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An Empirical Review of Electromagnetic Braking Systems

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ABSTRACT: Engineering complications in actual sense incorporate linguistic information process that proves complex to enumerate through conventional calculations since it is a representation of subjective knowledge. Failure to quantify linguistic information results, therefore, to assumptions in developing mathematical models. Moreover, in transportation engineering, several values are described through improbability, subjectivity; imprecision's as well as ambiguity. The electromagnetic braking system uses magnetic strength to decrease or stop the speed in wheel rotation. The idea of electromagnetic braking comes with the advantages and disadvantages of stresses in calipers and dissipation of heat.The electromagnetic braking system entirely depends on magnetic power to move the parts of the braking system. The system indulges the principle of if a magnetic field is induced in the rotating disc, then the other side produces the eddy current of the movement or rotation of the disc brake. The major parts of an electromagnetic braking system are braking discs, solenoid, circuit board, step-down transformer and battery power. In other words, human operators, dispatchers, drivers, as well as passengers, gauge the context of a situation through idiosyncratic knowledge or linguistic evidence in regular decisions. Electromagnetic braking system is classical example of increased effectiveness of braking system while minimizing losses. In this paper the focus is provided on comparison between Electromagnetic braking system and conventional exhaust braking system. The focus of Electromagnetic system is to increase the safety of the device meanwhile keeping the losses to minimum. The sole aim of the research study lies on providing advantages of both the systems as well as clearly mentioning their ambiguities.
Keywords: Electromagnetic braking, exhaust braking, eddy current, electromagnet

I. INTRODUCTION

This section introduces us to the research study. It consists of background of the research, significance of the research, research rationale, scope, questions, hypotheses, aim, and objectives.

A. Background Of The Research

Automobile industry is a constantly changing industry with the fast pace of technological developments and implementations. With introduction of new and powerful machine the need to stop these machines also arises. Not on stopping but increasing the efficiency to maximum in order to keep the energy losses to minimum. Generally friction braking or exhaust braking is used in the automobiles, friction or exhaust braking system comprises of means to use friction to convert Kinetic energy of body into Heat energy causing the motion to retard. The stopping force generated by a braking system is more than the actual energy generated by engines. Nowadays the greater power of engines and greater need for safety has caused to develop a system to minimize the dangers. Vehicle safety improvement is one area in the automobile industry that is increasingly being emphasized with passing time. Stability of vehicles running on the road is very much dependent on the ongoing improvements in brake technology. Currently, for the purpose of improving braking functionality and to have the least environmental impact, automotive manufacturers are investing in developing EMB (Electromechanical braking systems).

Electromagnetic brakes are simply an mechanical brakes which bring about retardation by applying electromagnetic induction in the disc brake in direction opposite to the rotation of the actual disc i.e. If vehicle is moving forward then rotation of disc will be clockwise (Frame of reference is from left hand side of vehicle) then the magnetic field will be counterclockwise. By this way the motion of the brake is retarded by the brakes but there is no physical contact in any case. This is a revolutionary concept. Hence electrical energy from the appropriate power source is used to the purpose. As any type of brake the heat energy is generated in the brakes which have to be exhausted into environment but wear and tear is minimized. Brakes are imperative for any vehicle and a substantial vehicle by and large uses grating brakes alongside Electromagnetic brakes. This venture primarily concentrates on building a slowing mechanism, which can be material in bike at fast and low upkeep cost. This framework utilizes an electromagnet connected directly to vehicle's battery. Electromagnetic brakes are likewise called electro-mechanical brakes or EM brakes and moderate or stop movement utilizing electromagnetic constrain to apply mechanical resistance.

B. Significance Of The Research

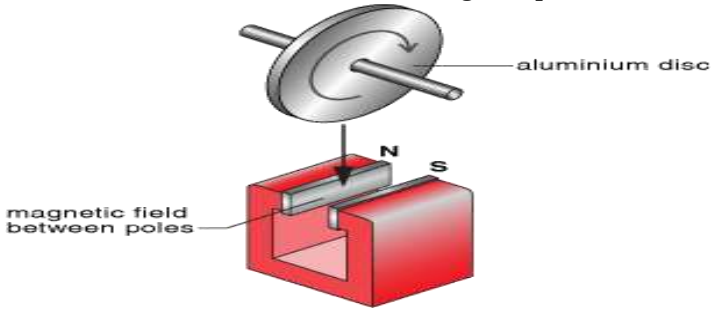
Electromagnetic brakes are a new revolutionary concept. It is found that electromagnetic brakes generate negative energy which is twice as that of the Energy generated by engines, and three times more the exhaust system. Types of braking system is Exhaust braking system

Drum brakes: In drum brakes the motion is retarded by using a brake pad mounted inside the drum of the wheel. Which brakes are applied then the pad lined with frictional material rubs against the drum and retardation is observed.

Disc brakes: Disc brakes are hydraulic type of braking system. In this braking system which brakes are applied fluid from master cylinder is generates pressure and this pressure is passed through fluid lines. This fluid applies pressure on slave cylinders, causing them to rub against the disc. Heads of slave cylinders are also coated with frictional material to increase the effectiveness.

When braking action is brought by the use of electromagnetic induction rotation Electromagnetic brakes brings about the same action as above stated brakes only with greater efficiency and effectiveness. In this report we observe the studies done on the said topic and various developments the field of braking and careful use of energy.

Aluminum disc between magnetic poles



Prototype brake setup

Vehicle safety improvement is one area in the automobile industry that is increasingly being emphasized with passing time. Stability of vehicles running on the road is very much dependent on the ongoing improvements in brake technology. Currently, for the purpose of improving braking functionality and to have the least environmental impact, automotive manufacturers are investing in developing EMB (Electromechanical braking systems). These braking systems are unique in the sense (Electromechanical braking systems). A greater torque becomes necessary to produce enough thrust that would be required to brake when these actuators are used. For this reason if a light weight, compact and effective electromechanical braking system is desired to be produced, the motor has to be compact as well thereby necessitating the addition of a reducer. Another factor to be taken care of is the intense vibration experienced by the braking system because of its positioning. A greater torque causes greater induced couple to produce enough thrust that would be required to brake when these brakes are used.

C. Research Rationale

Electromagnetic braking systems are a process design activity which is of paramount importance. For this reason, computerized automation is essential to integrate braking systems. A literature review of the state of the art trends and approaches for braking system is presented. Some shortcomings of the current approaches is also discussed new research focus areas are explored. A part that must be machined is held by an assembly or a

component. This assembly or component is further defined. It must be designed properly so that it would fit the shape of the part and also be compatible to the machining process. This review would discuss the basics and techniques etc. and would also dwell on planning, dedicated design, and verification of design and of course how all these can be integrated with the main process.

D. Scope of the Research

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 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. And this system needs very little of maintenance. 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 brakes on heavy vehicles. The frictions brakes can be used less frequently and therefore practically never reach high temperatures. The brake linings would last considerably longer before requiring maintenance and the potentially "brake fade" problem could be avoided. 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. Production costs, time required for product development, time required for process development are all significantly reduced by the proper utilization of tools. Not only the above-mentioned benefits but also the simulation techniques that are involved in braking systems give a boost to quality assurance of the final part. Moreover, it becomes easier to make cost estimates for making business related quotations to customers, specifying parameters as specifications for technical purposes as all these are required in the mechanisms prevalent in the business world (Huang, 2005).

E. Research Questions

The research will address the following questions:

- Do electromagnetic braking systems improve usability to enhance user experience?
- Is the purpose of improving braking functionality to have the least environmental impact inclining in developing EMB (Electromechanical braking systems)?
- Does venture primarily concentrate on building a slowing mechanism, which can be material in bike at fast and low upkeep cost?

F. Research Hypothesis

- **H1** Electromagnetic braking systems enhance user experience and consumer's satisfaction.

G. Research Aim and Objectives

The aim of the research is to analyze electromagnetic braking systems in order to suggest improvisations and outline the pros of improved systems.

Objectives of the research will be:

- To assess the tools and techniques for designing, implementing, and evaluating ubiquitous computing systems used by developers
- To formulate practical solutions that addresses the functionality of these systems.

This review considers the various steps that are required for the design. It also presents the various important researches that have been conducted the world over, and describes the requirements for braking systems that have developed over time. Moreover, the paper also dwells on the most important and related research that has been carried out in the field which has utilized intelligent techniques and principles that relate to this type of work. The review also presents the CBR approach (case based reasoning). It has been considered as the most successful he most successful approach. The presentation of this approach uses information on various applications, the different stages of systems based on design. It also describes the work principles as well as the relevant approaches that have been proposed. Also, the shortcomings in the current methods are highlighted (Heidar Hashemi, 2016).

II. RESEARCH METHODOLOGY

This section emphasizes the methodology and techniques for this research and the pattern considered most appropriate for this study. It is made up of the research purpose, study design, ethical considerations, and challenges encountered in the course of the research.

A. Research Purpose

This is a theoretical research with the sole aim of providing emphasized descriptions of various phenomenon and conditions persistent which are connected to situations, individuals, or occurring events. The aim of the research is to generalize the outcomes of theories which develop over the course of the study. Along with that, a descriptive and theoretical research is always carried out on the basis of sufficient knowledge of the researcher with hypotheses based on the questions and that there is not intent to investigate the clauses between situations and occurring events. Empirical study gained from literature review and secondary data are involved in most aspects of the research. Analysis and derivations are used as evidence or proof.

B. Study Design

The study design is a mixture of empirical and theoretical study design. Theoretical aspect accrues data from mathematical modelling and empirical aspect is in the use of available literature evidence in substantiating the assertions. The advantages of this design is because it is cheap, less time consuming, and it enables the comparison of data to come up with valid and reliable findings.

C. Ethical Considerations

The study adhered to the principal ethics requirements. Permission to proceed with this research was obtained from relevant authorities. The studies selected for the literature review met the ethical requirements and they were published in the public domain. The authors of the literature reviewed for secondary data were accredited in both the in-text citation and reference page for conformity to policy against plagiarism.

D. Challenges Encountered

Several challenges were encountered in this research. Given that it is a mixed study, the outcome of the literature review may not correlate with the theoretical modelling findings because as one is theoretical the other one is empirical evidence. It was cumbersome to get sufficient peer reviewed papers relevant to this topic because the field is least researched due to its rapid advancement. The time was limited and financial constraints experienced necessitated cheap and less time consuming study designs to be selected for the research.

Principles:

It is necessary to understand the following concepts before understanding about the Electromagnetic braking systems.

Electromagnetism: Electromagnetism is one of the four fundamental interactions in nature. The other three are the strong interaction, the weak interaction and gravitation. Electromagnetism is the force that causes the interaction between electrically charged particles; the areas in which this happens are called electromagnetic fields.

Magnetic Effect of Current: The term "Magnetic effect of current" means that "a current flowing in a wire produces a magnetic field around it". The magnetic effect of current was discovered by Oersted in 1820. Oersted found that a wire carrying a current was able to deflect a magnetic needle.

Electromagnet: An electric current can be used for making temporary magnets known as electromagnets. An electromagnet works on the Magnetic effect of current. It has been found that if a soft iron rod called core is placed inside a solenoid, then the strength of the magnetic field becomes very large because the iron ore is magnetized by induction.

Eddy currents: When the moving conductor is introduced in the magnetic field then current is generated in the conductor, this phenomenon is called as the Eddy currents.

Use of electromagnet in Roller coasters

III. RESULTS OF THE RESEARCH

This section presents the findings of the research. It provides results of the research on the available body of knowledge in regards to the topic of the study, which constitutes a review of relevant literature. It also provides the evidence obtained in the mathematical modelling section to come up with valid and reliable assertions. The results from empirical evidence and mathematical modeling are analyzed to provide credible conclusions.

A. Findings from Empirical Evidence Reviewed

Sumit Patel conducted the experiment for the working of the various types of braking system and concluded that Eddy current braking system is much more effective than the conventional braking system. Sumit Patel and his colleagues also performed an experiment yielding in to stopping time for the wheel at various RPMs. This experiment showed us the simplicity in application of the electromagnetic braking system. They proved all limitations of the Conventional braking system can be overcome by using of electromagnetic braking system. Sevvel P, Nirmal Kannan V and Mars Mukesh S have stated the use of electromagnetic braking system in the heavy vehicles to minimize the "Brake Fading" effect. Conventional automobiles use Anti-Lock Braking System to avoid locking of brakes and cause skidding, but with the Electromagnetic braking system there will be no direct contact between the brake pads and disc so the concern of locking of braking is avoided. They proposed the use of this technology in everyday lightweight automobiles as well. Oriano Bottauscio, Mario Chiampi and Alessandra Manzin conducted research on similar application of electromagnetic braking systems and they stated The electromagnetic diffusion and the electromechanical phenomena arising in a solid cylinder rotating inside a magnetic field are here analyzed. Also finite element voltage formulation study is has been explained in the said research paper. The influence on the dynamic behavior and energy dissipation of the material electric and magnetic properties, the geometrical parameters and the supply conditions is investigated considering a model problem. AkshayKumar S. Puttewar, Nagnath U. Kakde, Huzaifa A. Fidvi, Bhushan Nandeshwar has proved that electromagnetic braking system is more reliable than other braking systems. They have experimentally proved that 80% of the power applied to electromagnetic braking system is recovered. Said results were obtained by experimentally using a prototype costing very less. Hence the option is economically feasible. Various other research conducted by Japanese engineers on locomotive braking concludes that using of electromagnetic braking system is more efficient. Engineers suggested the use of electromagnetic brakes as an auxiliary brakes to the locomotives. Skid effect in the locomotives is minimized and danger of the accidents is greatly reduced.

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. 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. Hung-Chi Wu, 958-2, Ghung Shan Rd., Tao-Yuan, Taiwan This invention relates to an adjustable magnetic brake and in particular to one including an aluminum fan, a magnetic conducting ring enclosing the aluminum fan, a permanent magnet disposed within the aluminum fan, a fixing seat for keeping the permanent magnet in position, a sliding seat mounted in the fixing seat and provided with a bearing, a housing, bolts provided on one side of the fixing seat and extending out of the housing, a mounting plate connected with the bolts and a wire connected with the mounting plate such that when the wire is pulled outwards, the permanent magnet will be moved outwards. Jae-Woong Lee, Seoul, Rep. of Korea Disclosed is a magnetic brake system for a vehicle. comprising: a plurality of brake disk solenoids for generating the magnetic force; a plurality of brake pad solenoids for generating the magnetic force; a braking sensor for detecting whether a brake pedal is applied; a wheel speed sensor for detecting wheel speed; a magnetic polarity sensor for

detecting magnetic polarity of the brake disk solenoids; and a control unit for controlling the brake pad solenoids using signals from the braking sensor. The wheel speed sensor and the magnetic polarity sensor.

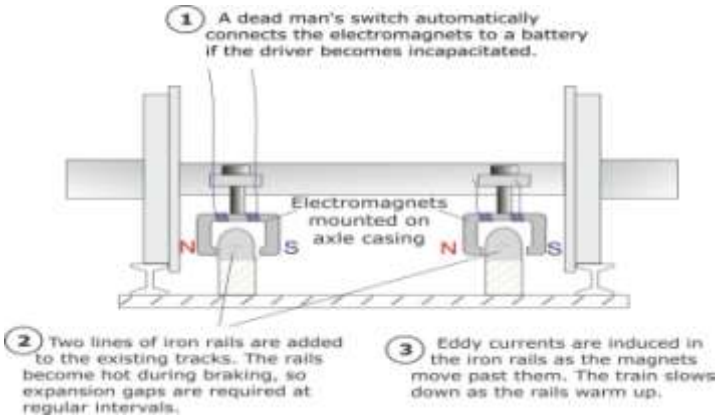


Fig 5. Electromagnetic brakes in locomotives

IV. WORKING

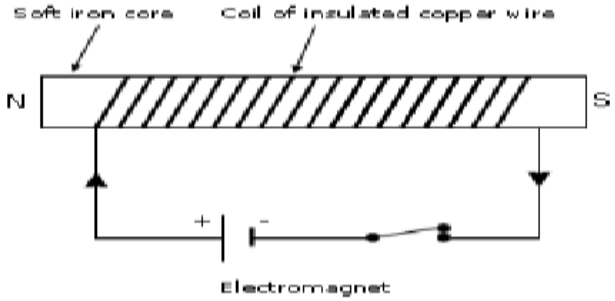


Fig 6. Basic Representation

When the current is passed through a conductor, the conductor develops the magnetic field i.e. the conductor is converted into electromagnet.

Experimental setup:

Fig 7. Experimental setu

Apparatus:
Metal Frame
Aluminum disc
Electromagnet
A DC motor
Controller

7.1.1.1 Sensor for measuring the RPM

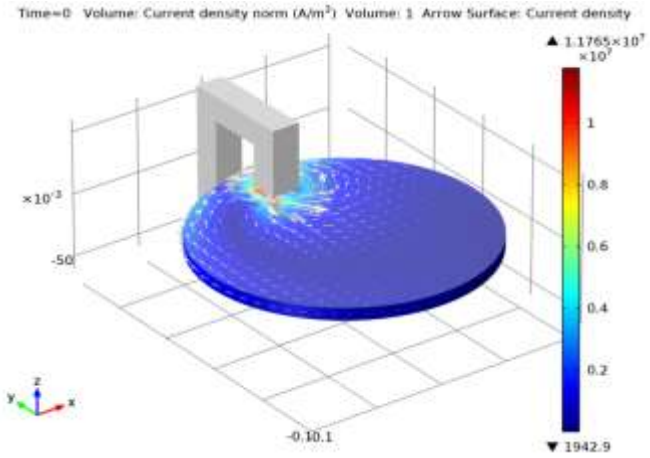


Fig 8. Stress Distribution on Disc

Working:

The eddy current brakes has its origin in France by a Frenchmen named as **Jean Bernard Foucault** in 19th century. HE observed that greater force is needed to rotate the copper disc in between two poles of magnet or magnetic poles, and at the same type the copper disc warmed up. The working principle of the electromagnetic brakes is based on the creation of the eddy currents with in a metal discs rotating between two electromagnets, which set up the force opposing the rotation of disc. Generally, when the brakes are not applied then the circuit is incomplete and the electromagnet is not energized. When in normal case the disc mounted on the shaft rotates without any retardation.

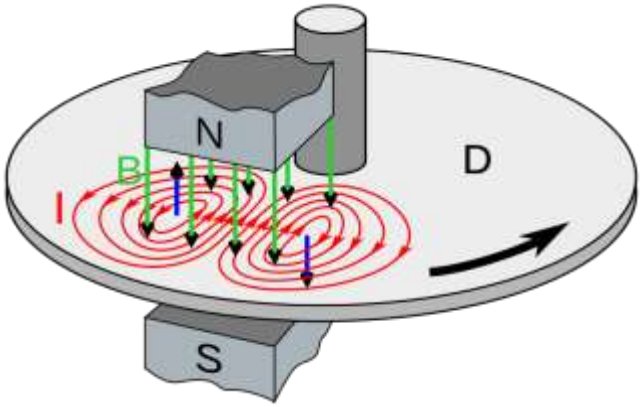


Fig 9. Induction of magnetic field

Incase of application of brakes the circuit is completed then the electromagnet is energized then eddy currents are generated in the rotating disc, the direction of force exerted by eddy currents is exactly opposite to the direction of rotation, hence causing the brakes to stop. This is the simple working of electromagnetic brakes where the amount of current applied is not measured. In practical application, rheostat is used to determine the energy requirement paired with RPM sensors. The braking force is indirectly proportional to the value of current. The development of Electromagnetic brakes was started by a French company associated with Raoul Sarazin developed and marketed several generations of electromagnetic brakes. A typical retarder consists of stator and rotor. The stator holds induction coils made up of aluminum wires. This is mounted on the frames on this makes the non rotating member or stator. The rotor consist of the two disc brakes which generate the braking action when electromagnets in stators are energized. Heat dissipation arrangement is given for cooling.

All the disc can function individually and the system can be controlled by micr controller. Hence if brakes on a single wheel fails then the system can sense the failure of braking asssembly and Force on other three wheels can be redistributed. Microcontroller can equally distribute the braking force hence avoiding loss of control in such a event. Incase of conventional braking system failure of brake on single wheel can cause imbalanced force which may cause loss of control and driver and vehicle may be pushed into harm's way instead of safety.

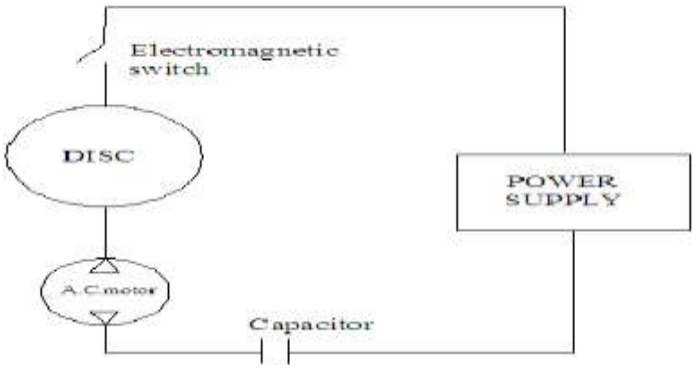


Fig 10. Block Diagram Representation

V. 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.
[4] As heat generation is less due to shared efforts by both the brakes, hence brakes remains cooler.
[5] Functioning of EM brakes is similar in all climates, i.e. no need for special changes in hot or cold climates like in case of disc brakes.
[6] Maintenance cost is very less
[7] Changing of parts due to wear and tear is less.
[8] Easier integration with anti-lock, traction system
[9] "Brake fade" effect is negligible, hence can be used for long hauls in trucks and other heavy vehicle.

VI. DISADVANATAGES

a. Electromagnetic braking system doesn't function well on lower RPMs as the Eddy current generated is of low power.
b. Large amount of electricity is needed for heavy braking, hence the battery life is reduced
c. Due to low speed limitation EM braking cannot be used as an independent system.
d. System can be bulky incase of vehicles needed larger braking force.

VII. APPLICATIONS

[1] Railways
[2] Coaches
[3] Roller coasters and other theme park rides
[4] Industrial lifts
[5] Heavy duty trucks
[6] Automobiles
[7] It can be applied to aeronautic application
[8] Slowing down a airplane on carrier ship

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