DESIGN AND ANALYSIS FOR ELECTROMAGNETIC BRAKING SYSTEM

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ABSTRACT:

An Electromagnetic Braking system utilizes Magnetic drive to connect with the brake, however the power required for braking is transmitted physically. The disc is associated with a shaft and the electromagnet is mounted on the edge .When power is connected to the curl(coil) a magnetic field is produced over the armature as a result of the present streaming over the loop and makes armature get pulled in towards the coil. Thus it builds up a torque and in the end the vehicle stops. In this venture the upside of utilizing the electromagnetic stopping mechanism in car is considered. These brakes can be consolidated in substantial vehicles as an assistant brake. The electromagnetic brakes can be utilized as a part of business vehicles by controlling the current provided to deliver the attractive flux. Making a few en-hancements in the brakes it can be utilized as a part of automobiles in future.

Introduction

Brake

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction

Most brakes commonly use friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat, though other methods of energy conversion may be employed. For example, regenerative braking converts much of the energy to electrical energy, which may be stored for later use. Other methods convert kinetic energy into potential energy in such stored forms as pressurized air or pressurized oil. Eddy current brakes use magnetic fields to convert kinetic energy into electric current in the brake disc, fin, or rail, which is converted into heat. Still other braking methods even transform kinetic energy into different forms, for example by transferring the energy to a rotating flywheel.

Brakes are generally applied to rotating axles or wheels, but may also take other forms such as the surface of a moving fluid (flaps deployed into water or air). Some vehicles use a combination of braking mechanisms, such as drag racing cars with both wheel brakes and a parachute, or airplanes with both wheel brakes and drag flaps raised into the air during landing.

Since kinetic energy increases quadratically with velocity ($k=m v^2/2$), an object moving at 10 m/s has 100 times as much energy as one of the same mass moving at 1 m/s, and consequently the theoretical braking distance, when braking at the traction limit, is up to 100 times as long. In practice, fast vehicles usually have significant air drag, and energy lost to air drag rises quickly with speed.

Need of a Braking System

In an automobile vehicle braking system is needed –

- To stop the moving vehicle.
- To de accelerate the moving vehicle.
- For stable parking of a vehicle either on a flat surface or on a slope.
- As a precaution for accidents.
- To prevent the vehicle from any damage due to road conditions.

Types of braking system

Brakes may be broadly described as using friction, pumping, or electromagnetics. One brake may use several principles: for example, a pump may pass fluid through an orifice to create friction

Frictional

Frictional brakes are most common and can be divided broadly into "shoe" or "pad" brakes, using an explicit wear surface, and hydrodynamic brakes, such as parachutes, which use friction in a working fluid and do not explicitly wear. Typically the term "friction brake" is used to mean pad/shoe brakes and excludes hydrodynamic brakes, even though hydrodynamic brakes use friction. Friction (pad/shoe) brakes are often rotating devices with a stationary pad and a rotating wear surface. Common configurations include shoes that contract to rub on the outside of a rotating drum, such as a band brake; a rotating drum with shoes that expand to rub the inside of a drum, commonly called a "drum brake", although other drum configurations are possible; and pads that pinch a rotating disc, commonly called a "disc brake". Other brake configurations are used, but less often. For example, PCC trolley brakes include a flat shoe which is clamped to the rail with an electromagnet; the Murphy brake pinches a rotating drum, and the Ausco Lambert disc brake uses a hollow disc (two parallel discs with a structural bridge) with shoes that sit between the disc surfaces and expand laterally.

A drum brake is a vehicle brake in which the friction is caused by a set of brake shoes that press against the inner surface of a rotating drum. The drum is connected to the rotating roadwheel hub.

Drum brakes generally can be found on older car and truck models. However, because of their low production cost, drum brake setups are also installed on the rear of some low-cost newer vehicles. Compared to modern disc brakes, drum brakes wear out faster due to their tendency to overheat.

The disc brake is a device for slowing or stopping the rotation of a road wheel. A brake disc (or rotor in U.S. English), usually made of cast iron or ceramic, is connected to the wheel or the axle. To stop the wheel, friction material in the form of brake pads (mounted in a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop.

Pumping

Pumping brakes are often used where a pump is already part of the machinery. For example, an internal-combustion piston motor can have the fuel supply stopped, and then internal pumping losses of the engine create some braking. Some engines use a valve override called a Jake brake to greatly increase pumping losses. Pumping brakes can dump energy as heat, or can be regenerative brakes that recharge a pressure reservoir called a hydraulic accumulator.

Electromagnetic

Electromagnetic brakes are likewise often used where an electric motor is already part of the machinery. For example, many hybrid gasoline/electric vehicles use the electric motor as a generator to charge electric batteries and also as a regenerative brake. Some diesel/electric railroad locomotives use the electric motors to generate electricity which is then sent to a resistor bank and dumped as heat. Some vehicles, such as some transit buses, do not already have an electric motor but use a secondary "retarder" brake that is effectively a generator with an internal short circuit. Related types of such a brake are eddy current brakes, and electro-mechanical brakes (which actually are magnetically driven friction brakes, but nowadays are often just called "electromagnetic brakes" as well).Electromagnetic brakes slow an object

through electromagnetic induction, which creates resistance and in turn either heat or electricity. Friction brakes apply pressure on two separate objects to slow the vehicle in a controlled manner

Literature review

[1] Stephen Z. Oldakowski, Bedford, Ohio A magnetic brake provides braking or locking capability and is remotely controlled by electric power. The magnetic brake comprises a rotatable shaft and a brake disc mounted on the shaft. A non-rotating core housing assembly located around the shaft includes a permanent magnet and a bipolar solenoid. A magnetic armature adjacent to the core housing assembly is capable of movement toward the core housing assembly and toward and into engagement with a brake disc to prevent rotation of the shaft. A spring urges the armature away from the core housing assembly and into engagement with the brake disc. The brake does not use any electric power to maintain the brake in the set mode with the rotating shaft fully locked or in the released mode with the rotating shaft fully released. The permanent magnet is of sufficient strength to hold the armature against urging of the spring until an opposite polarity is supplied by the solenoid.

[2] Karl Erny, Holzhausem An elevator drive has a brake device with compression springs to actuate brake levers, and brake linings on a brake drum creating a braking force. A sensor is provided to detect the movement of a brake magnet armature tappet. A bracket is attached to the brake magnet tappet on one end and a distance piece carrying the sensor housing is arranged on the other end. A restoring lug is attached to the existing mechanical indicator. A monitor evaluates the sensor signal and turns off the elevator drive in the event of dangerous operational states via a safety circuit. The system allows the state of the brake device to be monitored. The more the brake linings wear off due to abrasion, the smaller the distance between the armature and the brake magnet housing. If the armature is in contact with the brake magnet housing, the braking ability of the brake linings is completely void.

Objectives:

- Calculating main component theoretical values
- Developing each component with the help of cad tool solid works

- Assembling individual components with the help of solid works assembly
- Gathering required material data to analyses each object
- Knowing disc brake and sprocket maximum bearing capacity
- Suggesting one optimum material for each component

μ

DESIGN CALCULATION AND EQUATION

Design Of Electromagnet

- Outer core: 40mm X 40mm.
- Inner Core: 35mm X 25 mm.
- No. of turns on electromagnet (N) =800, (24 gauge wire)
- Current & Voltage supplied (I/V) = 7amp/230volts.
- Length of electromagnet (L) =35 mm.
- Let the plate, shaft & wheel assembly maximum weight is to be consider approx. 5kg. i.e. 49.05 N, so we know that,

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

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.
- μo is the permeability of free space.

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

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/m2.

Total magnetic flux in core:

Ø = B ×A

Ø = 0.0112×0.975 Ø = 0.0109 wb.

The magnetizing force

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

For air gap of 2.52 mm magnetic force is given by between magnet & plate. AT = H×L

= 8912.67×25×10^-3

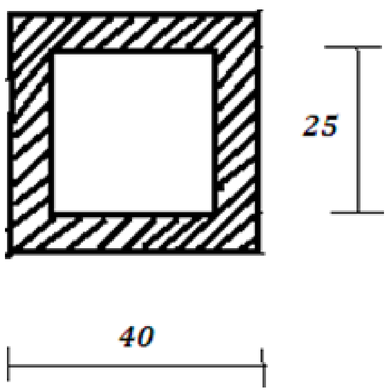
= 222.816 AT

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 for 2 magnets F = 76.84 approx



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.

Total radial load on ball bearing is,

=F1 + F2 + 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, Fr = $\frac{Fh}{2}$=Fr = 15 N

Equivalent dynamic load & rating life, Pe = V X $\frac{30}{2}$Fr x Ka

= 1 x 15 x 1.5 Pe = 22.5 N

L10 = $\frac{L_{h10} \ x \ 60 \ x \ n}{10^6}$

L10 from graph 4.6 PSG Design data book for 16000 rpm maximum speed of ball bearing is 31500 Hours. L10 = $\frac{31500 \ x \ 60 \ x \ 4300}{10^6}$

L10 =8127 million of revolutions. Basic dynamic capacity

L10 = $(\frac{C}{Pe})^{10/3}$ C = (L10)0.3 xPe

C = (8127)0.3 x 22.5

C= 335.09 kN.PSG Design data book 4.13.

4.6 PERFORMANCE TESTING

For constant speed at 4320 rpm. r = radius of wheel in m.

V = r ω

= 0.178 x

= 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,

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 = 5.3 Amp. , $a = \frac{V-U}{t}$, $a = \frac{0-80.352}{4}$, 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.

COMPONENTS USED

1) Battery
2) Electro magnets
3) Motor switch
4) Electromagnetic switch
5) Motor
6) Motor sprocket
7) Wheel sprocket
8) Wheel
9) Frame
10) Chain
11) Disc brake

Material selection

A material's property is an intensive, often quantitative, property of some material. Quantitative properties may be used as a metric by which the benefits of one

$\frac{2 \pi n}{60}$

material versus another can be assessed, thereby aiding in materials selection.

A property may be a constant or may be a function of one or more independent variables, such as temperature. Materials properties often vary to some degree according to the direction in the material in which they are measured, a condition referred to as anisotropy. Materials properties that relate to different physical phenomena often behave linearly (or approximately so) in a given operating range. Modelling them as linear can significantly simplify the differential constitutive equations that the property describes.

Material properties

Mild Steel

Young's modulus: - 2.0*10^11 Pa

Poison ratio: 0.29

Density:7850 Kg/m^3

Yield strength: 250Mpa

Thermal conductivity: 60.5 w/m-k

Stainless steel

Young's modulus: - 210*10^9 pa

Poison ratio: 0.29

Density: 8000 kg/m^3

Yield strength: 355*10^6 mpa

Thermal conductivity: 16.3 w/m-k

Super alloy 49

Young's modulus: - 1.66*10^9 Pa

Poison ratio: 0.29

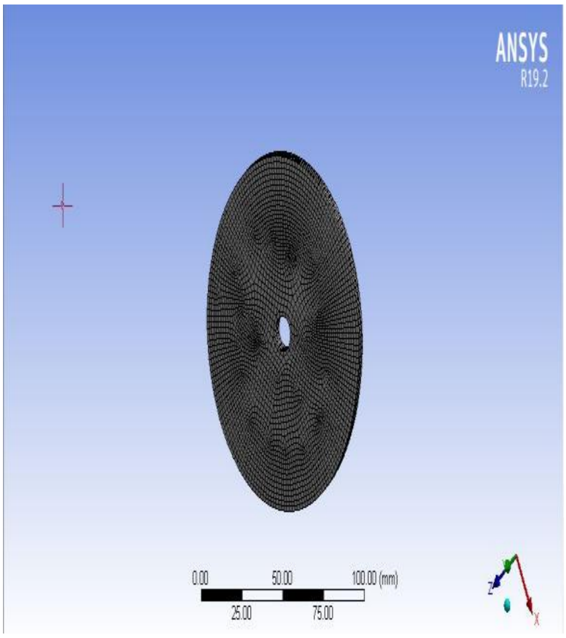
Density: 8165 Kg/m^3

Yield strength: 552Mpa

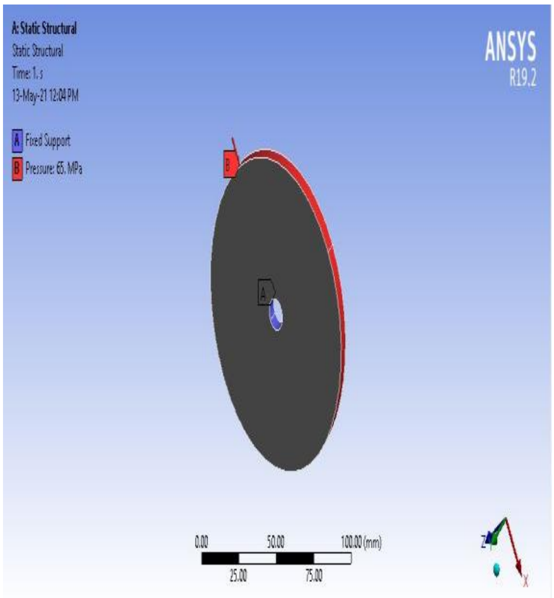
Thermal conductivity: 13.0 w/m-k

7.2 Meshing

After completion of material selection here we have to create meshing for each object meshing means it is converting single part into no of parts. And this mesh will transfer applied loads for overall object. After completion meshing only we can solve our object. Without mesh we cannot solve our problem. And here we are using tetra meshing and the model shown in below.



7.3 Boundary conditions



Static structural →supports→fixed support→select hole area \

Pressure →65 Mpa , 75 Mpa , 55 Mpa

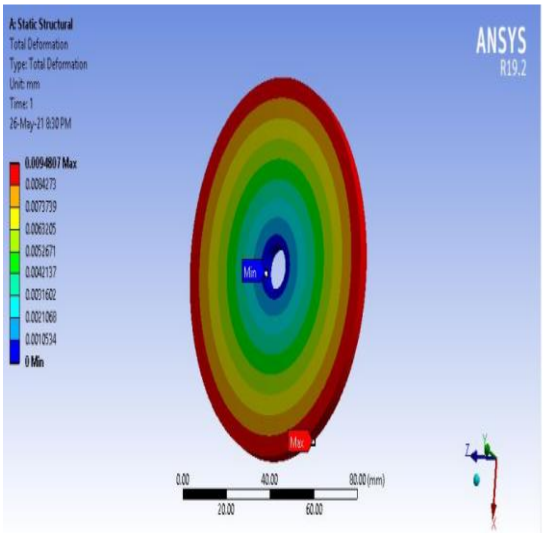
After completion of boundary conditions here we have to check results by solving. Just click on solve option and select results like deformation, strain, stress and safety factor values for the object.

Solution→solve→deformation

Solution→solve→safety factor

Solution→solve→stress

MILD STEEL



Analysis Result on Disc in a table

Material of Disc	Pressure in Mpa	Deformation in mm	Stress in Mpa	Strain in mm/mm	Safety factor
Mild Steel	55	0.009480	99.774	0.00049	5.811
	65	0.011205	117.92	0.00058	4.900
	75	0.012928	136.06	0.00068	4.261
Stainless steel	55	0.009610	99.569	0.00049	7.209
	65	0.112050	107.67	0.00054	5.884
	75	0.013111	135.78	0.00067	5.2866
Super alloy 49	55	0.011584	99.569	0.00059	12.282
	65	0.013690	117.67	0.30007	10.393
	75	0.015156	138.32	0.00086	11.201

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

Here electromagnetic braking system modeling were developed with the help of solid works, and then analyzed major components with the help of Ansys workbench tool, from analysis results it is clear that disc brake can withstand maximum amount of pressure on it up to 65Mpa, if the material is changes to super alloy 49 here the strength of the object has been increased nearly 2 times and this super alloy 49 is having high magnetic values also, by using stainless steel the amount of cost will reduce and the material can act as corrosion resistant. For sprocket also here suggest one material which is known as steel 440c, by using this material sprocket safety factor is increasing from 1.48 to 1.7 approximately, this difference is nearly 10 to 15%, so that by using steel 440c material sprocket strength will increase for same amount of density values.

ADVANTAGES

1. Problems of wear and tear is negligible

2. Potential hazard of tire burst due to excess temperature is prevented

3. Individual wheel braking is possible.

DISADVANATAGES

1. Electromagnetic braking system doesn't function well on lower RPMs as the Eddy current generated is of low power.

2. Large amount of electricity is needed for heavy braking, hence the battery life is reduced

3. Due to low speed limitation EM braking cannot be used as an independent system.

4. System can be bulky in case of vehicles needed larger braking force.

APPLICATIONS

1. Railways

2. Coaches

3. Roller coasters and other theme park rides

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