\frac{\mu\theta}{\sin\beta}$

$\frac{F1}{F2} = e^\wedge\frac{(0.23x3.062)}{\sin 19^\circ}$

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$\frac{F1}{F2}$ **= 8.698-- (1)**

V = $\frac{\pi d n}{60 x 1000}$

= $\frac{\pi x 30 x 8600}{60 x 1000}$

= 13.508 m/s

Fc =**mV^2**

= 0.0186 x $(13.508)^2$

Fc =**3.39 N**

4.2 Power Transmitted

P= $\frac{(F1 - F2)\ V}{1000}$

50 $X\ 10^{-3}$ = $\frac{(F1 - F2)\ X\ 13.508}{1000}$

F_1- F_2 = 3.7015N --- **(2)**

Put 1 in 2 we get

8.698F_2- F_2=3.7015 N

F_2= 0.48 N

F_1= 4.1823 N

4.3 Design of Shaft (Asme Code).

For commercial steel material shaft is to be design, According to ASME code Actual shear stress **$\tau_{act= 55N/mm^2}$**

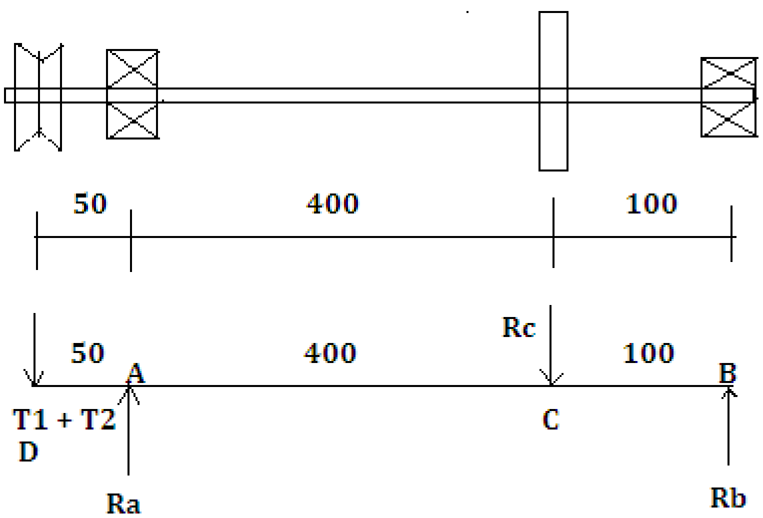
T = Π/16 x τ_{act} xd^3

$\Rightarrow \tau_{act} = \frac{16\ x\ T}{\Pi\ x\ d^3}$

$55 = \frac{16\ x\ 0.11\ x 10^{\ 3}}{\Pi\ x\ d^3}$

d=2.17mm

Similarly shaft is to be design as,



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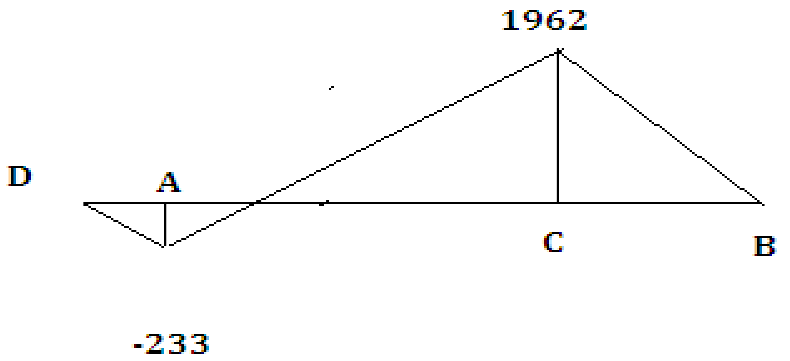

Σ M@ A =0

(4.66 x 50) + (R_B x 500) =(R_C x 400)

227.5 + 500R_B= 490.5

R_B = 0.526 N

Σ F_y =0

R_A + R_B = 4.66 + R_C

R_A + 0.526 = 4.66 + 4.905

R_A= 9.039 N

Bending moment diagram(BMD)

M_B= 0

M_A= - 4.66 X 50 = -233 N-mm.

M_C = 4.905 X 400 = 1962 N-mm.

T =(4.1823 – 0.48) X (60/2)

T= 111.069 N-mm.

M= maximum bending moment 1962 N-mm.

Equivalent Torque (T_e) =$\sqrt{(K_b \times M)^2 + (K_t \times T)^2}$

(T_e) =$\sqrt{(1.5 \times 1962)^2 + (1.25 \times 111.069)^2}$

(T_e) = **2946.27 N-mm.**

$\tau_{act}=\frac{16 \times T}{\Pi \times d^3}$

$55=\frac{16 \times 2946.27}{\Pi \times d^3}$

d=6.48 mm

But we select d = 20 mm as we have a pedestal bearing of minimum diameter of 20 mm.

V. SELECTION OF SHAFT BALL BEARING

In selection of ball bearing the main governing factor is the system design of the drive i.e. the size of the ball bearing is of major importance; hence we shall first select an appropriate ball bearing. Taking into consideration convenience of mounting of ball bearing.

As shaft diameter is 20mm so we have selected a pedestal ball bearing having dia-20mm to support the shaft.

For ball bearing6204 no.

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Total radial load on ball bearing is,

$=F_1 + F_2$ + Weight of rotor disc + Weight of shaft.

= 4.18 + 0.48 +4.905 + 19.62

= 29.185 N

Total radial load = 30 N.

Radial load on each bearing is,

$F_r = \frac{Fh}{2}$

$= \frac{30}{2}$

F_r = 15 N

Equivalent dynamic load & rating life,

Pe = V X Fr x Ka

= 1 x 15 x 1.5

Pe = 22.5 N

$L_{10} = \frac{L_{h10}\ x\ 60\ x\ n}{10^6}$

L_{10} from graph 4.6 PSG Design data book for 16000 rpm maximum speed of ball bearing is 31500 Hours.

$L_{10} = \frac{31500\ x\ 60\ x\ 4300}{10^6}$

L_{10} =8127 million of revolutions.

Basic dynamic capacity

$L_{10} = (\frac{C}{Pe})^{10/3}$

$C = (L_{10})^{0.3}\ xP_e$

$C = (8127)^{0.3}$ x 22.5

C= 335.09 kN.PSG Design data book 4.13.

VI. PERFORMANCE TESTING

For constant speed at 4320 rpm.

r = radius of wheel in m.

V = r ω

$= 0.178\ x \frac{2\ \pi\ n}{60}$

$= 0.178\ x \frac{2\ \pi\ x\ 4320}{60}$

V = 80.352 m/s.

According newton's law of motion,

V = u + at

$a = \frac{V-U}{t}$

Initial velocity of a wheel u=80.352 m/s and final velocity v = 0

For constant speed & current varying from step by step,

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Step-1 I = 1.4 Amp. , a = $\frac{V-U}{t}$,a = $\frac{0-80.352}{8}$, **a = - 10.044 m/s^2.**

Step-2 I = 2.7 Amp. , a = $\frac{V-U}{t}$, a = $\frac{0-80.352}{7}$, **a = - 11.478 m/s^2.**

Step-3 I = 4.1 Amp. , a = $\frac{V-U}{t}$, a = $\frac{0-80.352}{6}$, **a = - 13.392 m/s^2.**

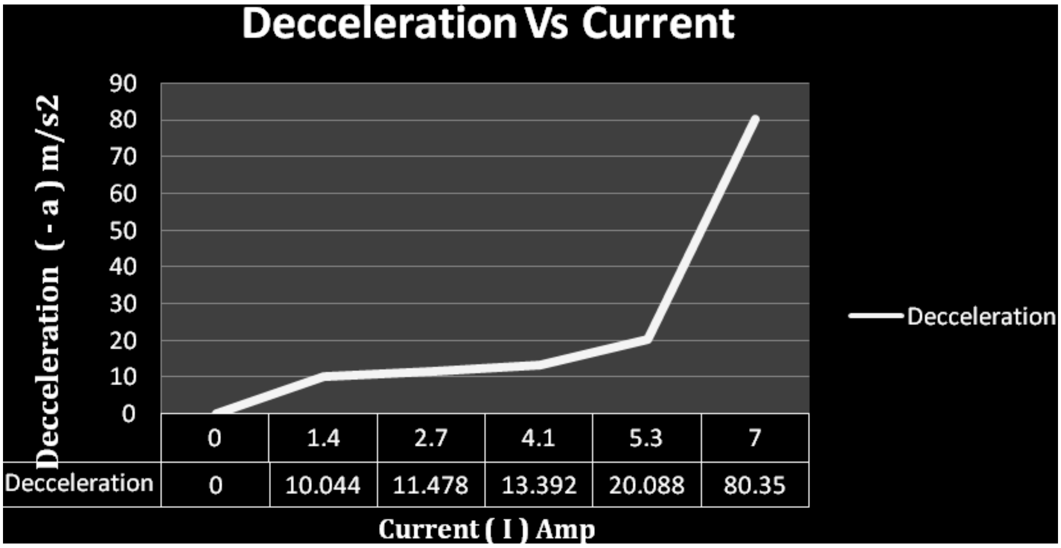
Step-4 I = 5.3Amp. , a = $\frac{V-U}{t}$, a = $\frac{0-80.352}{4}$, **a = - 20.088 m/s^2.**

Step-5 I = 7 Amp. , a = $\frac{V-U}{t}$, a = $\frac{0-80.352}{1}$, **a = - 80.35 m/s^2.**

Graph shows braking performance at constant speed, with current variation.

NOTE :-ve sign indicates deceleration of the wheel.

VII. RESULT TABLE



VIII. CONCLUSION

Electro-magnetic system is to be more reliable than the existing braking system. In oil braking system or air braking system, there are chances of brake failure While in electromagnetic braking system as four electromagnet are placed around the plate an having small air gap between them, in case any electromagnet brake fails the brake dose not completely fails remaining three electromagnet work properly. And this system required very low maintenance. This type of braking system not only helps in effective braking but also helps in reducing the frequency of accidents to a minimum. From the advantages of electromagnetic brake over friction brake it can be used on heavy vehicles where the brake fading problem exists. Based on this same concept is developed for application on lighter vehicles. Electromagnetic braking is a non contact type of braking system. electromagnetic brake can be used as auxiliary braking system with friction braking system to avoid overheating. Electromagnetic braking system is cheaper than other braking system.

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