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Analysis of Electromagnetic Braking System

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ABSTRACT
This project aims to develop an electromagnetic braking system model capable of applying brakes without any friction loss and without losing the energy supplied. It uses a two electromagnets which runs by the supply of power from the circuit. Also, there is a wheel which is attached to the motor so when the power the supplied, by the help of motor the wheel rotates. Then a fan is attached near electromagnets to cool the electromagnets from excessive heating. A metal bar is in the vicinity of the electromagnets and wheel so when the electromagnets produces eddy currents which stops the rotating wheel or rotor. This model helps in a way to be used as retardation equipment in vehicle.

Keywords:-Brakes, Electromagnetic braking system, Speed etc.

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I. INTRODUCTION

In today's era safety is the first priority in automobile manufacturing industry. Braking system in automobiles ensure the optimization and good control over the vehicle and reduces the chances of accidents. Braking System should ensure the safety and comfort of the passenger, driver and other road user. The brake must be strong enough to stop the vehicle during emergency within shortest distance. The convention braking system are bulky and power to weight ratio is low. Most of the braking systems utilize friction forces to transform the kinetic energy of a moving body into heat that is dissipated by the braking pads. The overuse of friction-type braking systems causes the temperature of the braking pads to rise, reducing the effectiveness of the system. An electromagnetic brake is a new and revolutionary concept. These are totally friction less. Electromagnetic brakes are the brakes working on the electric & magnetic power. Electromagnetic Braking System is used which is efficient way of braking with high power to torque ratio and also provide less amount of friction.

An Electromagnetic Braking system uses Magnetic force to engage the brake, but the power required for braking is transmitted manually. The disc is connected to a shaft and the electromagnet is mounted on the frame .When electricity is applied to the coil a magnetic field is developed across the armature. The eddy-current is created by the relative motion between a magnet and a metal (or alloy) conductor. The current induces the reverse magnetic field and results in the deceleration of motion. The proposed mechanism implements this phenomenon in developing a braking system. The potential applications of the braking system can be a decelerating system to increase the safety of any vehicle. As a result it develops a torque and eventually the vehicle comes to rest. In this project the advantage of using the electromagnetic braking system in automobile is studied. These brakes can be incorporated in heavy vehicles as an auxiliary brake. The electromagnetic brakes can be used in commercial vehicles by controlling the current supplied to produce the magnetic flux.

Making some improvements in the brakes it can be used in automobiles in future. It also reduces the maintenance of braking system. An advantage of this system is that it can be used on any vehicle with minor modifications to the transmission and electrical systems. The major parts of an electromagnetic braking system are braking disc, Electromagnets and battery power. Electromagnetic braking system is classical example of increased effectiveness of braking system while minimizing losses. In our prototype we focus on Electromagnetic system is to increase the safety of the device meanwhile keeping the losses to minimum. An effective design is one which performs the required task efficiently and is safe under extreme operating conditions, while being economical in the material used as well as the manufacturing process needed yet having an aesthetic appeal. Analysis aids in understanding the behaviour of a component under a particular loading cycle for both failures and redundancies.

For a design optimization of prototype it is necessary to look into the design aspects and literature available in order to better understand the need of the components .Our team goes through various different review papers so we can know about other people's work on different brakes. We studied numerous papers in which different researchers have given their contribution on the development this certain topic. Sevvel , Nirmal Kannan , Mars Mukesh in their paper Innovative Electro Magnetic Braking System [1] specified that an

Electromagnetic Braking system uses Magnetic force to engage the brake, but the power required for braking is transmitted manually. The electromagnetic brakes can be used in commercial vehicles by controlling the current supplied to produce the magnetic flux. Lindberg; Teppo (Nuppulinna, FI) Assignee: Kone Oy (Helsinki, FI) United States Patent[9] invented a vehicle braking system including a brake disk structure defining an annular surface means and having an axis, an annular magnet support assembly disposed adjacent to the annular surface means in the direction of the axis, a plurality of circumferentially spaced apart pairs of circumferentially spaced apart permanent magnets mounted on the magnet support and circumferentially spaced apart thereon, each pair Arranged with like the polarities of the pairs of permanent mag nets facing the annular surface means alternating circumferentially, an annular pole piece support assembly, and a plurality of ferromagnetic pole pieces mounted on the pole piece support assembly and circumferentially spaced apart in positions between the annular surface means and the permanent magnets, each pole piece disposed adjacent to a pair of the permanent magnets and having a circumferential length substantially greater than the circumferential length of either of the adjacent pair of permanent magnets. United States Patent, US 6,286,637B1, Kwangju Institute of Science & Technology (KR) was published In which the two cores are arranged the edge of the brake disc while being spaced apart from each other at an angle of (90) each of the cores is wound with a coil thus forming and electric magnet A control units calculates Dc or Ac control in response to a speed signal output from the sensor thus outputting control current value to the coils, while the AC current is variable in the frequency in accordance with the pedalling force as well known to those skilled in an art known contact brakes for cars are designed to be operated by hydraulic or pneumatic pressure thus pressing against the brake disc of a wheel using frictional brake pads are frictionally in that the brake pads and making a car go slow or stop. Akshaya S. Putt war and Nagnath U. Enhancement of Braking System in Automobile Using Electromagnetic Braking published in IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), in 2009[3] discovered that electromagnetic brakes can build up a power which is almost double the most extreme power yield of a normal motor, and no less than three times the braking energy of a fume brake to stop the vehicle. These results of electromagnetic brakes make them essentially more focused possibility for elective hindrance hardware's contrasted and different retarders. This project expects to limit the brake inability to stay away from the street mis - happenings. While in electromagnetic braking system as four-disc plates, coils and firing circuits are attached individually on each wheel, even any coil fails the brake does not completely fails remaining three coil works properly. The electromagnetic brakes can be used as an auxiliary braking system along with the friction braking system to avoid overheating and brake failure. When these brakes are combined with mechanical brakes, it increases the life of brake and act like fully loaded brakes. These electromagnetic brakes can be used in wet conditions which eliminate the anti-skidding equipment. Similarly (ICEVT) October 30-31, in 2018, Surakarta, Indonesia[2] researchers aimed to investigate the relationship between braking torque with the amount of coil and the air gap in single disc axial brake ECB (Eddy current braking). FEM is used in ECB performance modelling. In this paper by changing the air gap and number of conductors the torque is also changed. By using FEM, we can find this. The braking torque is strongly affected by the parameter of eddy current brake. By result of this research we can conclude that smaller air gap increases the braking torque and also number of conductors is improving the performance of eddy current brake also by change in design the braking torque is also change. Better braking performance is obtain when using 0.5mm air gap and 360 conductors. Yash Gandhi & Dipam Modh in their review Paper on Eddy Current and Electromagnetic Brake[13] found that the larger thickness of disc, a greater number of turns of electromagnet and higher electrical conductivity of conductor influences the generation of greater braking torque. Greater the speed greater the efficiency. Design and Development of Electromagnetic Braking System Sivasubramanian R, Siva sundar S, Umakhesan A, Ravel M, Saravanan M [9] Electromagnetic brake slows down a moving object by means of electromagnetic induction, in which it will create a resistance. A pressure is created by the Friction brakes on two separate objects to gradually reduce the speed of the vehicle in a controlled way. The current of the magnet turns in the form of heat of the plate which will reduce the kinetic energy. In this magnetic type of braking system whenever force is applied by the driver on the brake pedal the intensity of braking is sensed by a pressure transducer and delivers the output actuating signals to the microprocessor. This controller sends a signal to the capacitor and from the respective unit a pulsating D.C. current is sent to the power pack. [8-9] As per the driver's requirement a proportionate torque is developed to decelerate the vehicle. The paper published by Yogesh Kumar Yadav1, Aadarsh Kumar Shah2, Jitendra Kumar Yadav3, Jitendra Pratap Patel4 Electromagnetic Braking System [11] focuses around utilization of electromagnetic power to stop vehicle. An Electromagnetic Braking structure uses Magnetic power and what's more turn current to attract the brake, however the power required for braking is transmitted through current source. The circle (rotor) is associated with a pole and the electromagnet is mounted on the calliper and lasting magnet is intertwined or mounted on plate at an edge. Exactly when control is associated with the twist an appealing field is created over the armature because of the present gushing over the circle and influences armature to get pulled in towards the twist. Because of fascination between magnets in callipers and circle, it builds up a torque which restricts the movement of rotor and in the long run the vehicle stops and furthermore,

whirlpool current is produced on the plate when exceptionally quality magnet is set close to the moving circle. Swirl current created in the plate build up their own attractive field which contradicts the connected attractive field. In this manner, rotor or circle stops by torque created because of resistance of attractive field i.e. (of provided and vortex current`s attractive field). Along these lines, this brake utilizes both attractive power and also whirlpool current to connect with brake. These brakes can be joined in substantial vehicles and auto as an assistant brake. The electromagnetic brakes can be utilized as a bit of business vehicles by controlling the current provided for make the engaging development.

Design & Theoretical Study of Electromagnetic Braking System [12] tells us about the behaviour of two different materials to be used as brake disc which are aluminium & copper was studied. The experiment also aimed to see the effects of increasing the current induced into electromagnet which produce drag force that will slow down the motion. A few graph been presented to show the best material to be used as the brake disc for electromagnetic braking system using eddy current project. The variation in braking time & braking torque with respect to variation in air gap & current was studied & graphs were plotted to show the results.

II. Construction

The system consists of a rectangular shaped frame, made up of mild steel. The pillow bearings are mounted on the frame by welding. The shaft is being hold in between the bearings. The wheel and the mild steel disc is mounted on the shaft at a specific distance. Two AC type electromagnets are situated near the mild steel disc and mounted on the frame. The torque is provided to the shaft through chain drive, which is driven by a motor, mounted on the frame.

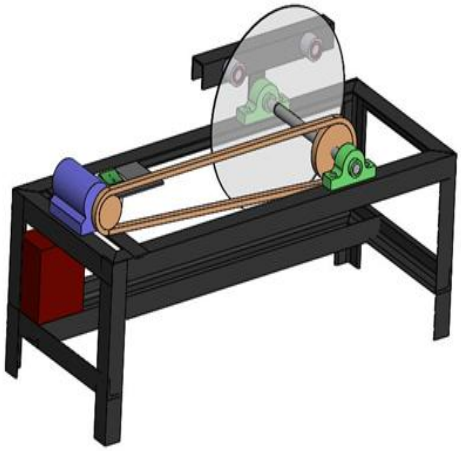


Fig 3.1 (CAD Model)

III. Working

Electromagnetic brakes operate electrically, but transmit torque mechanically. This is often why they are utilized to refer as electro-mechanical brakes. Over the years, Electromagnetic brakes became referred to as electromagnetic, pertaining to their actuation method. The variability of applications and brake designs has increased dramatically, but the essential operation of braking remains same. Single face electromagnetic brakes structure approximately 80 percent of all of the facility applied brake applications. The electromagnet is energized by the AC supply where the magnetic flux produced is employed to supply the braking mechanism. When the electromagnet isn't energized, the rotation of the disc is free and accelerates uniformly under the action of weight to which the shaft is connected. When the electromagnet is energized, magnetic flux is produced thereby applying brake by retarding the rotation of the disc and therefore the energy absorbed is appeared as heating of the disc. So, when the armature is interested in the sector the stopping torque is transferred into the sector housing and into the machine frame decelerating the load. The AC motor makes the disc to rotate through the shaft by means of pulleys connected to the shaft.

IV. Analysis and Calculations

Fig 5.1 (Fabricated model of electromagnetic braking system)

The brake Rotor, Shaft, mountings and frame are the crucial component as every force experienced by the model is passed on through it. Also analysing every effect of this complex ever changing moment and forces becomes complicated. A worst case scenario's is therefore recommended where forces are scaled and restrains are applied in view of real time. The team performed various finite element computational analysis to match approximately with the actual conditions that will be experienced by the component so as to avoid failure in real-time. There are many different types of analysis that must be completed to ensure that the part in question is able to withstand the applied loads. In addition, there are other factors that must be included in each analysis to ensure that the analysis itself is correct. In order to analyse the part correctly, the restraints must be an accurate representation of the real world scenario and the loads must be calculated for different loading scenarios. Finally, the mesh must be as homogenous as possible. This would include minimizing the difference in aspect ratio between elements, as well as maximize element mapping quality. We must ensure that all of the meshes we use for the different components in our assembly are set up to be compatible with one another. The main objective behind analysis was to check the maximum stress induced, predict the life of component and establish a suitable factor of safety in design. All of the analysis was done in student package of Solid works Simulation module. Modal analysis was also done on the component to determine how the system behaves in its displacement dynamic response. It was done to check how different frequencies naturally excite the system to a degree where resonance fluctuates through the component resulting in dropping of life expectancy of the system.

- **Brake Rotor**

Material: Cast Iron IS 2062,
Torque applied 30Nm
Maximum Tensile Strength: 410 MPa

- **Shaft:**

Material: Mild Steel
Maximum Tensile Strength: 440 MPa

- **Frame and mountings:**

Material: Mild Steel
Maximum Tensile Strength: 440 MPa

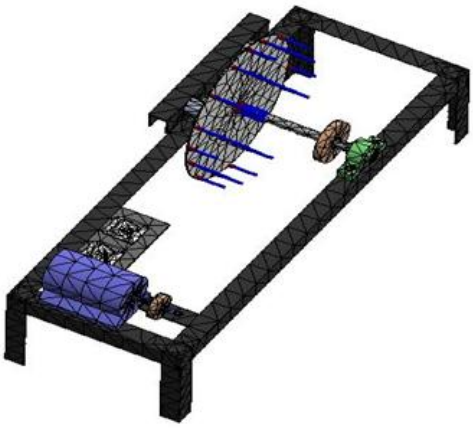


Fig 5.2 (Stress Distribution on CAD Model)

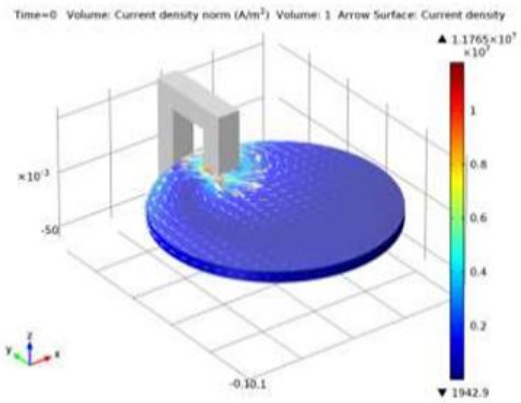


Fig 5.3 (Stress distribution on Disc)

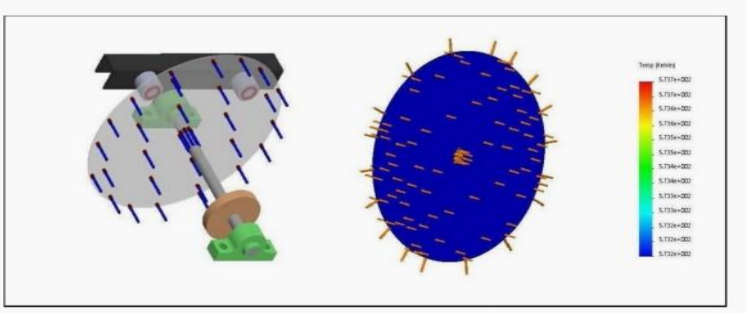


Fig. 4.2 Electromagnetic force distribution on Rotor

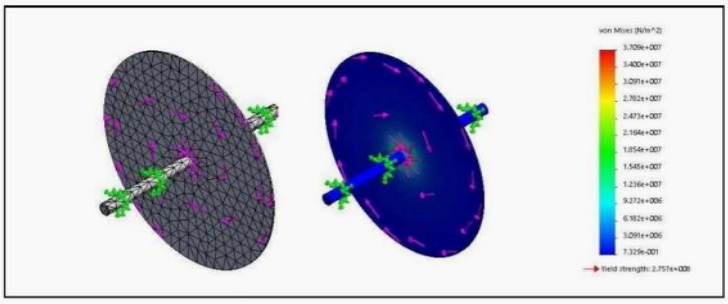
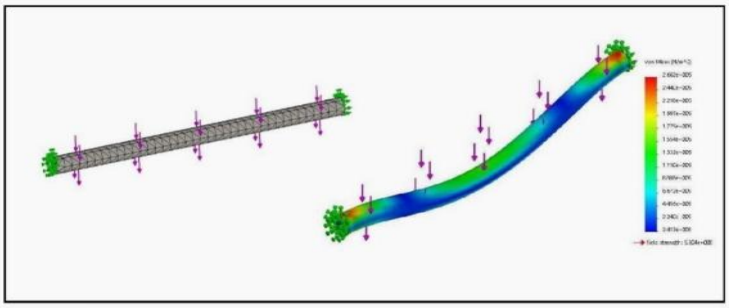


Fig. 4.3 Torque Effect on Rotor and Shaft



Calculations

Nomenclature:-

T = Torque on disc.

r = Radius of rotor disc.

ω = Angular velocity of disc.

Fc = Centrifugal force.

N_1 *= Input pulley speed= speed at driving pulley in RPM.*

N_2 *= Output pulley speed= speed at driven pulley in RPM.*

d_1 *= Input pulley diameter in cm.*

d_2 *= Output pulley diameter in cm*

Calculation:-
1.Force at wheel lock or maximum braking force can be calculated by following:
FL = Mdal × g × ur
FL = possible braking force on axle
Mdal = dynamic axle load
g = acceleration due to gravity
ur = coefficient of friction between road and tire.

2. Braking torque require to stop wheel
T = BF × R/r
BF = Braking force
T = brake torque
R = radius of tire
r = speed ratio between the wheel and brake.

3. Braking force obtained by eddy current
Fe = pie × D2 × d × B0 2 × c × v/4ρ
*c = ½ [1 – (1/4) * 1/(1 + r/A)2 (A – r/D)2]*
Fe = braking force (N)
D = diameter of soft iron pole (m)
d = disk thickness
B0 = air gap induction at 0 speed (T)
A = disk radius (m)
c = proportionality factor, ratio of total disk Contour (outward curve) resistance to resistance of Disk contour (outward curve) part under pole.
v = tangential speed of the rotating disk
ρ = specific resistance of disc material.

Consider, N_1 *= Input pulley speed= speed at driving pulley in RPM.*

N_2 *= Output pulley speed= speed at driven pulley in RPM.*

d_1 *= Input pulley diameter in cm.*

d_2 *= Output pulley diameter in cm.*

Here, $N_1 = 1000\ RPM\ , d_1 = 5.5\ cm , d_2 = 11.0\ cm$.

As $\frac{N_2}{N_1} = \frac{d_1}{d_2}$

Therefore, $N_2 = 500\ RPM$

Consider, r *= Radius of rotor disc.*

ω *= Angular velocity of disc.*

Here, $r = 3.5\ in = 88.9\ mm = 0.0889\ m$

$$\omega = \frac{2\pi N_2}{60} = \frac{2\pi(500)}{60} = 52.35\, rad/s$$

To convert RPM into relative centrifugal force (F_C),

$$F_C = (N_2)^2 \times 1.118 \times 10^{-5} \times r$$

$$= (500)^2 \times 1.118 \times 10^{-5} \times 88.9$$

$$= 248.48\, N$$

To calculate the torque (T) *on disc,*

$$T = F_C \times r$$

$$= 248.48 \times 0.0889$$

$$= 22.089\, Nm = 23\, Nm$$

Therefore we have considered $23\, Nm$ for the prototype to maintain the FOS. Stopping distance and other parameters are based on real-time model based results.

V. Application and Future Scope

A revolutionary invention is made in the field of brakes. The Electromagnetic brakes are excellent replacement for conventional automobile brakes. The use of Electromagnetic brakes can be done for lighter vehicles also. With some modification, a regenerative braking system can be equipped with the Electromagnetic brakes. The Electromagnetic brakes are the future of automobile brakes.

- Electromagnetic brakes were before used in the application of locomotives where the set up was a drum brake which is totally different from the present designs and works on the same principle and it is well used in the present high speed electric trains.
- The electromagnetic braking system is not only used in automobiles it is even used in the industrial fields where to retard or slow down the moving parts which is not efficiently performed by the other conventional methods.
- Now a days these types of braking systems are used in the field of motorsports where it is more responsive and effective and it is been used in cars like McLaren P1, La Ferrari
- Where the electromagnetic brakes are even used as clutches in other fields where they have a high holding power to the other components which will be easier to transfer the work.
- The electromagnetic braking system is even used in the industrial robotic applications where the requirement of pausing the actions.
- This type of braking system is even used in the recreational purposes where an example of the climbing devices where the rope gets locked at a particular height with the help of the electromagnetic braking inside.

VI. Conclusion

The Electromagnetic braking system is found to be more reliable as compared to other braking systems. In addition, it is found that electromagnetic brakes make up approximately 80% of all of the power applied brake applications. Electromagnetic brakes have been used as supplementary retardation equipment in addition to the regular friction of the brakes. This enhanced braking system not only helps in effective braking but also helps in avoiding the accidents and reducing the frequency of accidents to a minimum. Furthermore the electromagnetic brakes prevent the danger that can arise from the prolonged use of brake beyond their capability to dissipate heat. ABS usage can be neglected by simply using a micro controlled electromagnetic disk brake system. For the brake distribution of the electromagnetic braking system, the abrasion, noise, harmful friction dust, and the risk of thermal failure in braking system were reduced obviously. The braking power delivered in this brake is not as much as the plate brakes. Subsequently, it can be utilized as an auxiliary or crisis slowing mechanism in the automobile field. Electromagnetic braking system is found to be more reliable as compared to other braking systems. In oil braking system or air braking system even a small leakage may lead to complete failure of brakes. While in electromagnetic braking system as four, this enhanced braking system not only helps in effective braking but also helps in avoiding the accidents and reducing the frequency of accidents to a minimum. The blend of swirl present and attractive powers makes this brake more successful. These electromagnetic brakes can be used in wet conditions which eliminate the anti-skidding equipment, and cost of

these brake are cheaper than the other types. The concept designed by us is just a prototype and needs to be developed more. It can not only be used in the field of automotive but also in the field of aeronautics. Hence the electromagnetic braking system can be a better technological revolution in the future application.

- Advantages and Disadvantages of electromagnetic braking system over conventional braking system has been studied.
- Electromagnetic brakes have higher performance than conventional brakes in high speeds but it cannot be used at low speeds. Hence it must be used as an auxiliary brake during high speeds.
- With decrease in Air Gap there is increase in Magnetic flux passing through the rotor resulting in increased Braking Torque and hence reduced Braking time.
- Cast Iron disc of thickness 1.5mm having an air gap of **1mm** provides the best results.
- The speed of the disc reduces from 500 rpm to 0 rpm in **2.8s.**
- By observing real time rotor stopping distance we can conclude that vehicle stopping distance is reduced to a huge extend with reducing friction losses.

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