Design and Development of Contactless Breaking System for Automobiles

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ABSTRACT

The contactless brake is a new and revolutionary concept, maintenance free brake system is a modern technology braking system used in light motor & heavy motor vehicles like car, jeep, truck, buses etc. This system is a combination of electro-mechanical concepts. The frequency of accidents is now-a-days increasing due to inefficient braking system. In this research work, with a view to enhance to the braking system in automobile, a prototype model is fabricated and analysed.

Keyword: -. *Brakes, Eddy Currents, Retardation.*

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1. INTRODUCTION

When electromagnets are used, control of the braking action is made possible by varying the strength of the magnetic field. A braking force is possible when electric current is passed through the electromagnets. The movement of the metal through the magnetic field of the electromagnets creates eddy currents in the discs. These eddy currents generate an opposing magnetic field, which then resists the rotation of the discs, providing braking force. The net result is to convert the motion of the rotors into heat in the rotors.

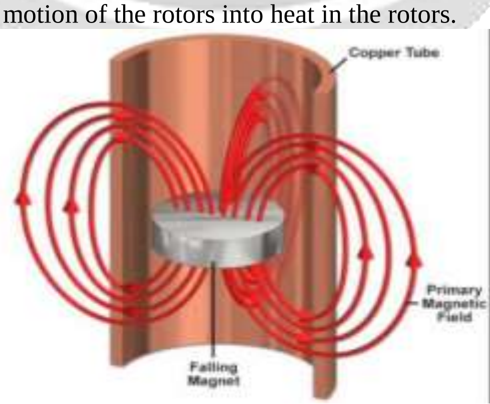

Figure 1: copper pipe & Neodymium magnet

Eddy currents are flow in a circular path. They get their name from "eddies" that are formed when a liquid or gas flows in a circular path around obstacles when conditions are right. When an electrically conductive material is placed in the coil's dynamic magnetic field electromagnetic, induction will occur and eddy currents will be induced in the material. Karnopp, M., (1989). Eddy currents flowing in the material will generate their own "secondary" magnetic field which will oppose the coil's "primary" magnetic field according To the Lenz's rule.

2. LITERATURE REVIEW BASED ON RESEARCH PAPERS

1. N. Paudel, S. Paul, and J. Z. Bird in his paper general 2-D analytic based transient formulation for a magnetic source moving above a conductive plate has been derived. The formulation is written in a general forms of magnetic source can be utilized. The derived field and force equations need to be computed by evaluating a single integral. The conductive region was solved for the vector potential whereas the air region was solved for the magnetic scalar potential. The inverse Laplace transform of the vector potential was obtained by using the Heaviside expansion theorem. The transient solution for the normal and tangential forces along the surface of the conductive plate were obtained by using Maxwell's stress tensor and Parseval's theorem. The use of Parseval's theorem circumvented the need for inverse Fourier transforming. The derived equations were validated by comparing them with two different 2-D FEA transient models.
2. Authors: Virendra Kumar Maurya, RiturajJalan, H. P. Agarwal, S. H. Abdi, Dharmendra Pal, G. Tripathi and S. Jagan Raj.
   With all the advantages of electromagnetic brakes over friction brakes, they have been widely used on heavy vehicles where the 'brake fading' problem is serious. The same concept is being developed for application on lighter vehicles. A Halbach magnetized mover was applied to a high-speed eddy current braking system. Based on analytical 2-D field solutions considering dynamic end effect, the magnetic field, eddy current distribution, and forces according to the secondary relative permeability and conductivity were presented. It was observed that the air-gap flux density has a non-uniform distribution for the high speed. Comparisons between numerical simulations and experimental data were also presented.
3. Authors: Andrew H. C. Gosline, Student Member, IEEE, and Vincent Hayward, Fellow, IEEE
   The pertinent background to dissipative actuation and passivity control of haptic interfaces were first discussed to familiarize the reader with the focus of this paper. Basic eddy current brake physics were presented, the design of an ECB damper for the Pantograph haptic interface was described, and results from an experimental optimization of damping hardware were discussed. A prior existing time domain passivity control methodology was adapted for the use of physical damping, rather than virtual. The physically damped passivity controller was shown to improve stability of virtual stiff wall. The authors would like to note that virtual walls rendered using the physical dampers do not have the characteristic "sticky" feel that is typical of walls increases considerably. There are also limitations to the use of physical dampers for passivity control. First, as this method is dependent on additional hardware, a haptic interface would have to be equipped with programmable physical dampers to make use of this method. Second, as the dampers actuate slower than the motors, the system energy could be in the active region longer than if virtual damping was used.
4. Authors:- Kapjin Lee, Kyihwan Park
   In order to solve the problems of the conventional hydraulic systems such as time delay response due to pressure build-up, brake pad wear due to contact movement, bulky size, and low braking performance in a high speed region, an eddy current brake system is developed and its performance is investigated by using a scaled model. Braking torque analysis is performed by using an approximate theoretical model and the braking torque is experimentally compensated. Optimal torque control which can shorten the braking distance is achieved by maintaining a desired slip ratio which gives the maximum braking force coefficient. A sliding mode controller is used for the optimal torque controller. From simulation and experimental results, it is observed that the eddy current brake (ECB) provides a fast braking response because it is capable of fast anti-lock braking.

3. DESCRIPTION

3.1 Components selected for the project has the following specifications:-

- **WHEEL**

A wheel is a circular component that is intended to rotate on an axle bearing. The wheel is one of the main components of the wheel and axle which is one of the six simple machines. Wheels, in conjunction with axles, allow heavy objects to be moved easily facilitating movement or transportation while supporting a load, or performing labor in machines.

Figure 2: Wheel

Common examples are found in transport applications. A wheel greatly reduces friction by facilitating motion by rolling together with the use of axles. In order for wheels to rotate, a moment needs to be applied to the wheel about its axis, either by way of gravity, or by the application of another external force or torque.

- **SHAFT**

A drive shaft, driveshaft, driving shaft, propeller shaft (prop shaft), or is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them.

Figure 3: Shaft

As torque carriers, drive shafts are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia.
To allow for variations in the alignment and distance between the driving and driven components, drive shafts frequently incorporate one or more universal joints, jaw couplings, or rag joints, and sometimes a splined joint or prismatic joint.

- **PULLEY**

A pulley is simply a collection of one or more wheels over which you loop a rope to make it easier to lift things. Pulleys are examples of what scientists call simple machines. That doesn't mean they're packed with engines and gears; it just means they help us multiply forces. If you want to lift a really heavy weight, there's only so much force your muscles can supply, even if you are the world's strongest man.

But use a simple machine such as a pulley and you can effectively multiply the force your body produces. A pulley is a wheel on an axle or shaft that is designed to support movement and change of direction of a cable or belt along its circumference. Pulleys are used in a variety of ways to lift loads, apply forces, and to transmit power.

Figure 4: Pulley

Material used for pulley is cast iron. We are attaching pulley to the motor shaft and another to the shaft to reduce the speed of the motor.

- **V-BELT**

V belts solved the slippage and alignment problem. It is now the basic belt for power transmission. They provide the best combination of traction, speed of movement, load of the bearings, and long service life. They are generally endless, and their general cross-section shape is trapezoidal. The V shape of the belt tracks in a mating groove in the pulley, with the result that the belt cannot slip off. The belt also tends to wedge into the groove as the load increases the greater the load, the greater the wedging action improving torque transmission and making the V-belt an effective solution, needing less width and tension than flat belts. V-belts trump flat belts with their small center distances and high reduction ratios. The preferred center distance is larger than the largest pulley diameter, but less than three times the sum of both pulleys. Optimal speed range is 300–2,130 m/min. V-belts need larger pulleys for their thicker cross-section than flat belts.

- **COPPER DISC**

Copper disc is the main part of the project. It is mainly used for breaking purpose and generating the EDDY current. A disc brake is a type of brake that uses calipers to squeeze pairs of pads against a disc in order to create friction that retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. Hydraulic disc brakes are the most commonly used form of brake for motor vehicles but the principles of a disc brake are applicable to almost any rotating shaft.

Figure 5: Copper Disk

Compared to drum brakes, disc brakes offer better stopping performance because the disc is more readily cooled. As a consequence discs are less prone to the brake fade caused when brake components overheat. Disc brakes also recover more quickly from immersion (wet brakes are less effective than dry ones).

- **NEODYMIUM MAGNET**

A neodymium magnet (also known as NdFeB, NIB or Neo magnet), the most widely used type of rare-earth magnet, is a permanent magnet made from an alloy of neodymium, iron and boron to form the $Nd_2Fe_{14}B$ tetragonal crystalline structure. Developed in 1982 by General Motors and Sumitomo Special Metals, neodymium magnets are the strongest type of permanent magnet commercially available.

Figure 6: Neodymium Magnet

They have replaced other types of magnets in the many applications in modern products that require strong permanent magnets, such as motors in cordless tools, hard disk drives and magnetic fasteners. Neodymium magnets are graded according to their maximum energy product, which relates to the magnetic flux output per unit volume. Higher values indicate stronger magnets and range from N35 up to N52.

- **SINGLE PHASE 1 H.P. MOTOR**

Figure 7: Motor

An induction or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type. We are using motor for power transmitting to the shaft.

3.2 Design of model

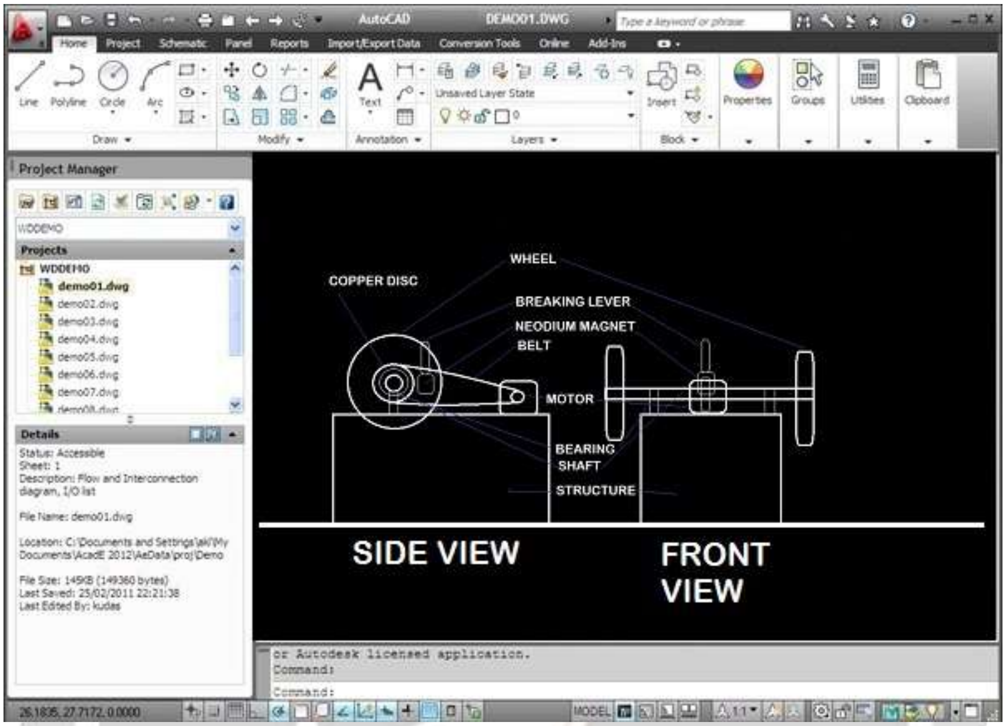

Figure 8: AutoCAD model

3.3 Design Calculations

- **MOTOR SELECTION**

Hence, WE ARE SELECTING 1 HP AC SINGLE PHASE MOTOR.
1 HP = 746 WATTS
RPM of motor = 1400

We know that
$P = 2 \times \pi \times N \times T / (60)$
$746 = 2 \times \pi \times 1400 \times T / (60)$
T = 5.090.9 N.mtr
T = 5090.9 N.mtr

- **DESIGN OF SHAFT**

Now, we know torque is 5099.9 N
Shaft Dia = ds
Now,
Torque Transmitted to the Shaft
$T = \pi/16 \times (ds)^3 \times \tau_{ms}$
$5090.9 = \pi/16 \times (ds)^3 \times 35$
$(ds)^3 = 13430.35$

ds = 23.77 mm
We are selecting Diameter of Shaft 25 mm

- **DESIGN OF V-BELT**

Speeds in the two pulleys are related by the equation

$N_d / N_D = D/d$

N_d = speed in the small pulley in R.P.M (Connected with motor)= 1400 RPM

N_D = speed in the larger pulley, in R.P. M (Connected with shaft) = ?

Small pulley diameter = 3 inch = 76.3 mm

Larger pulley diameter = 12 inch = 304.8 mm

$N_d / N_D = D/d$

$1400 / N_D = 304.8/76.3$

$N_D = 350$ RPM

$V = \pi DN/60 = 5582.08$ mm/sec

V = 5.582.08 m/s

Now,

$$\theta d = \pi - 2\sin^{-1}\frac{D-d}{2c}$$

= 153.5" = 2.679 *radians*

= 206.5° = 3.604 *radians*

The length of the belt is given by the expression,

$$L = \sqrt{4C^2 - (D-d)^2} + 1/2(D * \theta D + d * \theta d)$$

from above , L = 1.781Mtr
Where, D=282.44 mm
L = 1781.21mm
d-76.3 mm
C=179.37 mm
Mass of one belt is given by, *m = A * L * p*
Taking density, *p* = 1200 $Kg/_m3$
2 40° as from Shigleys Table 17-9
*mass, m = 1200 * 1.781 * A - 2137.2/4 Kg*

Centrifugal tension in the belt is given by, $T_c = mv^2$

$T_c = m * 5.582^2 = 70727A$ N

Maximum tension in the belt is given by, $T = \quad * A$

Given the allowable stress in the belt is, $_{ali} = 7.0\ Mpa$

Therefore, T $= 7.0 * 10^6 * A\ N$

Tension on the belt in the tight side,$T_1 = T - T_c = (7.0 * 10^6 A — 70727A)$

T_1 =6929273A

T_2 = Tension in the slack side

The above parameters are related to the groove angle and coefficient of friction by the following expression,

$$2.3\log\left(\frac{T_1}{T_2}\right) = \mu * \theta_d \operatorname{cosec}\beta$$

Substituting for the values in the above equation,

$T_2 = 2.44 * 10^s A$

Power transmitted by the belts is given by, $P = (T_1 - T_2)\ v$ ** no of belts*

But from earlier calculations, the power transmitted is 0.7311 KW Taking the number of belts to be 1,

$0.7311 * 10^3 = (6.2537 * 10^s.4 - 2.44 * 10^s\ A) \times 5.582 * 1$

so, $A = 735\ mm^2$

The standard dimensions for v-belts, we choose the dimensions that give the nearest area to the one calculated above.

From Standard Table,

we select belt of type- A Groove

Width -13 mm

Thickness - 8 mm

- **POWER LOSS VIA EDDY CURRENT**

$P = (\pi^2 B_P^2 d^2 f^2)/(6K \rho D)$

Where

P is the power lost per unit mass (W/kg),

Bp is the peak magnetic field (T),

d is the thickness of the sheet or diameter of the wire (m),

f is the frequency (Hz),

k is a constant equal to 1 for a thin sheet and 2 for a thin wire,

ρ is the resistivity of the material (Ω m), and

D is the density of the material (kg/m3)

4. CONCLUSIONS

With all the advantages of contactless brake over friction brakes, they have been widely used on heavy vehicles where the 'brake fading' problem is serious; which can be eliminated at the higher speeds. The same concept is being developed for application on lighter vehicles. A prototype will be developed for providing a demo of high-speed eddy current braking system. Based on analytical 2-D field solutions considering dynamic end effect, the magnetic field, eddy current distribution, and forces according to the secondary relative permeability and conductivity were presented.

5. REFERENCES

[1] Kapjin Lee, Kyihwan Park "Optimal robust control of a contactless brake system using an eddy current", Department of Mechatronics, Kwangju Institute of Science and Technology, 500-712,South Korea, 20 October, 1998.

[2] S. ANWAR, R.C. STEVENSON "Torque characteristics analysis for optimal design of a copper-layered eddy current brake system", Department of mechanical engineering, Purdue University Indianapolis, Indiana 46202, USA; Automotive Component Holdings, LLC, Ypsilanti, MI 48198, USA, 23 April, 2011

[3] Henry A. Sodano, Jae-Sung Bae, Daniel J. Inman, W. Keith Belvin "Concept and model of eddy current damper for vibration suppression of a beam" 27th January, 2005.

[4] Andrew H.C. Gosline,"Eddy current brakes for Haptic Interfaces: Identification, and control. Student member, IEEE, and Vincent Hayward, Fellow, IEEE.

[5] E. simeu and D. Georges "Modeling and control of an eddy current brake". TIMA Laboratory, 46, avenue Felix Viallet, 38031, France, September, 1995 .

[6] Virendra kumar Maurya, Rituraj Jalan, H.P. Agarwal. S.H. Abdi, Dharmendra Pal, G.Tripathi and S. Jagan Raj. "Eddy current braking embedded system" BBD University Campus, Lucknow, Uttar Pradesh, India.

[7] Manuel I Gonzalez, "Experiments with eddy currents: the eddy current brake", Department of physics, spain. 20th April, 2004.

[8] Kerem Karakoc, Afzal Suleman, Edward J. Park. "Analytical modelling of eddy current brakes with the application of ime varying magnetic fields", Department of mechanical engineering, university of Victoria, Canada.

[9] N. Paudel, S. Paul, and J.Z. Bird. "General 2-D transient eddy current force equations for a magnetic dource moving above a conductive plate". Department of electrical and computer engineering, university of north Carolina at charlotte, 9201 university city boulevard, Charlotte, NC 29223, USA,2012.

[10] Seok-Myeong Jang, member, IEEE, Sung-Ho Lee, and Sang-Sub Jeong. "Characteristic analysis of eddy-current brake system using the Linear Halbach Array". September, 2002.