Eddy Current Braking In Automobiles

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Abstract - *Eddy Current Braking slows a moving object by creating eddy currents through electromagnetic induction which create resistance. In normal case if the speed of the vehicle is very high, the brake does not provide that amount of high braking force and it will leads to skidding and wear& tear of the vehicle. Because of this drawbacks of ordinary brakes, arises a simple and effective mechanism of braking system 'The eddy current brake'. Eddy current is one of the most outstanding of electromagnetic induction phenomena. Even though it appear many technical problems because dissipative nature it has some valuable contributions. It is a frictionless method for braking of vehicles including trains. As it is a frictionless brake, periodic change of braking components are reduced. Embedded Eddy Current brake is employed in automobiles, the braking would be more efficient than the present friction based brake and braking cost in automobiles could be reduced to a larger extend. Also toxic smell caused by friction brakes during vehicle motion can be reduced.*

Key Words: Conventional Braking System, Eddy Current, Aluminium Disc, Electromagnet, Eddy Current Braking System, Eddy Current Embedded Conventional Braking system, Ansys

1. INTRODUCTION

Towards green technology, which focused on the importance of environment conservation, a move to a new braking system is needed. A new braking system to replace the current braking system which used the brake pad will help to reduce the air pollution that actually happen when we do braking using the conventional system. Brake wear debris represent obviously potential hazard to environment (Kukutschova et al, 2009) [2]. Wear debris contains several hazardous elements that may interact with DNA of living organisms and cause carcinogenesis (Uexkull et al, 2005) [3]. Eddy current braking has a lot of advantages compared to conventional braking system. The advantages such as it can reduce the wear of brake pad, vibration and it is environmental friendly. Eddy current braking was said as environmental friendly because it can reduce the pollution of wear debris from brake pad itself. Realizing the importance of a new braking system that could lead into environmental friendly and reduce common problems mentioned above, this experiment was conducted to study the behaviour of eddy current braking system which uses an electromagnet and aluminium as the brake disc material. In electromagnetic induction, eddy current is one of the most important phenomena which can be applied in various kinds of research and application. This eddy current braking occurred when a magnetic drag force is produced to slow down the motion when a conducting material is moving through a stationary magnetic field (Jou et al, 2006) [8]. The changing magnetic flux induces eddy currents in the conductor and these currents dissipate energy and generate drag force (Jou et al, 2006) [8]. Therefore, there are no contacting elements by using this electromagnetic braking system which will lead to reduce the wear of brake pad. This situation will also reduce the wear debris pollution into our environment.

1.1 Conventional Braking System

Braking forms an important part of motion of any automobile or locomotive. Effective braking ensures the safety of the passengers and goods an automobile or a locomotive is carrying. The most basic designs of the braking system involve the conversion of kinetic energy to heat energy by friction. This is accomplished by friction between two rubbing surfaces. These brakes pose several problems i.e. significant wear, fading, complex and slow actuation, lack of fail-safe features, increased fuel consumption due to power assistance, and requirement for anti-lock controls. The conventional type brake system which uses a hydraulic system has many problems such as time delay response due to pressure build-up, brake pad wear due to contact movement and bulky size.

1.2 Eddy Current

"EDDY", the term developed by Focault Bae J. S. (2004), found that when the magnetic flux linked with a metallic conductor changes, induced currents are developed in a conductor in the form of closed loops (fig-1). These currents are known as eddy current. When there is a conductive material, which breaks through a time varying magnetic flux, eddy current are developed in the conductor. Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field. These eddy current flow inside the conductor developing a magnetic field of opposite polarity as the applied magnetic field. The magnitude of the current in a given loop is proportional to the strength of the magnetic field, the area of the loop, and the rate of change of flux, and inversely proportional to the resistivity of the material. The interaction of two magnetic fields causes a force that resists the change in magnetic flux. A nearby conductive surface will exert a drag force on a moving magnet that opposes its motion, due to eddy currents induced in the surface by the moving magnetic field. This effect is employed in eddy current brakes.

1.3 Break Disc

Aluminium is the best material compared to copper and zinc to be use as the disc brake for eddy current braking using electromagnetic induction. Aluminum reacts better and faster compared to the other two materials. Besides that, increasing the current induced will increase the drag force that been produced and will slow down the motion better. This can be seen when the current increase, the speed of the disc rotation has been reduced. Also aluminium does not get attracted in a magnetic field but Eddy current generation due to electromagnetic induction is high. As the thickness of disc increases the generation of eddy current increase and hence higher breaking torque to stop the rotating disc can be achieved.

1.4 Electromagnets

Electromagnets are DC type that can be powered by battery. Electromagnets are selected instead of permanent magnet as electrical actuation is faster than mechanical actuation with lower losses. Also magnetic field can be created at the time when it is needed only unlike permanent magnet. The strength of magnetic field can be increased by increasing the current flowing through the coil or increasing the number of turns of winding. For high magnetic field, permanent magnet is very bulky and installation is very difficult. Electromagnet is light and can be installed anywhere and does not interfere with other metals.

2. METHODOLOGY

When a conductor in the form of disc rotating at a high speed, is placed in a magnetic field it breaks the magnetic flux lines, hence an electromotive force (emf) will be induced in the disc by Faraday's law of electromagnetic induction. Due to this emf eddy currents are generated in the disc. These eddy currents are generated in loops (fig-1). These Eddy current generates a magnetic field on its own due to self-induction which opposes the source magnetic field. Due to this a drag force is created which convert kinetic energy of rotating disc to heat energy. This heat energy is then dissipated out by convection. Braking force is proportional to change in magnetic flux. Hence braking force obtained is proportional to strength of magnetic field and rate of change at which the disc is cutting the magnetic field that is velocity of disc.

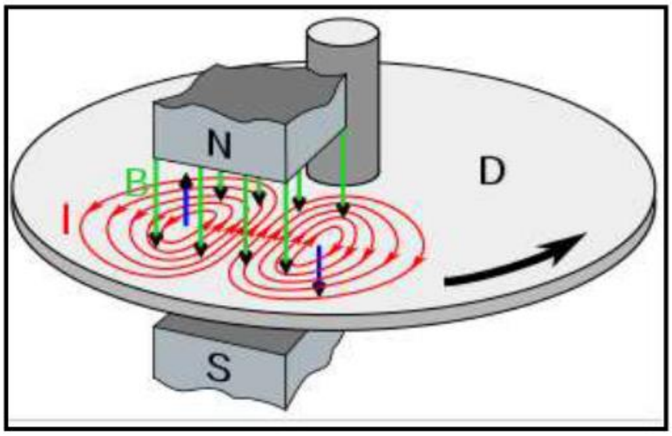

Fig -1: Eddy current generation

2. 1 Advantages

1) These are non-mechanical, no moving parts hence no friction , 2) Fully resettable, no parts need to be replaced, 3) Can be activated at will via electrical signal., 4)Low maintenance cost, 5) Operates at any rotational speed.

2. 2 Disadvantages

1) Braking force diminishes as speed diminishes with no ability to hold the load in position at standstill,
2) Dependency on electric current

2.3 Experimental Setup

Experiment is conducted in a two wheeler (Yamaha crux). Aluminium disc of thickness 13 mm is attached to the chain sprocket of bike (fig-2). Electromagnet of 12 volt 14 ampere rating is used and is attached near to the aluminum disc with an air gap of 3 mm (Fig-3). The 3 mm air gap is selected to reduce the reluctance in magnetic field to the disc. The electromagnet can be powered directly from the magneto winding of the vehicle. However in this experiment two 7 ampere battery in parallel is used (fig-4).

Fig -2: Aluminium disc attached to sprocket

Fig -3: Electromagnet attached near to disc (3mm gap)

Fig -4: Battery in parallel connection

3. ANALYSIS

Analysis is done using ANSYS R15.0. The 3d model of the disc was made in DS Solidworks 14. The eddy current braking convert kinetic energy of rotating disc to heat energy which is dissipated to surrounding. The heat energy is dissipated by convection. As disc is rotating in air heat transfer occur by forced convection.

3.1 Temperature Distribution

Temperature distribution of aluminum disc (fig-5) is analyzed. Electromagnet rating are 12 volt 14 ampere. So maximum heat input to disc is 12*14=168 watts. The heat is dissipated to surrounding by forced convection as disc is rotating. The ambient temperature is taken as 30^0c. The maximum peak temperature reached is 30.097^0c. Because of the discontinuity in the aluminium disc due to the bolts, temperature developed is more between the bolts.

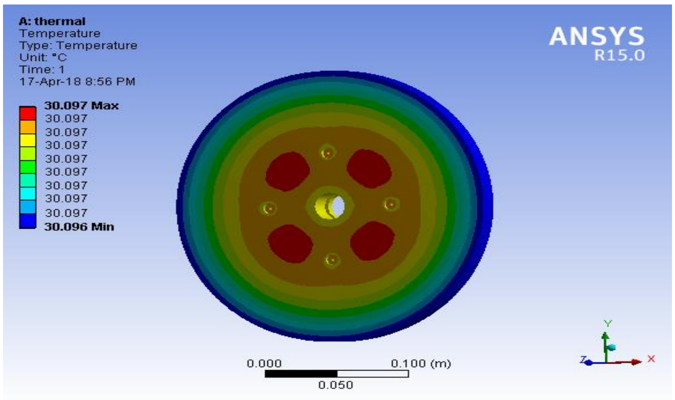

Fig -5: Temperature distribution of aluminium disc

3.1 Deformation of Disc during Braking

During braking a drag force is created in the disc and due to this the disc may deform. Assuming the maximum speed of vehicle to be 100 kmph, the total weight with passenger be 200 kg.

100 kmph=27.7 m/s
By conservation of energy,
Work done = change in kinetic energy
Final velocity =0 m/s
Kinetic energy = .5*mass*velocity^2
Final kinetic energy =0
Fb x displacement = 0- (.5*200*$(27.7)^2$)
Where Fb is braking force
Let the braking distance be 30m
Fb x 30 = 76729
Fb = 76729/30
Fb = 2500 N

Applying this constraint on ANSYS the deformation chart is obtained (fig-6). The maximum deformation is found to be 2.6829×10^{-5} m. This is below the yield strength of aluminium and hence disc will not get deformed.

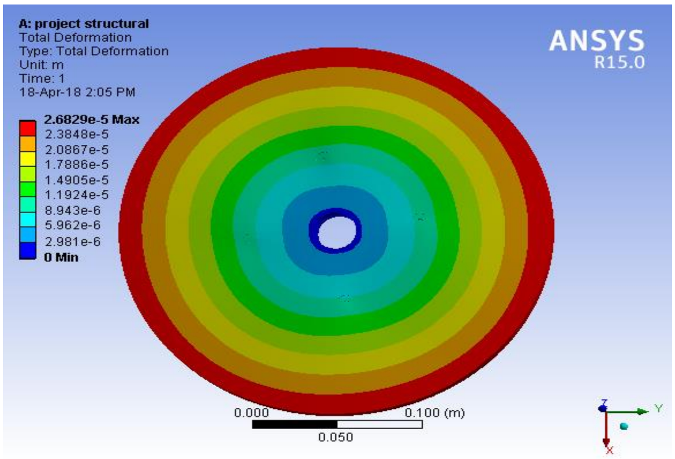

Fig -6: Deformation of disc during braking

4. RESULTS

The experiment is conducted on keeping the vehicle on center stand. The speed are measured using a tachometer and time is measured using stop watch. The speed of the wheel reduced from 70 kmph to 0 kmph within 5 seconds. The wheel does not get stopped instantaneously but it slows down the speed and bring it to rest. Hence wheel locking is avoided and antilock braking system is not needed. Since there is no locking of wheel, skidding is prevented.

5. DISCUSSIONS

Eddy braking system is successfully implemented and tested. This braking system can be incorporated along with conventional braking system as Eddy Current Embedded Conventional Braking System. Eddy current braking can be successfully used as an auxiliary brake. This is particularly useful to heavy and long distance travelling vehicle. In case of heavy vehicles the normal brakes get heated up and become less efficient on continuous usage. In this case eddy current braking can be used efficiently. Also eddy braking can be used as a safety brake. Eddy braking also find application in high speed vehicles as braking force is proportional to speed of vehicle. The world is moving towards greener technology and electric vehicles are gaining more and more popularity. Thus cleaner braking like eddy current braking system find more applications in future. Eddy current braking are trialed with electric trains and was successful. This can be successfully incorporated to automobiles. Power required for magnetic field can be taken directly from magneto winding of automobile and hence dependency of battery is low.

6. CONCLUSION

Eddy current braking produce effective braking with low wear and tear. The maintenance cost of this braking system is very low. Eddy current braking is a non-contact breaking system and hence there is no friction and low wear and tear. Thus debris produced in braking is very low and hence is ecofriendly. Eddy current braking is a cleaner way of braking. Wheel skidding is avoided as the wheel does not get locked. It is highly suitable at high speed. It works on electricity and consumes very small amount of power for a tiny time period. It only Consumes small space therefore installation is easy

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REFERENCES

[1] A.Aravind , V.R.Akilesh, S.Gunaseelan, S.Ganesh “ Eddy current embedded conventional braking system” - IJIRSET Volume 5, Special Issue 7, April 2016

[2] K. Kukutschovaa, V. Roubiˇceka, K. Malachovab, Z. Pavliˇckovab, R. Holuˇsab, J. Kubaˇckovac, V. Miˇckac, D. MacCrimmond, P. Filip d. 2009. Wear Mechanism in Automotive Brake Materials, Wear Debris and its Potential Environmental Impact, International Journal of Wear

[3] O. Uexkull, S. Skerfving, R. Doyle, M. Braungart. 2005. Carbide Antimony in brake pads—a carcinogenic component, J. Cleaner Prod. 13(2005) 19-31.

[4] Er shivanushrivastava “A Parametric Analysis of Magnetic Braking – The Eddy Current Brakes – For High Speed and Power Automobiles and locomotives” IJAREEIE Vol. 3, Issue 8, August 2014

[5] Sevvel “Innovative Electro Magnetic Braking System” IJIRSET Volume 3, Special Issue 2, April 2014

[6] Der-Ming Ma “The Design of Eddy-Current Magnet brakes “December 2010 Department of Aerospace Engineering, Tamkang University, Danshuei, Taiwan 25137, Republic of China

[7] Akshyakumar S Puttewar “Enhancement of Braking System in Automobile Using Electromagnetic Braking” IJAREEIE, 2010

[8] M. Jou, J.K. Shiau, C.C. Sun. 2006. Design of a Magnetic Braking System,

[9] Journal of Magnetism and Magnetic Materials, 304(2006) c234-c236.

[10] Gigih Priyandoko, M.Z Baharom, (2015), “Eddy current braking experiment using brake disc from aluminium series of A16061 and A17075”

[11] G. Priyandoko, M.Z. Baharom, (2011), “Eddy Current Braking Study for Brake Disc of aluminium, Copper and Zink, Regional Engineering Postgraduate Conference (EPC) 2011

[12] P. Hanyecz, (1982), “Calculation of Braking force in Eddy current brakes”, Department of Theoretical Electricity. Technical University Budapest

[13] Gurav Mahadeo, Neeraj Gupta, Shivam Chaturvedi, Pratik Raut International Journal of Advance Research, Ideas and Innovations in Technology,2017

[14] “Experiments with eddy currents: the eddy current brake”- Manuel I Gonzalez- Departamento de F´ısica, Universidad de Burgos, 09006 Burgos,Spain

[15] “Design of an Innovative Car Braking System using Eddy Currents”- David Jose Torres Cruz- Bachelor in Aerospace Engineering, Instituto Superior Tecnico (IST), 2002 & MASTER OF APPLIED SCIENCE in the Department of Mechanical Engineering. University of Victoria

[16] Gagarin, G., Kroger, U. And Saunweber, E., „„Eddy-current magnetic track brakes for high speed trains,““

Joint ASME/IEEE/AAR Railroad Conference, pp. 95–99, 1987

[17] Marc T. Thompson, Edward Pribonic, (2003)," Eddy current braking apparatus", USPO6533083

[18] P. J. Wang and S. J. Chieuh, "Analysis of Eddy-Current Brakes for High Speed Railways" Transactions On Magnetics, VOL 34, NO.4, JULY 1998

[19] Kyi Wan Park; Kap J in Lee, (2001), "Contactless eddy current brake for cars", USPO6286637

[20] Pushkin Kachroo, (1997), "Modelling and control of Electromagnetic brakes", Faculty Publications, University of Nevada, Las Vegas