"Design and Fabrication of Electromagnetic Breaking system"

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Declaration

We declare that the work contain in thesis is our own, except where explicitly Stated otherwise, in the addition this work has not been submitted to obtain another degree or qualification.

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Dedication

"Dedicated to parents and teachers
Who have supported us all the way
Since the beginning of our education"

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NOMENCLATURE

Symbol	Description
l_g	Air Gap
θ	Angular Velocity of Wheel
Σ	Conductivity of material (Cast Iron)
I	Current
D	Disc Thickness
R	Distance b/w center of disc and radius of pole
R_e	Effective disc radius
M	Frame mass
N	Number of turns
μ_o	Permeability of air
S	Pole Area
V	Translational velocity
T_b	Braking Torque
P_d	Dissipated Power

CHAPTER 1

Introduction and Background

1.1 Introduction and Background

In Pakistan, vehicles produced locally are not certified to meet the same standards as those made by international companies, or the vehicles imported from the parent countries like Europe, America, South-East Asia, and South America. The main cause of these safety hazards is the local productivity of vehicles due to the least availability of resources and vehicles. Though Advanced Braking Models are now used in most cars still accident rate is increasing day by day due to Braking Failure. For instance, Suzuki produces 5-star models for Europe and South Africa, but it is still producing 0-model cars locally having failed braking system [2].

Every year 9% of accidents are caused due to brake failure in Pakistan. This is also because of the road conditions and the conventional Braking System used in vehicles. Braking Failure means the leakage occurs due to the damaged seals to the cylinder which is a common failure in Hydraulic Brakes. Brake Pedals worn out and breaking down of Fluid is the serious cause of accidents. Due to extreme weather conditions, brakes could overheat due to friction which results in low brake efficiency. To overcome this fatality rate Electromagnetic Braking System, hope to reduce this death rate and improve the efficiency of the vehicles [2].

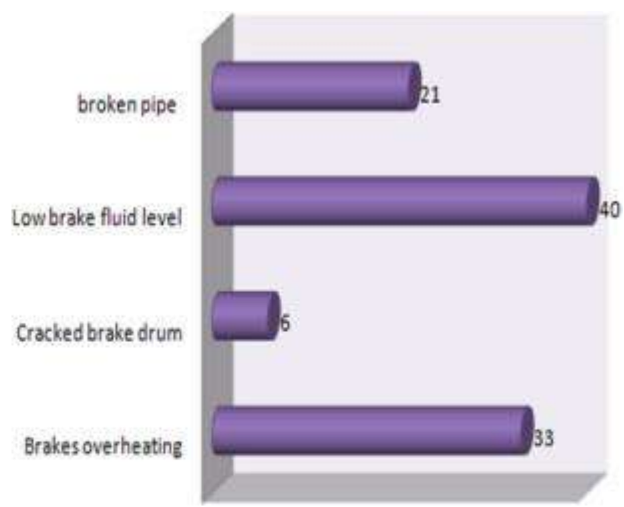


Figure 1-1: Common Brake Failure Statistics

1.2 History

The electromagnetic Braking System was first invented by Granville Tailer Woods in 1887. They were specifically designed to be used for Trains but later used in other systems in conjunction with conventional brakes i.e., Hydraulic Brakes, Disc Brakes, and Drum Brakes. They were first termed electro-mechanical brakes which later changed to electromagnetic brakes because of their working principle [13].

1.3 Working Methodology

The electromagnetic Braking System works on the principle of change in energy(kinetic) into thermal. As the brake is applied, they exert a magnetic force on the disc and stops the vehicle in a record short time regardless of the vehicle's speed Although it has electric actuation, the torque is mechanically transmitted by an electromagnetic brake system. As the coil is ignited when the brake receives voltage or current, this process creates a magnetic field. As a magnetic field is produced, the coil becomes an electro-magnet which produces magnetic flux. The armature is drawn to magnetic flux. The hub and armature are normally attached where the rotating shaft is. The shaft stops as the coil interacts with the hub and armature The armature can then turn with the shaft once the brake no longer receives current. When power is released from these types of brakes, armature gets in distance from the braking surface by the spring generating a small air gap[26].

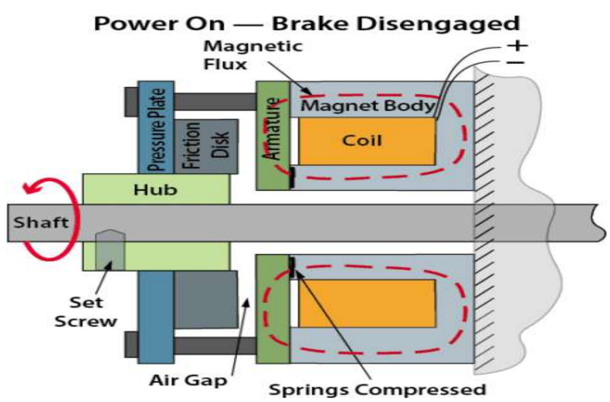


Figure 1-2: Electromagnetic Braking System (Brake Disengaged)

Eddy current brakes to stop a vehicle, depending upon the strength of opposing fields, whereas electromagnetic brakes employ magnetic fields which cause the lever to get against the rotating shaft which finally stops the vehicle. These types of brakes depend upon eddy currents which are made when a conductor goes through the field, as the name infers. The conductor at that point creates its field, which response with the first field to stop the conductor. Electromagnets are used instead of permanent magnets in eddy current brakes because the magnetic field's power can be better regulated by electricity The system has fewer moving components than an electromagnetic brake since it depends on an attractive field to work as a brake. As a result, this lasts longer. Eddy current brakes are commonly employed to provide varying resistance levels in crisis shutoffs, high-velocity trains, and event congregation attractions, as well as in workout equipment[26].

1.4 Problem Statement

Heat Dissipation and Wear and Tear are the main causes every year most conventional braking system fails. This causes a lot of maintenance. To overcome the pre-mentioned problems and induce longevity to the brakes, electromagnetic brakes are a reasonable option.

1.5 Aim & Objectives

Selection and Usage of suitable Electromagnetic Braking System in an automobile to reduce wear and tear, braking time & braking distance. Following are the main objectives of the designed project:

1. To Develop Prototype of Electromagnetic Braking System for Automobile applications for experimental analysis of braking time and braking distance.
2. To analyze and compare the performance parameters of Electromagnetic Braking System with conventional system.

1.6 Relevant Schematic Diagram

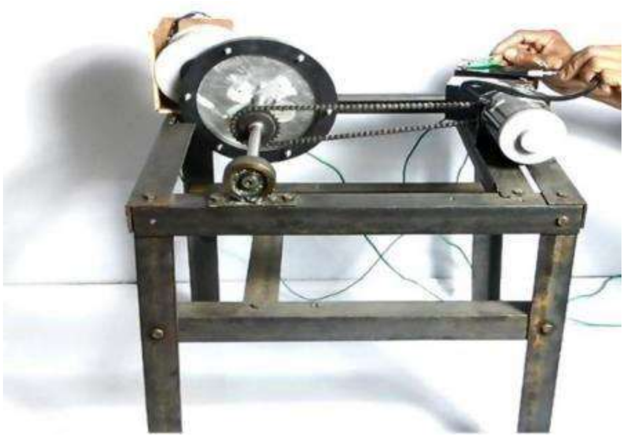


Figure 1-3: Schematic Diagram

1.7 Components required

- Electric Motor
- Wheel
- Power Control
- Electromagnet
- Brake Shoe
- Spring
- Bearing

1.8 Project Plan

Project Management Design

The total duration of the project is 14 months (May 2022 to July 2023) which is further divided into following four phases.

- **Phase 1 (Collection of relevant literature and data)**

The estimated time for this phase is 10 months (May 2022 to February 2023) in which different literatures will be studied.

- **Phase 2 (Study of literature and literature review)**

The estimated time for this phase is 7 months (May 2022 to November 2022).

- **Phase 3 (Designing and fabrication)**

The Estimated time for this will be 4 months (October 2022 to January 2023).

- **Phase 4 (Experimental and result analysis)**

The estimated time for this will be 3 months (February 2023 to April 2023).

- **Phase 5 (Thesis write up and submission)**

The estimated time for this will be 3 months (May 2023 to July 2023).

Table 1-1: Project Plan

	2022								2023							
Phase	**May**	**June**	**July**	**August**	**Septemb**	**October**	**Novemb**	**Decembe**	**January**	**Februar**	**March**	**April**	**May**	**June**	**July**	**August**
Collection of data																
Study of literature and literature review																
Designing and fabrication																
Experimental and result analysis																**SUBMISSION**
Thesis write up and submission																

CHAPTER 2

Literature Review

From the literature review, it is analyzed that there are various parameters which affect the Braking System in terms of braking time and braking distance. In comparison with EMB system conventional system requires more time to stop the automobile after brake has been applied. To address this challenge, electromagnetic braking systems with reduced size in automobiles and contactless has been appeared as a feasible solution. This project describes the development and usage of electromagnetic braking systems in automobile applications to study the effect on braking time and braking distance in comparison with the conventional braking systems.

2.1 Design and Realization of a Controlled Electromagnetic Breaking System

(Achille Ecladore, Yungho Edickson,Mbaka, Nfah Eustace)(14 August 2023)

Industrial machines with sharp moving blades are extremely dangerous to workers. These machines often rotate for some time (called the run-down time) before completely stopping due to little or no brakes. In the case where brakes are used, they are mechanical in nature and are associated with problems of wear out and frequent maintenance among others. In this paper, we proposed a mathematical model and implementation of an electromagnet and design and construction of a mechanical support frame and a controller for the electromagnetic braking system. The electromagnetic braking system works on the principle of electromagnetism. To realize the semicircular electromagnets, we coil the gauge wires several times around a ferromagnetic core material. The electromagnet was connected to a 12 V 7 Ah battery and was used to lift a load whose mass and corresponding weight were predetermined using a scale balance. The magnetic force generated was equal to the amount of maximum load it could lift. The mechanical frame, on which the electromagnets, motor, battery, switches, and chain drive system were mounted, was designed using SolidWorks and constructed by measuring, cutting, and joining of iron materials. A microcontroller and a power MOSFET were used in the control circuit to drive the electromagnet. Major results such as the realized electromagnets and the magnitude of the electromagnetic force (1.43 N) produced by the electromagnets are presented. The mechanical frame and the control circuit are also presented. The braking force was greater than the rotation torque of the disc, and hence braking was achieved[1].

2.2 Design of Electromagnetic Braking System

(Nayak, Diptimayee, Samal, Soumya Sekhar, Mallick, Bikash Kumar) (7 July 2023)

Electromagnetic brakes are the brakes working on the electric power & magnetic power. They work on the principle of electromagnetism. The working principle of this system is that when the magnetic flux passes through and perpendicular to the rotating wheel the eddy current flows opposite to the rotating wheel/rotor direction. This eddy current trying to stop the rotating wheel or rotor. This results in the rotating wheel or rotor comes to rest/ neutral. These are totally friction less. These brakes are an excellent replacement on the convectional brakes due to their many advantages. The reason for implementing this brake in automobiles is to reduce wear in brakes as it friction less. Therefore, there will also be no heat loss. The electromagnetic brakes are much effective than conventional brakes & the time taken for application of brakes is also smaller. There is very few need of lubrication. Electromagnetic breaks gives such better performance with less cost, which is today's need[2].

2.3 Design and development of motion-based auto braking system

(Dr. Narayanaswamy, Karthik, Mohammed Ismail, Mohammed Danish) (3 December 2022)

Two-wheeler vehicles are the essential part of transportation, bicycle, bikes, and other vehicles are everywhere and we can say that they are one of the important parts of human needs. The transportation vehicles that are made today haven't changed from many years; means they need an upgradation in terms of braking. Road safety is an issue of worldwide concern on human life and property. The development of collision avoidance system is the improvement in which it can bring out vehicular safety. The collision avoidance system consists of a radar sensor which is installed in the vehicle undergoes constant scanning. If any obstacle found on the road, it sends the signal to the driver in the form of warning. Hence there is a need to convert the signal from milli volts to micro volts which is done using filtering circuit. The amplified signal is passed to the microcontroller for steering operations. Microcontroller process the data and showcases it on LCD. Microwave motion sensor of HB series works in X-band which is designed for movement detection. It consists of Dielectric Resonator Oscillator (DRO), microwave mixer and patch antenna. Increased in road accidents due to pedestrians, blind spot vehicles or dark spot vehicles, poor visibility, crossing animals is happening now a day and it is gradually increasing day by day. Because of this both the sides will suffer. Conventional available proximity devices have its own limitations by sensing range or sensing speed. For this reason, ARS441 Doppler radar-based system is designed. Since human negligence or error is the main cause for occurrence of accidents where rear end collisions are the most common form, it is critical to equip with safety systems in vehicles. The safety systems can be either active or passive. The latter such as seatbelts, airbags and crumple zones have been widely employed for many years and it has almost reached its full potential in reducing the number of casualties. As far as we are concerned, we are focusing on making the braking more efficient and effective both in terms of safety of life and braking of the vehicle safely, hence this system will help in saving lives[3].

2.4 Intelligent Braking System Using Electromagnetic Actuators

(Shinde, Aditya, Pawar, Harsh wardhan, Shukla, Gulab Salve, Advait) (May 2022)

Abstract: Accident prevention has been one of the leading areas of research today. Our paper is designed to prevent accidents due to loss of control, drunken driving, and rash driving, using circuitry aided by a microcontroller kit. In our work, braking distance and the distance of the obstacle are taken into consideration along with the speed of the vehicle. The sensor helps in finding the speed of movement of the vehicle and the ultrasonic sensor senses the distance of the object in front. These sensors provide real- time inputs to the microcontroller program. Using sensor the system will sense the speed of the vehicle and with the microcontroller, it will calculate the distance required to bring the vehicle to a complete stop for that speed. Breaking motors is incorporated to activate the brakes thereby achieving automatic breaking procedures. The system helps in conjunction with the driver judgment if the driver doesn't sense the obstacle and applies the brake at the right time then the microcontroller initiates braking motor to apply the brakes automatically. Our future work deals with incorporating real time brake shoe wear system to provide enhanced feature for the intelligent braking system. By looking at safety in terms of avoiding accidents in the first place. And then protecting occupants when a crash is unavoidable. We can prevent more accidents, save more lives, and reduce insurance and medical costs to society. Intelligent Braking System approach represents a significant shift from the traditional approach to safety, but it is fundamental to achieving the substantial benefit[4].

2.5 Electromagnetic c System using Ultrasonic Sensor

(Khan, Mohd. Sabir Rao, Arun Kumar, Naresh, Sharma, Jeetendra Kumar) (8 Jul 2021)

The concept of our paper is based on the automatic braking system. As we know that most time the accident takes place due to loss of control, drunk & drive and much more breaking reason. In our system there is a sensor that detects the speed of movement of the vehicle and an ultrasonic sensor, that sense the distance of the object in front of the vehicle. The sensor system will sense the speed of the vehicle or object in the front while the microcontroller calculates the distance required to stop the moving vehicle. The whole system is automatic and the braking application will take place without any manual input therefore it will decrease the rate of error hence the rate of road accidents[5].

2.6 Electromagnetic braking system Principle of electromagnet Brake system

(Sailesh, Bantu, Krishna, R Hari) (20 July 2021)

Renewable energy resources are preferred as compared to conventional energy resource due to their environment friendly nature. Micro-hydropower plant is one of the best renewable energy sources that provides electricity to hilly and rural areas. Micro-hydropower plants are mostly installed at natural heads and runoff rivers. Lack of a reservoir at the headrace of micro-hydropower plant results in variable water flow to the turbine. Also, consumer load connected to the generator varies with time. The variation in water flow to the turbine and consumer load changes result in variation in generator output power and frequency. This paper presents a novel and innovative electromechanical control system that keeps generator frequency constant as the consumer load varies. The mechanical control part of this system controls water flow to the turbine using dc motor and sliding gate. The electric part of this controller keeps the generated power equal to ballast load power and consumer load power. The ballast loads are turned on and off at the zero crossing to the sinusoidal wave of the generator output that minimizes transients and power losses in switching. Electromechanical controller increases efficiency of micro-hydropower plant and also increases the reliability of power supply[6].

2.7 Design and fabrication of efficient electromagnetic braking system for Bangladesh railway: A prototype approach

(Chowdhury, Raise Uddin Hridoy, Rafat Mahmud Rafiq uz zaman, Md Sifa)(11 March 2021)

Electromagnetic brake is a new and revolutionary concept. Electromagnetic braking system is a modern technology braking system used in light motor & heavy motor vehicles. The purpose of this research work is to develop a concept of designing and fabricating an electromagnetic braking system for Bangladesh railway which can be used in lieu of existing frictional braking system. The methodology is based on creating a magnetic field on the heads of E-shape core through electricity and attaching circular ferromagnetic material parts under every train carriage. This created magnetic field penetrates train wheels and circular ferromagnetic parts to steadily reduce train motion. This research work finds the proposed electromagnetic braking system reliable and efficacious. The proposed electromagnetic braking system is found to be efficacious for both high and low speed train. This paper presents the implementation of electromagnetic braking system through a prototype[7].

2.8 Design and analysis for electromagnetic braking system

(Lakkam Ram Sai Prajwal, Harish)(July 2021)

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 enhancements in the brakes it can be utilized as a part of automobiles in future[8].

2.9 Design and experimental analysis of electromagnetic braking system

(Gembali, Srinivasa Gupta Rao, A. N.Brahmeswara, Naresh)(21 January 2021)

A conventional braking system uses the disc or drum for application of brakes. Application of pressure force through brakeshoe on drum caused the vehicle to slow down and stop. During the action of brake Kinetic energy developed by vehicle is converted in to heat energy due to friction between brake shoe and drum. Therefore, brake is an essential element to stop the vehicle by conversion of energy. Continuous application of brake results wear and tear on braking pads, intern reduces its effectiveness. braking is to convert. In this work, a concept on magnetic braking system has been introduced, basis for which is Lenz’s law. An aluminum disc is used to fit into the wheel of a bicycle and the influence of different parameter on braking torque have been analysed analytically as well as experimentally in this proposal[9].

2.10 Investigation of characteristics of Magnetic Braking System

(Ganeshkumar, S Ashwath, R Chandrakand, P)(July 2021)

Magnetic braking system is the most emerging technology in the automobile sectors. Braking system is the one which is mainly considered while describing the safety in driving of any automobiles. Magnetic braking system is the emerging concept which is to be incorporated with the conventional braking system in the automobiles to increase the efficiency of the braking system. The working of the braking system is explained with prototypic model. The ferromagnetic material is attached to the axle of the rear wheel and is surrounded by a casing containing magnetic coils. On the application of brake with the help of the electricity, the magnetic coils generate the repulsive force against the rotating element on the rear axle. Which helps to slow down the vehicle in an efficient manner[10]

2.11 Magnetic Braking System Using Electromagnetic Force

(Hairil, Budiarto) (June 2020)

A vehicle is a transportation that is widely used by humans as transportation for daily activities. Vehicles generally use mechanical brakes to do braking, these mechanical brakes have a system that requires friction forces to produce a slowdown in the vehicle. The frictional forces carried out will make erosion of the mechanical brake pads and the need to periodically replace the bearings. In this study discussed the design and manufacture of braking systems using electric brakes to support the performance of mechanical brakes. Electric brakes that have advantages in the media used compared to mechanical brakes, namely electric brakes do not require friction media to slow down, but electric brakes use four aluminum plates as magnetic force media, while coils or windings with the inner core will produce electromagnetic force as an actuator braking. The braking system that is carried out will maintain the speed according to the setpoint value of 5100 rpm. This electromagnetic braking results in a maximum braking of 500 rpm and takes between 9 and 15 seconds to reach the steady state position[11].

2.12 Design and Analysis of Efficient Electromechanical Braking System (EBS)

(Atif Saeed, Hashim Soomro, Zain Haider Khan, Mufaddal Arif) (September 2020)

Using electromagnetic induction, the electromagnetic brake slowly keeps slow the moving vehicle under which it will produce resistance. The Friction brakes create a pressure on the two separate objects to reduce the vehicle speed in a Controlled mode. The magnet current turns in the form of plate heat which definitely lowers the kinetic energy. In this magnetic type of braking device, as the driver applies force on the brake pedal, a pulsating D.C. current is sent to the power pack. As per the driver’s requirement a proportionate torque is produced to decelerate the vehicle. In oil braking or air braking systems even a small leakage can result in complete brake failure and cause accidents In previous braking system we use oil which is a natural element and it has many other usages so if we exchange our hydraulic braking system with electromagnetic braking system so it may help us in economic growth and it is a clean and affordable energy[12].

2.13 System of electromagnetic braking

(Paul, K Sugun Road, Visadala X) (Sep 2019)

A non-contact braking system was proposed to solve the shortcomings of standard braking systems. Upright magnetic braking methods get very little mention in the extensive literature, which is good news for businesses. To build an upright magnetic system, determining the magnetic flux is a critical step. Fluctuating magnetic flux induces eddy currents in the conductor. These currents burn energy in the conductor and generate drag force in order to slow down the movement. Thus, a finite element model is utilized to examine the impacts of air gaps and track materials on magnetic flux density. The model's predicted magnetic flux is within the permissible range, according to the test findings. Based on the results, it will be simpler to develop magnetic braking systems[13].

2.14 Design of a new bilayer multipole electromagnetic brake system for a haptic interface

(Iqbal, Hashim Yi, Byung Ju) (10 December 2019)

This paper deals with the design, simulation and experimental verification of a new bilayer multipole electromagnetic brake. The design utilizes the superposition principle of magnetic flux across the inner and outer layers of axially-oriented electromagnetic poles to provide gradual braking about the single axis of rotation. The braking principle exploits the Coulomb friction between the two rigid contact surfaces. Compared with conventional, multi-pole, multi-layer type radial brakes in haptic applications, the proposed design provides high fidelity of free motion through an absolutely disconnected rotor. The design also provides a wide operating range by delaying the saturation limit of a magnetic circuit for a wide range of input power. In this paper, the analytical model of the brake is derived and compared with the FEM-based simulation results. The optimal design obtained from multi-objective optimization was experimentally verified for its capability in haptic applications[14].

2.15 Experimental determination of electromagnetic brake parameters of the positioning system

(Perz, Piotr, Wilczyński, Dominik, Malujda, Ireneusz) (March 2019)

The paper presents the results of an electromagnetic brake test of a hybrid positioning system consisting of a pneumatic cylinder and an electromagnetic brake. Brake tests were carried out on the MTS Insight testing machine, which determined the attraction forces of the electromagnet depending on the size of the air gap and the current flowing through the winding of the electromagnet. The time constants of the positioning unit and the electromagnet were measured, which allowed to develop an effective control system reaching shorter times and higher positioning accuracy as well as a higher average piston speed. The presented system ensures free programming of displacements of the actuator and maintaining the set position. Obtaining higher average speeds of the pneumatic cylinder piston is possible due to the use of effective control parameters such as shortening the braking phase and the time of reaching the desired position[15].

2.16 Design and fabrication of frictionless magnetic braking system

(Mhatre, Rahul Nikam, Kaustubh Pawar, , Sayali Magar, Prof Varsha) (APRIL 2018)

The principle of braking in road vehicles involves the conversion of kinetic energy into heat. This high energy conversion therefore demands an appropriate rate of heat dissipation if a reasonable temperature and performance stability are to be maintained. While the design, construction, and location features severely limit the heat dissipation function of the friction brake, electromagnetic brakes work in a relatively cool condition and avoid problems that friction brakes face by using a totally different working principle and installation location. By using the electromagnetic brake as supplementary retardation equipment, the friction brakes can be used less frequently and therefore practically never reach high temperatures. The brake linings thus have a longer life span, and the potential brake fade problem can void. It is apparent that the electromagnetic brake is an essential complement to the safe braking of heavy vehicles[16].

2.17 Design and fabrication of electromagnetic braking system for four wheeler

(M Sampathkumar, A Sakthivel, P Tharun Prasad, S Vinothkumar, R Vinothkumar) (2018)

These brakes designed by controlling for equipment, automobiles and movers are suitable for AC&DC power supplies up to 12 v to 220 v and are suitable for wide range of drum sizes 10 to 380 mm dia these brakes are suitable with a rated torque ranging from 100kg-cm for the smallest brake up to 2000 kg-cm for a 380mm dia at 50% coil rating, the coil remains in circuit for a maximum 5 min out of every 10min. Since these brakes are closed position, the release of brake shoes is affected by energizing the electromagnetic coil which over comes the spring force and shoes are moved clear of drum by lever system so that the drum is free to rotate without any friction. When the power given to the electromagnetic coil the coil gets energized and in turns the plunger pulls down. The plunger in turn operates the arm of the brake and the brake opens. When specied brake drum both pin bush type and flexible geared type can be supplied along with the brakes[17].

2.18 Design and Fabrication of Intelligent Mechatronic Braking System

(Rajyalakshmi, M Kranthi Kumar, BKrishna, Vaibhav) (April 2018)

At Present, vehicles are often equipped with active safety systems to reduce the risk of accidents, many of which occur in the urban environments. The most popular include Antilock Braking Systems (ABS), Traction Control and Stability Control. All these systems employ different types of sensors to constantly monitor the conditions of the vehicle, and respond in an emergency. In this paper, the use of ultrasonic sensors in safety systems for controlling the speed of a vehicle is proposed. An intelligent mechatronic system includes an ultrasonic wave emitter and receiver provided on the front portion of a car emitting and receiving ultrasonic waves frontward in a predetermined distance. Then a microcontroller is used to control the speed of the vehicle based on the detection pulse information to push the brake pedal and apply brake to the car stupendously for safety purpose[18].

2.19 Design, Fabrication and Parametric Analysis of Electromagnetic Braking System

(Pandey, Shivam, Holmukhe, R. M., Pandey, Satyam) (28 Oct 2018)

The aim of this practical study was testing as well as analysis of parametric dependency on braking torque. The experimentation was done by fabrication of eddy current braking system in optimized way in terms of size of braking system, weight of material used for fabrication, shape of the complete braking system for appropriate application and overall cost. The methodology used was practical study of variation of electrical as well as mechanical parameters on braking without losses, wear tear in addition to noise due to the friction The eddy current barking is caused by the influences of magnetic flux on non-magnetic materials which have certain conductivity and are in motion. In this study magnetic flux is produced by the electromagnets which are interfaced to the rotating discs via air gap. The rotating discs are mounted on a shaft, which is driven through a prime mover or any other rotating device, the braking of which needs to be done. The complete assembly is mounted on a mild steel frame in order to increase the stability as well as to reduce the system vibrations. After energization of electromagnets, the production of eddy currents on the disc elements was realized, wherein the flux produced by eddy currents interacts with the stators flux which causes braking of the rotating element. The variations in the braking torque due to change of various electrical and mechanical parameter has been practically studied through lab experimentation. The results of this investigation prove that the electromagnetic braking is more appropriate as compared to mechanical braking. The probable applications of the result of the study are in electrical vehicles in automotive sector, braking of electrical motors in manufacturing sectors[19].

2.20 Experimental Analysis of Automatic Disc Braking System

(A.Karthick, L.Prakash)(2017)

The main objective of this project is for security system. If vehicle moves very near to the opposite vehicle then it applies brake automatically. It is used for avoiding accident over by racing in highways and parking or busy traffic areas through pneumatic braking. Pneumatic braking system works faster when compared to other devices. So we can achieve the high efficient operation by programming the micro controller. The circle brake is a gadget for abating or ceasing the turn of a wheel. Contact causes the plate and joined wheel to moderate or stop. Brakes change over grating to warm, however in the event that the brakes get excessively hot, they will stop, making it impossible to work since they can't disseminate enough warmth. This state of disappointment is known as brake blur. Circle brakes are presented to extensive warm worries amid routine braking and uncommon warm worries amid hard braking[20].

2.21 Design and Fabrication of Electromagnetic Engine

(Suhel, Syed Baseganni, Chetan, Dinakar, Naveen) (2017)

An electromagnetic brake uses electromagnetic induction to slow down a moving object by creating resistance. The friction brakes on two different objects provide a pressure that progressively reduces the vehicle's speed in a regulated manner. The magnet's current is converted to heat on the plate, which reduces the kinetic energy. The intensity of braking is monitored by a pressure transducer in this magnetic kind of braking system whenever the driver applies force to the brake pedal, and the output actuating signals are delivered to the microprocessor. This controller provides a signal to the capacitor, and a pulsating D.C. current is transmitted to the power pack from the relevant unit. To slow the car, a proportionate torque is created based on the driver's requirements[21].

2.22 Design and development of the embedded control system for intelligent bicycle trainer based on electromagnetic braking

(Wang, Yanyuan)(2016)

Traditional bike trainer mostly uses mechanical way to control resistance, it has the disadvantages of single function, complex resistance control, low intelligence and lack of fitness index, so that it cannot meet the needs of the market. In view of the shortcomings of the traditional bicycle device, the electromagnetic brake principle is used to carry on the design and development of intelligent bicycle trainer based on the embedded control system Firstly, the resistance braking device based on the principle of electromagnetic brake are designed to achieve no friction, no wear and no noise cycling resistance control; secondly, the hardware of the embedded control system for bicycle trainer is completed by designing resistance control circuits, sensor interface circuits, power circuits and other circuits, which select the ARM LPC1114 chip as the core. Then, the software system of the embedded control system for bicycle trainer is designed. Real-time operating system RTX is used as the main framework for program design, and multi-mission design methods are used to design and realize Bluetooth communication, brake drag control, acquisition and conversion of speed and other function modules. Finally, the function and performance testing for the embedded control system for intelligent bicycle trainer are carried on and it turn out to be that the trainer can adjust the resistance in real-time and wirelessly, collect and calculate the heart rate, body-building time, real-time speed and riding distance. Therefore, it can meet the requirements of design and the needs of various types of body-building of users, monitor and analysis the fitness motion data so as to allow users to access the data of fitness information. Compared to traditional bicycle trainer, the design increases the intelligence level to some extent[22].

2.23 Advances in Full Control of Electromagnetic Waves with Meta surfaces

(Zhang, LeiMei, Shengtao Huang, Kun Qiu, Cheng Wei)(2016)

Meta surfaces, two-dimensional versions of metamaterials, retain the great capabilities of three-dimensional counterparts in manipulating electromagnetic wave behaviors, while reducing the challenges in fabrication. By judiciously engineering parameters of individual building blocks (such as geometry, size, and material) and selecting specific design algorithms, meta surfaces are promising to replace conventional electromagnetic elements in nano plasmonic/photonic devices. Significantly, such concept can be readily promoted to other disciplines, such as acoustics, thermal physics, and seismology. In this article, the latest advances in full control of electromagnetic waves with meta surfaces are briefly reviewed from a functionality perspective. A broad avenue towards real-life applications of metamaterials has been opened up, although they are still at their infant stage. At the end, several promising approaches are suggested to extend the applications of meta surfaces[23].

2.24 Electromagnetic Brake/Drive Unit design for small aircraft environmentally friendly ground operations

(György Bicsák, Dávid Sziroczák, Godwin Eseosa Abbe)(2015)

This paper introduces a concept to reduce the harmful gaseous emissions of aircraft produced during ground operations. The idea is an integrated solution using a frictionless electromagnetic brake system, which is also capable of operation in drive mode. Using this system, less power is required from the engines during taxi, resulting in potential fuel savings. In this paper a typical business jet was used as an example aircraft to demonstrate the concept. For small aircraft taxi losses can be significant compared to the total mass of the aircraft, however braking power is more manageable than in the case of larger aircraft, airliners for example. After the preliminary simulation of the braking and taxiing phases, system requirements were determined and the system architecture was designed. Particular focus was placed on system safety, reliability, and economic benefits. Besides these primary considerations, novel ideas were also investigated, like the favorable effect of the landing gear spinning up on tire life, or the reduced wear of the break unit[24].

2.25 Design of Advanced Electromagnetic Emergency Braking System

(Kulkarni, Mr. Parag Satish)(June, 2015)

A brake is a device by means of which artificial frictional resistance is applied to a moving member, in order to retard or stop the motion of a machine. In the process of performing this function, the brake absorbs either kinematic energy of moving member or potential energy given up by objects lowered by hoists, elevators etc. An emergency brake is a backup braking system designed to function even when there is total brake failure. It works through purely mechanical means, and is independent of the hydraulic system which controls the brakes normally. In addition to being used in emergency situations, an emergency brake is also used as a parking brake, to prevent the car from rolling away, should it slip into gear. Like all parts of the braking system, the emergency brake should be checked regularly to ensure that it is in good working order[25].

2.26 A review paper of the current scenario of the magnetic braking system

(Modi, Umang SBhavsar, Swapnil C)(2015)

Current paper contains three reviewed research papers on the electro-magnetic braking. Electro-magnetic braking is now taking a good pace in the applications on the day to day stuffs like cars, machine stopper and as motion retarder as well. Rather than a conventional contact friction braking, this system are more efficient, quick in the response and has no wear so it has good durability. So three different papers are reviewed and summarized here to know the principles, applicability and future scope of electro-magnetic braking system[26].

2.27 Integrated Electromagnetic Disk Braking system

(Thalako tunage, Amila Hemantha)(17 June 2015)

With the rate of current technological development road systems of the near future will be congestive by autonomous vehicles, connected cars, smart bikes, pedestrians and existing vehicles. To keep pace with this evolution by improving the safety of passengers, brake systems will have to be modernized and reliable. Reliability of the braking system is profoundly significant circumstance. Electromagnetic braking system is spanking solution for this since it can easily integrate with automatic obstacle avoiding systems and due to the quick respond capability. The objective of this paper is to introduce new electromagnetic braking system with the energy saved by regenerative braking technology[27].

2.28 Enhancement of Braking System in Automobile Using Electromagnetic Braking

(Puttewar, Akshya kumar S Kakde, Nagnath U Fidvi, Huzaifa, Bhushan)(2014)

An electromagnetic brake is a new and revolutionary concept. Electromagnetic braking system is a modern technology braking system used in light motor & heavy motor vehicles like car, jeep, truck, busses 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 analyzed. It is apparent that the electromagnetic brake is an essential complement to the safe braking of heavy vehicles. It aims to minimize the brake failure to avoid the road accidents. 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[28]

2.29 Design of double-disc friction and electromagnetic hybrid brake system of passenger car

(He, Ren Gu, Xiao Dan Shi, Jun)(11 August 2014)

The electromagnetic brake has already been acknowledged by users as one kind of contactless brake. In this paper, the basic principle and application of electromagnetic braking technology were briefly introduced first. Then the structure of the innovative hybrid brake with double disc was put forward. It employed an electromagnetic braking to reduce brake pad wear and braking system thermal recession. Based on the design requirements, the friction brake and the electromagnetic brake were designed respectively. Finally, in order to verify that whether the designed hybrid brake meets the design requirements, a bench test was carried out. The electromagnetic braking torque characteristic was tested. The results showed that the electromagnetic braking torque could approach 198Nm[29].

2.30 Design and establishment of HIL testing bench for electromagnetic and hydraulic hybrid brake system

(Liu, Xue Jun He, Ren Liu, Cun Xiang Zhang, Er Li)(6 February 2014)

This paper discussed the brake performance and reviewed the research progress of the eddy current-hydraulic hybrid brake system. The paper mainly described the design principle of HIL testing bench, and presented a structure drawing of HIL testing bench. Based on the basic principle and structure of HIL testing bench, a real testing bench including hardware, software, interface, and virtual controller on PCs etc., is manufactured. Through two kinds of experiments on wet and dry road, the results indicates that the hybrid brake system has a perfect performance, the HIL testing bench of hybrid brake system is very convenient to study and simulate the braking system. Since the simulation on PCs cannot solve lots of actual problems, with the HIL testing bench, more actual research project can be done in the future[30].

2.31 Electromagnetic Braking System

(Routh, Pratyush Kumar Sagar, Prem Kumar, Rajesh Paul, Sarnendu)(2008)

The point to create this project electromagnetic braking system model was that to create a braking system capable of applying brakes without any friction and without losing the energy supplied to the system. It uses two electro magnets which runs by the supply of power from the circuit. There is a wheel that is attached to the motor so whenever the power is supplied the wheel starts to rotate with the help of the D.C motor for the purpose of cooling the electromagnets we uses a fan which we placed near the electromagnets so we can say that this fan works as a air type cooling system. A metal bar is placed between the electromagnets and wheel so when the magnetic flux passes perpendicular to the direction of rotation of wheel electromagnets produces eddy currents which flows in the direction opposite of the wheel which causes retardation and then stops the rotating wheel or rotor. This model helps in a way to be a used a retardation equipment in vehicles where sudden or emergency brakes are not commonly used[31].

2.32 Reference Model

Figure 2-1: Reference Model

2.33 Literature gap table

Table 2-1: Literature gap

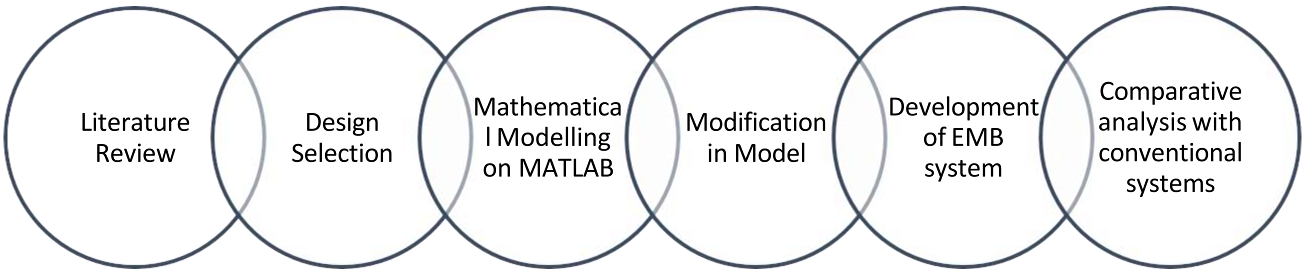
Author	Material		Parameters	Results
	Magnet	Brake Disc		
Nayak, Diptimayee, Samal, Soumya Sekhar, Mallick, Bikash Kumar [2]	NdFeB	Al,Cu,Brass	Thickness, Material Magnetic Properties	Al has better percentage of speed reduction with 8mm thickness
Sailesh, Bantu, Krishna, R Hari [6]	NdFeB	Gray Cast Iron, Al-6061, Al-7075,Al-7475	Braking Force, Number of Discs, Ultimate Yield Strength	A greater number of discs increases melting point temperature. Al-6061 has higher braking disc Temperature and thermal conductivity Al-7075 has greater UYS (upper yield stress)

Lakkam Ram Sai Prajwal, Harish[8]	Solenoid	Al	Induced Current, Air Gap, Disc Thickness, Electromagnet Turns	Induced Current and Air Gap majorly contributed to braking effect by RPM reduction. Disc Thickness and electromagnet turns are not much effective
Gembali, Srinivasa Gupta Rao, A. N.Brahmeswara, Naresh [9]	NdFeB	Al	Distance between disc and magnet, Speed and Torque	Distance between disc and brake reduces Torque and magnetic Field Intensity. Number of magnets reduce stopping distance and stopping time.
Paul, K Sugun Road, Visadala X) [13]	Solenoid	Steel	Clamp Force, Brake Force, Rotational Energy, Magnetic Field Strength, Magnetic Flux Density	Each tire has a separate braking coil, failure in any of braking coil cause accident. EMB can resist greater heat dissipation due to soft tough and temperature resistant disc liner.

CHAPTER 3

Methodology

The methodology adopted for the completion of the Electromagnetic Braking System comprises the following stages. The literature view is the first thing that needs to be done for the overview of the design and work done previously. The literature review is described and discussed in detail before in CHAPTER 2. The next step is the design selection and modification. The hierarchy of steps is shown as:



This methodology is followed onwards in the design project thesis report.

3.1 Discussion on Design:

3.1.1 Design 1:

The first design studied was a fill of coils and stand upon the tension springs. The housing was filled with epoxy resin and thus the temperature of the resin stated the main issue in the defective brake design. It is analyzed that the magnetic flux of the brake and the lining friction established is the main reason for the high temperature gradient of the Electromagnetic Brake which causes the failure of the Brake.

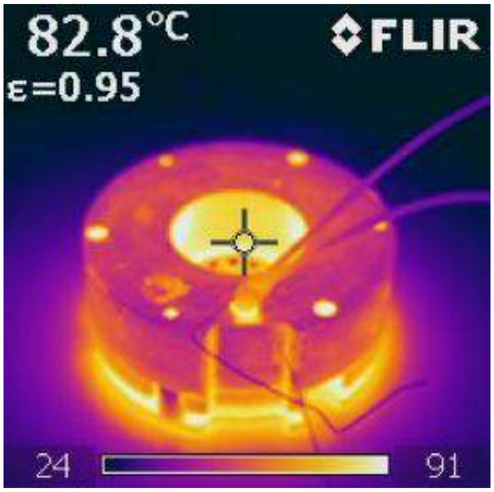


Figure 3-1: Temperature Distribution of Brake at steady state condition

The other big failure of the brake detected is because of the springs. Armature imbalance because of the different spring constants value which disturbs the housing and causes irregular wear and tear of the housing.

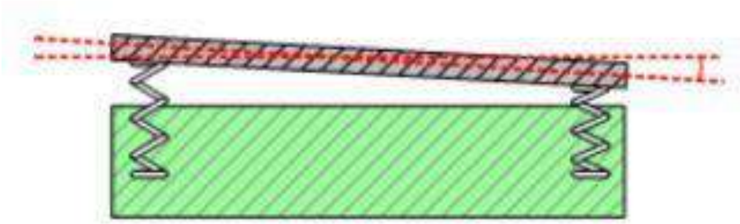


Figure 3-2: Armature Imbalance because of different spring constants

3.1.2 Design 2:

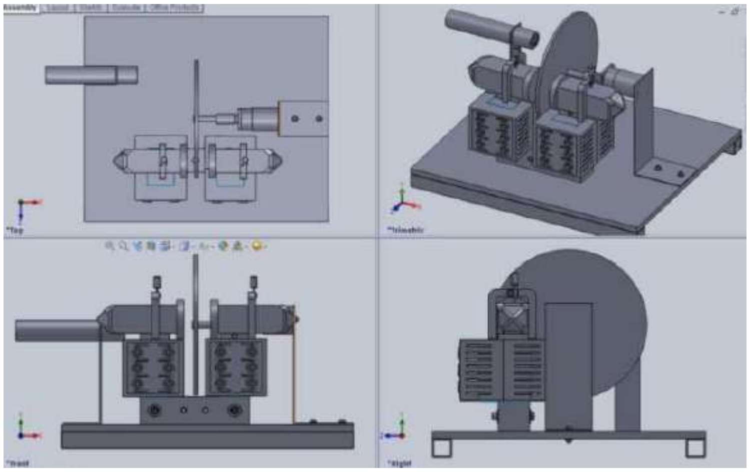


Figure 3-3: 3D view for the electromagnetic braking using eddy current study

In this design, two electromagnets along with two power motors are used which makes the system quite bulky. However, it reduces the stopping time by a much significant level. But the reason to modify this design is that too much magnetic flux induces heavy eddy currents in the disc attached to the wheel which will damage the wheel and makes its life shorter.

3.1.3 Design 3

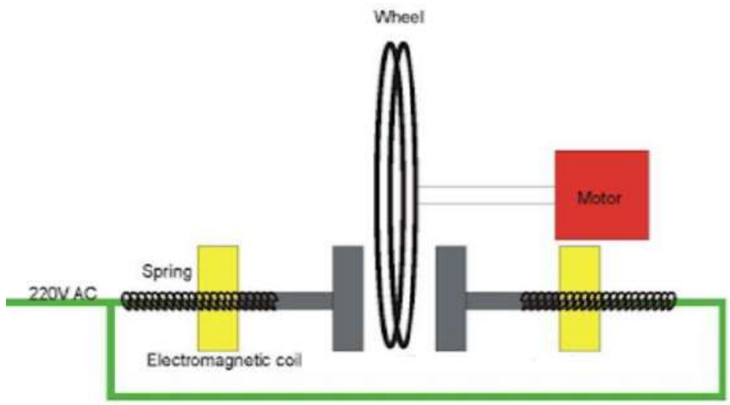


Figure 3-4: Electromagnetic Braking System

This design has its following limitations in the perspective that:

- As this system is bulky it requires a large space between the gearbox and the axle which is not practical as the vehicle has its own designed weight.
- Also, the system cannot be lubricated or greased.
- As this system is free of the controllers and designed power requirements so, it will only slow down the vehicle not completely stop it.

3.1.4 Design 4

Figure 3-5: Assembly Drawing of EMB system

This design is selected and then modified to meet the requirements of the Final Fabricated Electromagnetic Braking System Model. The proposed design is presented as the following:

3.2 Adopted Brake System

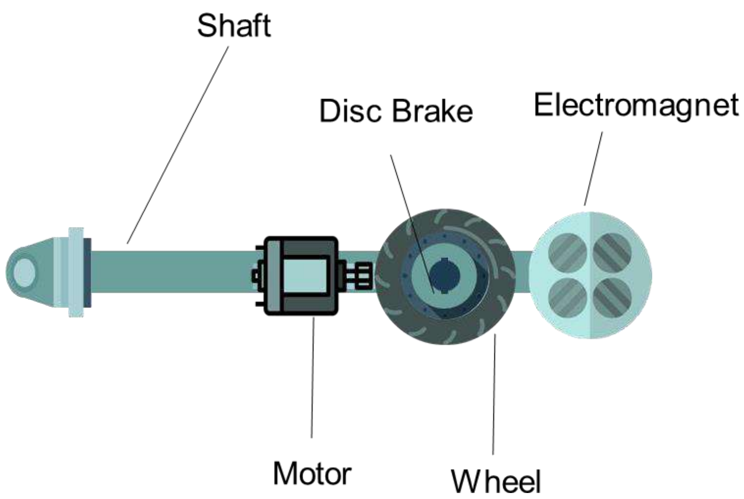


Figure 3-6: Proposed Design

This design is modified, based on following considerations:

- Magnetic Intensity increases the eddy currents which helps to shorten the stop time.
- On the RPM side, the plate is installed to reduce power consumption so that comparatively smaller magnets will be used.
- The wheel is on the Torque side to divide the power transmission and to minimize magnetization.

3.3 Design Calculations

To discuss the parameters of the model and visualize the trends and better understand the parametric behavior of the model following mathematical equations are proposed which are combined and derived to perfectly fit the model.

Table 3-1: Values of constants and abbreviated data

Symbol	Value	Name
μ_o	12.868×10^{-7}	Permeability of air
σ	1×10^{7}	Conductivity of material (Cast Iron)
S	$2.82\ 10^{-2}\ m^2$	Pole Area
d	1 – 5 mm	Disc Thickness
R	70 mm	Distance b/w center of disc and radius of pole
l_g	1 – 4 mm	Air gap
N	25 - 300	Number of turns
i	6 – 12 A	Current
θ	$6 – 70\ \frac{rad}{s}$	Angular Velocity of Wheel
v	$25 – 220\ \frac{m}{s}$	Translational velocity
m	35 kg	Frame mass
R_e	90-250 mm	Effective disc radius
D	13 inches	Diameter of wheel

The Magnetic Flux of the electromagnetic s given by the function as stated below.

$$B = \frac{\mu_o n i^2}{l_g} \quad (3.1)$$

The Braking Torque as the function of Dissipated Power and angular speed of the wheel is given as [40]:

$$T_b = \frac{P_d}{\theta} \quad (3.2)$$

The dissipated power is given as the function of the following parameters of :

$$P_d = \sigma R^2 S d\theta^2 B^2 \qquad (3.3)$$

Combining (3.1), (3.2) and (3.3) The resultant is the Braking Torque as the function

of the required parameters of :

$$T_b = \frac{\sigma R^2 S d\theta \mu_o n i^2}{l_g} \qquad (3.4)$$

To determine Braking Torque independently, it is evident that it can be found by using Braking Force applied and the effective disc radius of the braking system.

$$T_b = F_b . r_e \qquad (3.5)$$

To extract the Braking Force, to get the alternative formula for Braking Torque the following mathematical equation is used:

$$KE = \frac{1}{2} mv^2$$

$$\text{Braking energy} = F_b . \text{Braking Distance}$$

$$\text{Braking Distance} = \frac{\frac{1}{2} mv^2}{\text{Braking Force}} \qquad (3.6)$$

The Braking Torque in terms of Braking Distance can thus be found by the following equation. This can further help us to determine the relationship between the Braking Torque and Braking Distance.

$$T_b = \frac{\frac{1}{2} mv^2}{\text{Braking Force}} . r_e \qquad (3.7)$$

By comparing (3.7) and (3.4):

$$\text{Braking Distance} = \frac{\frac{1}{2} mv^2}{\frac{\sigma R^2 S d\theta \mu_o n i^2}{l_g}} . r_e \qquad (3.8)$$

Also braking torque is given by

$$T_b = \frac{F.D}{2.Re}[41] \qquad (3.9)$$

By Newton's second law

$$F = \frac{mv}{t} \qquad (3.10)$$

Putting value of from (3.10) in (3.9)

$$T_b = \frac{m.v.D}{2.Re.t} \qquad (3.11)$$

By comparing (3.4) & (3.11)

$$\frac{\sigma R^2 Sd\theta\, \mu_o ni^2}{l_g} = \frac{m.v.D}{2.Re.t} \qquad (3.12)$$

By rearranging

$$t = \frac{\frac{m.v.D}{2.Re}}{\frac{\sigma R^2 Sd\boldsymbol{\theta}\, \mu_o ni^2}{lg}} \qquad (3.13)$$

$$\text{Braking Time} = \frac{\frac{m.v.D}{2.Re}}{\frac{\sigma R^2 Sd\boldsymbol{\theta}\, \mu_o ni^2}{lg}} \qquad (3.14)$$

Equation (3.8) and (3.14) are the required equations for the mathematical modelling task.

3.4 2D and 3D Models:

3.4.1 Shaft:

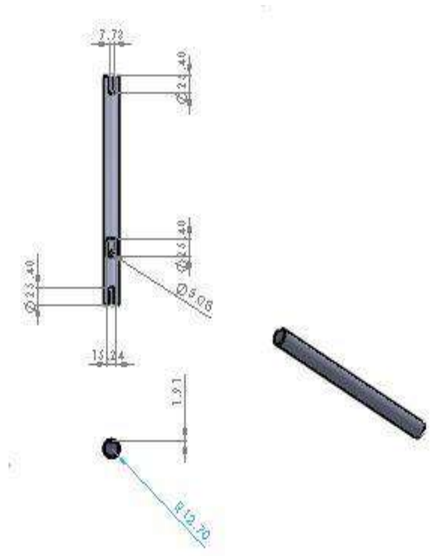


Figure 3-7: Shaft 2D 3D Model

3.4.2 Disc Plate:

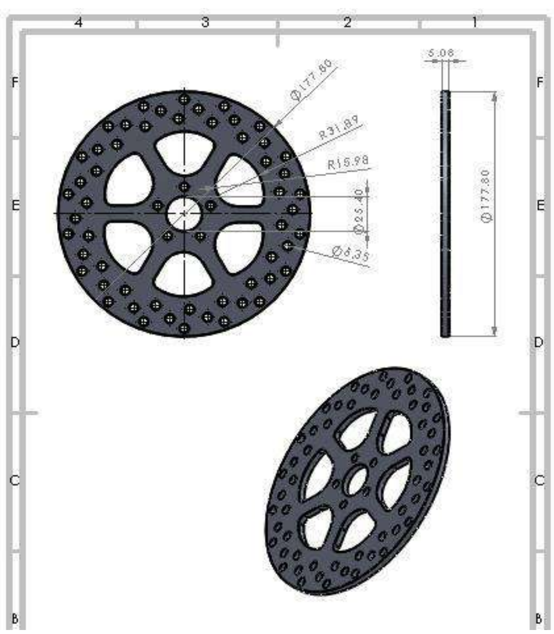


Figure 3-8: Disc 2D 3D Model

3.4.3 Tyre:

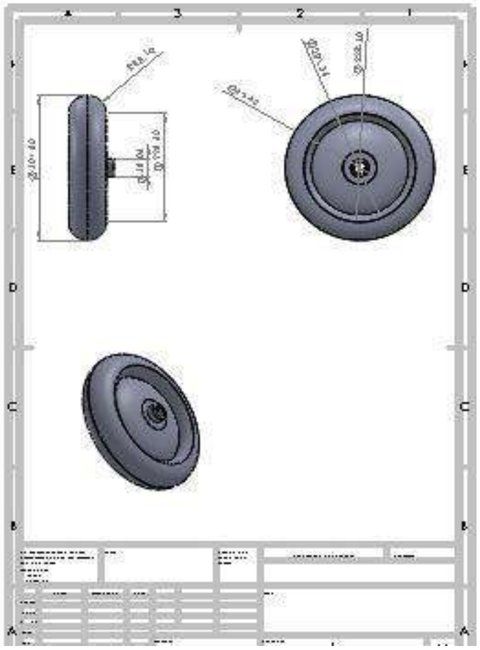


Figure 3-9: Tyre 2D 3D Model

3.4.4 Fan:

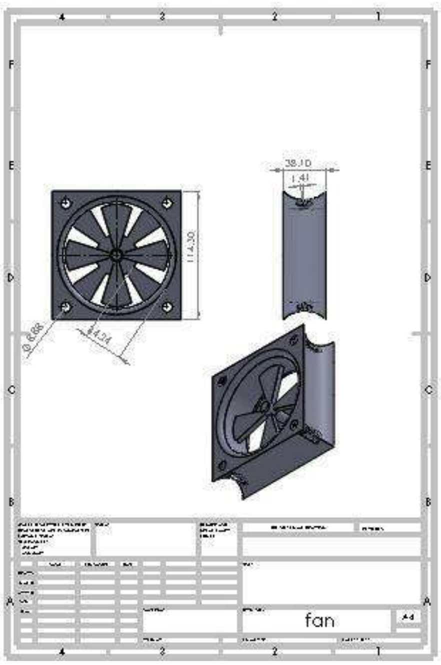


Figure 3-10: Fan 2D 3D Model

3.4.5 Micro Controller:

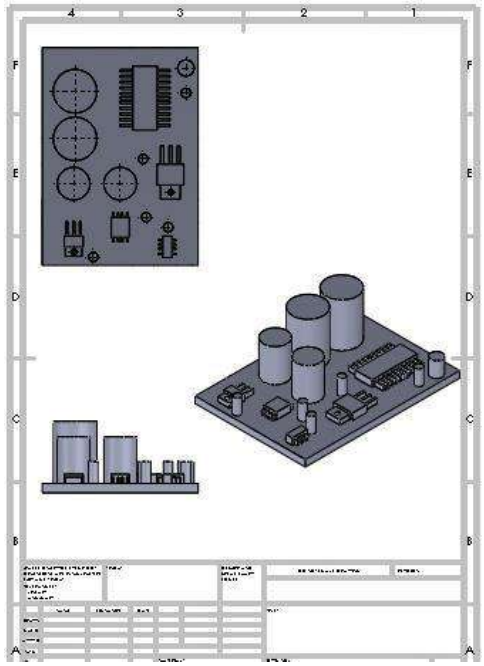


Figure 3-11: Micro controller 2D 3D Model

3.5 Complete Assembly Model:

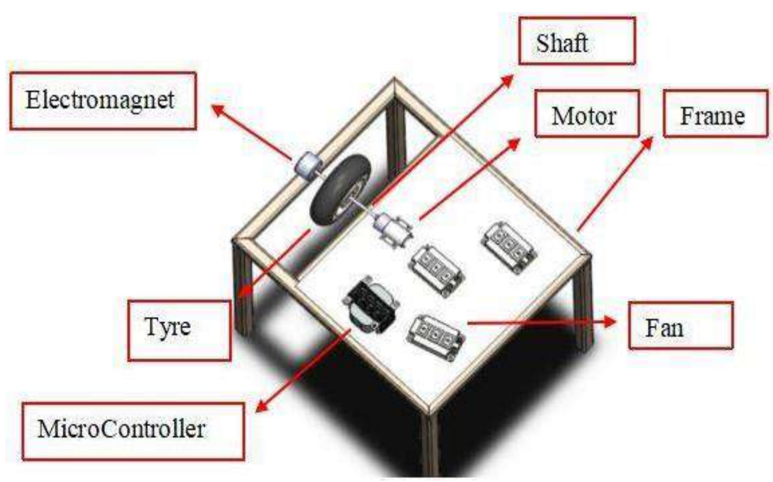


Figure 3-12: Complete Assembly

3.6 MATLAB Model:

On MATLAB using the above derived equations different models are developed for the parametric analysis.

Note: The parameters are presented and directed in the first part of the Code and the other codes are based on those designed parameters to select the final dimensions of the model

3.6.1 MATLAB code for Braking Time and Air Gap

For Braking Time and Air Gap the value is checked on the following parameters given in the code:

```
r=250;
S=2.8e-2;
R=70;
sig=1e7;
munot=12.868e-7;
m=35;

lg=1:4;
d=1:5;
N=25:300;
thetadot=6:70;
i=6:12;
v=20:220;
D=13
for i= 6:12;

BT=(m.*(v(25).^2).*D.*lg)./(sig.*(R.^2).*2.*Re.*S.*d(5).*thetadot(6).*munot
.*N(50).*(i.^2));
        plot(lg,BT);
        xlabel('lg');
        ylabel('BT');
        hold on;
```

3.6.2 MATLAB code for Braking Time and Current

For Braking Time and Current the value is checked on the following parameters given in the code:

```
for lg=1:4;

BT=(m.*(v(25).^2).*D.*lg)./(sig.*(R.^2).*2.*Re.*S.*d(5).*thetadot(6).*m
unot.*N(50).*(i.^2));
        plot(i,BT);
        xlabel('i');
        ylabel('BT');
        hold on;
end
```

3.6.3 MATLAB code for Braking Time and Distance

For Braking Time disc thickness d the value is checked on the following parameters given in the code:

```
for i= 6:12;

BT=(m.*(v(25).^2).*D.*lg)./(sig.*(R.^2).*2.*Re.*S.*d.*thetadot(6).*muno
t.*N(50).*(i(6).^2));
        plot(d,BT);
        xlabel('d');
        ylabel('BT');
        hold on;
end
```

3.6.4 MATLAB code for Braking Distance v/s Disc Thickness

By using MATLAB code for the relationship between Braking Distance and d is designed as:

```
for lg= 1:4;

BD=(m.*(v(25).^2).*r.*lg)./(2*sig.*(R.^2).*S.*d.*thetadot(6).*munot.*N(
50).*(i(6).^2));
        plot(d,BD);
        xlabel('d');
        ylabel('BD');
        hold on;
end
```

3.6.5 MATLAB code for Braking Time and Effective Electromagnet radius

By using MATLAB code for this relationship:

```
Re = 50:90
for lg=1:4;

BT=(m.*(v(25).^2).*D.*lg)./(sig.*(R.^2).*2.*Re.*S.*d(5).*thetadot(6).*
munot.*N(50).*(i(4).^2));
        plot(Re,BT);
        xlabel('Re');
        ylabel('BT');
        hold on;
end
```

3.6.6 MATLAB code for Braking Distance and Air Gap

By using current, MATLAB code for the relationship between l_g and Braking Distance is designed as:

```
for i= 6:12;

BD=(m.*(v(25).^2).*r.*lg)./(2*sig.*(R.^2).*S.*d(1).*thetadot(6).*munot.
*N(50).*(i.^2));
        plot(lg,BD);
        xlabel('lg');
        ylabel('BD');
        hold on;
```

3.6.7 MATLAB code for Braking Distance and Number Of Turns

MATLAB code for the relationship between Braking Distance and Number of Turns is designed as:

```
for i= 6:12;

BD=(m.*(v(25).^2).*r.*lg)./(2.*sig.*(R.^2).*S.*d(1).*thetadot(6).*munot
.*N*(i(6).^2));
        plot(N,BD);
        xlabel('N');
        ylabel('BD');
        hold on;
end
```

3.6.8 MATLAB code for Braking Distance and Current

MATLAB code for the relationship between Braking Distance and Number of Turns is designed as:

```
for lg=1:4;

BD=(m.*(v(25).^2).*r.*lg)./(2*sig.*(R.^2).*S.*d(5).*thetadot(6).*munot.
*N(50).*(i.^2));
        plot(i,BD);
        xlabel('i');
        ylabel('BD');
        hold on;
end
```

3.7 Model Specifications

Following are the specifications of parts and elements are used for the development of modified electromagnetic braking system model:

Table 3-2: Specifications of Fabricated Model

Design Element	**Specifications**
Wheel Size	13 inches
Wheel Diameter	2.5 inch
Bearing	6203
Shaft	17 mm
Motor	1300 RPM or 300 Watt
Frame Size	2 m × 2 m × 2.5 m
Brake Disc	Steel
Conductivity (Brake Disc)	1×10^7
Brake Disc diameter	12 mm
Air Gap	4 mm
Electromagnet	125 mm thickness and 2-25 A magnets

3.8 Material Required

3.8.1 Wheel and Tyre

Figure 3-13: Wheel and Tyre

3.8.2 Electromagnet

The electromagnet is a kind of magnet where the attractive field is created by an electric flow. The attractive field vanishes when the current is switched off. Electromagnets are normally comprised of protected wire twisted into a loop. A current through the wire makes an attractive field that is moved flat broke in the focal point of the curl deeply.

Figure 3-14: Electromagnet

3.8.3 PWM Drivers Box

This box is used to vary the speed and power of the electric DC motor which in turn affects the intensity of the brake. This driver box switches the transistors available in the invertor on and off section for the provision of simulated sine wave voltage to the electric DC motor.

Figure 3-15: PWM Drivers Box

3.8.4 Motor

Figure 3-16: Motor

3.8.5 Frame

Figure 3-17: Frame

3.9 Construction

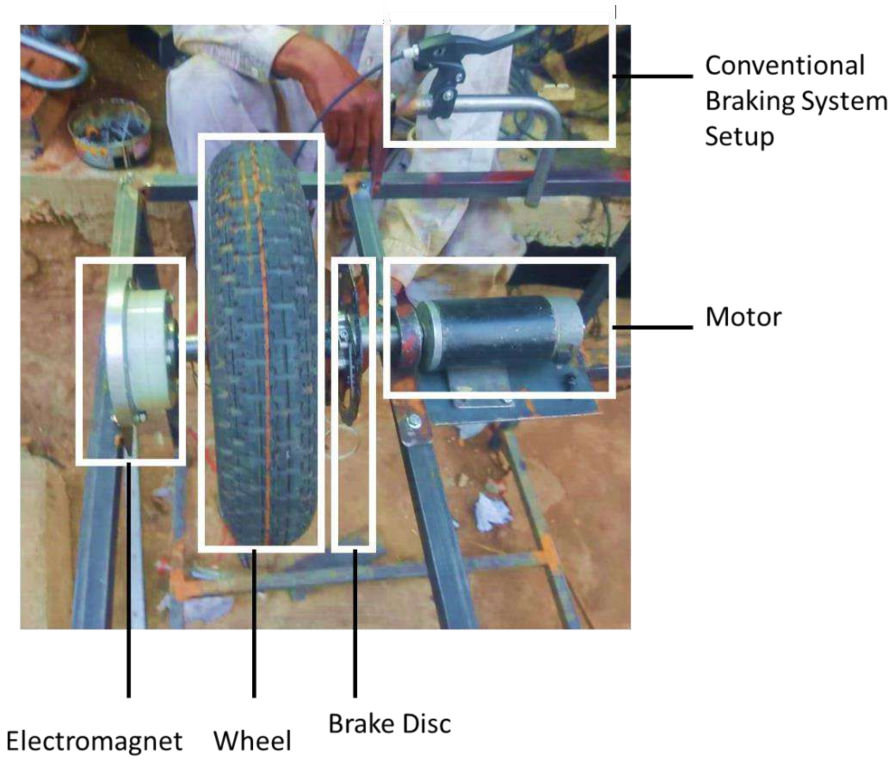


Figure 3-18: Alignment of Materials on Frame

The wheel is attached directly to the motor to provide direct RPM. The belt and pulley option are neglected to maximize the RPM to the wheel and vary the RPM with Arduino coding. The electromagnet is also attached with the alignment on the Torque side. To make a comparative analysis and to complete experimentation, the Brake disc is attached along with the conventional braking system model to get the direct readings for the experimentation purposes. To avoid the vibrations the frame will be attached directly to the bottom with the help of extension Bolts. The joining is done through welding and fastening.

To drive the Motor and to Control the intensity of the Electromagnet PWM drivers are used according to the purpose as already explained in section 3.8.3.

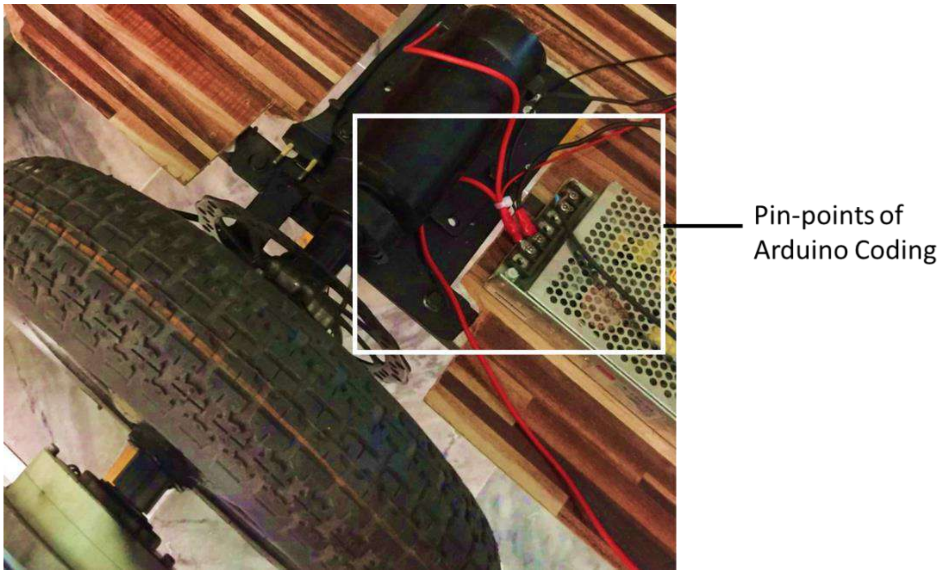


Figure 3-19: PWM Drivers Coding

Arduino Software is used for the Coding of PWM Drivers. The pinpoints can be extended for the manual installation of the Brake. However, the brake is automated here. Speed, Brake, and Buzzer are attached on pinpoint 5,3, and 12 respectively. The buzzer is configured on output. While loop is used for the buzzer to start and stop in the time span of milliseconds. The code is as follows:

```
Int speed_duty=100;
Int break_duty=100;
Int Speed=5;
Int Break=3;
Int buz=12;
void setup() {
Serial.begin(9600);
analogWrite(3,0);
analogWrite(5,0);
pinMode(buz,OUTPUT);
```

```
while((analogRead(A5)<1000) )
{digitalWrite(buz, 1 );delay(100);
digitalWrite(buz,0);delay(200);
}
while((analogRead(A6)<1000) )
{digitalWrite(buz, 1 );delay(100);
digitalWrite(buz,0);delay(200);
}
digitalWrite(buz, 1 );delay(1000);
digitalWrite(buz,0);delay(100);
// the loop routine runs over and over again forever: void loop(){
// read the input on analog pin 0:
speed_duty= 255-(analogRead(A6)/4);
break_duty= 255-(analogRead(A5)/4);
if(break_duty>255){break_duty=255;}
if(break_duty<O){break_duty=O;}
if(speed_duty>255){speed_duty=255;}
if(speed_duty<10){speed_duty=10;}
break_duty= 255-(analogRead(A5)/4);
if(break_dutY>255){break_duty=255;}
if(break_dutY<O){break_duty=O;}
if(speed_dutY>255){speed_duty=255;}
if(speed_dutY<10){speed_duty=10;}
Serial.print("SPEED:");
Serial.print(speed_duty);
Serial.print(" Break:");
Serial.print(break_duty);
Serial.println(""); if(break_dutY>10)
```

```
{
analogWrite(Speed,0);
analogWrite(Break,break_duty);
digitalWrite(buz,1);delay(50);
digitalWrite(buz,0);delay(200);
}
If (break_duty<10)
{
analogWrite(Speed,speed_duty);
analogWrite(Break,0);
}
```

3.10 Group Members Images

Figure 3-20: Fabrication of Project by Group Members

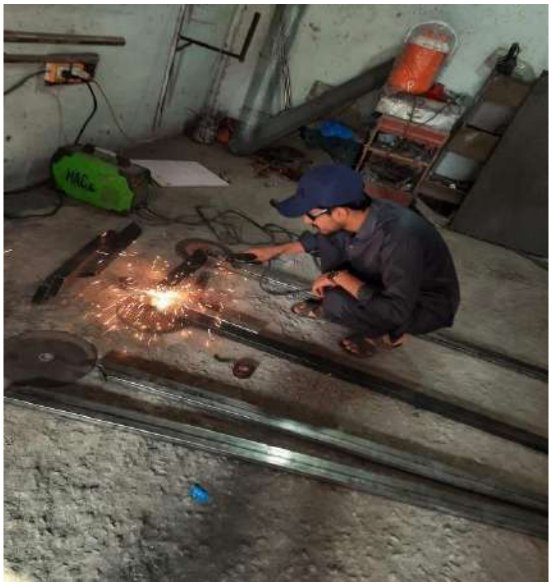


Figure 3-21: Frame Welding short

3.11 Final Experimental Model

Figure 3-22: Experimental Model of Electromagnetic Braking System

3.12 Cost Analysis of Project

Table 3-3: Cost Analysis of Project

Sr #	Name	Qty	Price
1	Table frame	1	4000
2	Electric Motor	1	15000
3	Wheel	1	5000
4	Electromagnet	1	10000
5	Disk break and clutch	1	1000
6	Electric supply	1	2000
7	Intensity control and speed control relays	2	300
8	Cooling fan	1	1500
9	Transformer	1	1300
10	Alarm and sensor	2	400
11	Holding Bracket and bearings	2	450
12	Nut bolts and wires	Due to requirement	400
13	Hard board sheet	1(2ft*2ft)	200
14	Transportation cost	Petrol, Local Convince	9000
	Total		50550

CHAPTER 4

Experimentation and Result Discussion

Experimentation is carried out manually on the fabricated model. A stopwatch is used to record the brake time and then the Braking Distance is calculated through the Respective RPM of the wheel along with the stopping time. Conventional and Electromagnetic Braking are both recorded. Meanwhile, the RPMs of the wheel are recorded with the help of a Tachometer. The following data is obtained under the following experimentation:

4.1 Braking Time

Table 4-1:Experimental Braking Time of Electromagnet and Conventional Braking System

Serial Number	**RPM**	**Electromagnet Braking Time (s)**	**Conventional Braking Time (s)**	**Advantage**
1	550	0.11	0.13	15%
2	650	0.13	0.26	50%
3	750	0.15	0.33	55%
4	850	0.18	0.47	62%
5	1000	0.33	0.68	51%

4.2 Braking Distance

Braking Distance is calculated through the formula:

$$\text{Braking Distance} = d = \frac{\omega t}{r} \tag{5.1}$$

Where:

ω = angular velocity of wheel

r = radius of wheel

t = Braking Time

d = Braking Distance

Table 4-2: Experimental Data of Electromagnetic and Conventional Braking Distance

Serial Number	RPM	Electromagnet Braking Distance (m)	Conventional Braking Distance (m)	Advantage
1	550	0.23	0.27	15%
2	650	0.33	0.6	50%
3	750	0.43	0.96	55%
4	850	0.59	1.56	62%
5	1000	1.28	2.6	51%

4.3 MATLAB Results

Following are the results obtained from the MATLAB modeling of the Contactless Electromagnetic Braking System. The MATLAB modelling was done on the parameters of Air Gap, Current, Radius of Electromagnet, and Disc thickness for the Braking Time and Air Gap, Current, Number of Turns and Disc Thickness for the Braking Distance. The following behavior is recorded for these parameters and then with graphs in section 4.4.

Table 4-3: Parametric Relations of Contactless Electromagnetic Braking Model (Braking Time and Braking Distance) using MATLAB

	Parameter	Behavior
Braking Time	Air Gap	Direct or increasing
	Radius of Electromagnet	Inverse or decreasing
	Current	Inverse or decreasing
	Disc Thickness	Inverse or decreasing
Braking Distance	Air Gap	Direct or increasing
	Number of Turns	Logarithmic Decrease
	Current	Inverse or decreasing
	Disc Thickness	Inverse or decreasing

4.4 Graphical Results on MATLAB

The following are the graphical results obtained through the data for the development of Electromagnetic Braking System Modelling on MATLAB. The braking Time relations with the parameters of Air Gap, Current, Effective Disc Radius and Disc Thickness.

From modelling results performance parameters optimal values are selected for the development of electromagnetic braking. (a) the optimal value of current is selected to be 4 amperes at which Braking time is practicable. (b), (c) and (d) air gap is selected to be 4mm. All these values are obtained to be optimal at mass of 35kg of the total system.

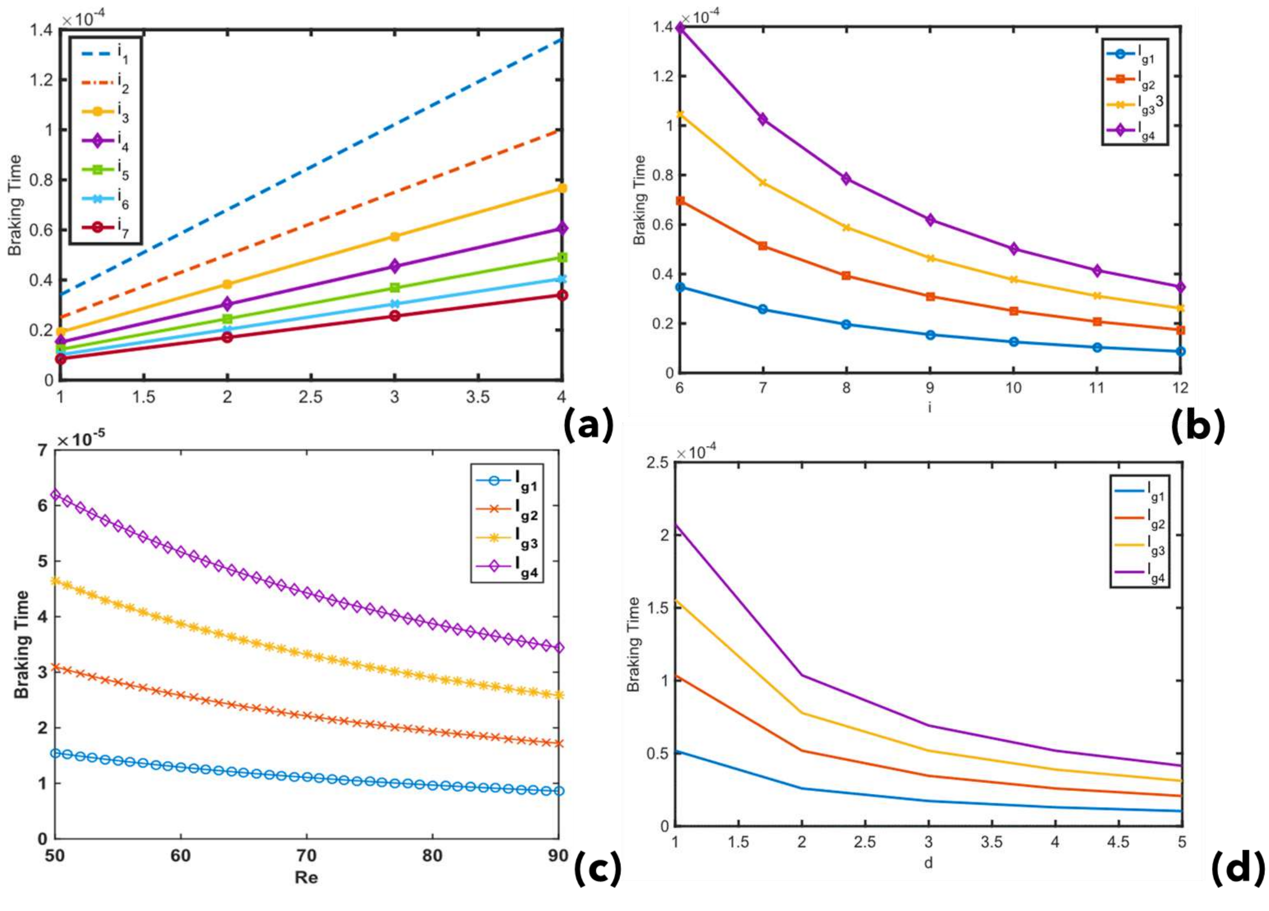


Figure 4-1: Braking Time v/s (a) Air Gap (b) Current (c) Effective Disc Radius (d) Disc Thickness

shows the Relationship of Braking Distance of Electromagnetic Braking System with parameters: Disc Thickness, Number of Turns of Electromagnet, Air Gap, and Current.(a) brake disc of thickness 3mm and diameter 12mm is selected of material steel. By analyzing the results of (b) Solenoid is the optimal solution to change the magnetic field of the electromagnet based upon the induced current. This magnetic field is automated through PWM drivers between the range of 2-

25A and the best performance of the system is observed on 4 Amperes. The air gap and current at which braking distance has optimal results is observed on 4mm and 4 Amperes respectively.

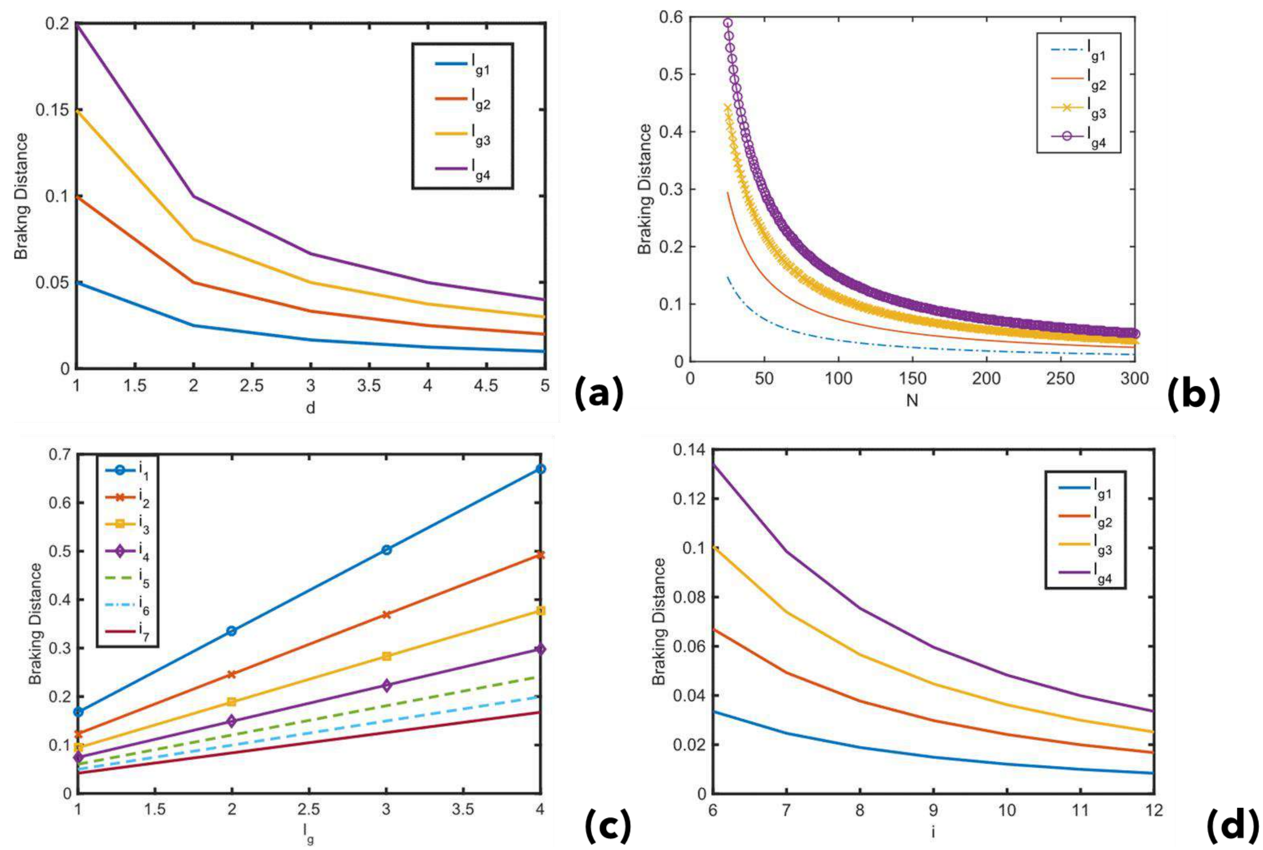


Figure 4-2: Braking Distance v/s (a) Disc Thickness (b) Number of Turns (c) Air Gap (d) Current

4.5 Braking Time and Braking Distance

From the experimental data, we drew the following graphical interpretation and intended to compare the electromagnetic braking data with the conventional Braking System. We can visualize the effect of increasing the RPM of the wheel increases the Braking Time of the vehicle and thus the vehicle takes a long to stop. As we compare both the electromagnetic braking and conventional braking behavior, we see that Electromagnetic Braking time is way less than the conventional Braking time for the same respective RPM values.

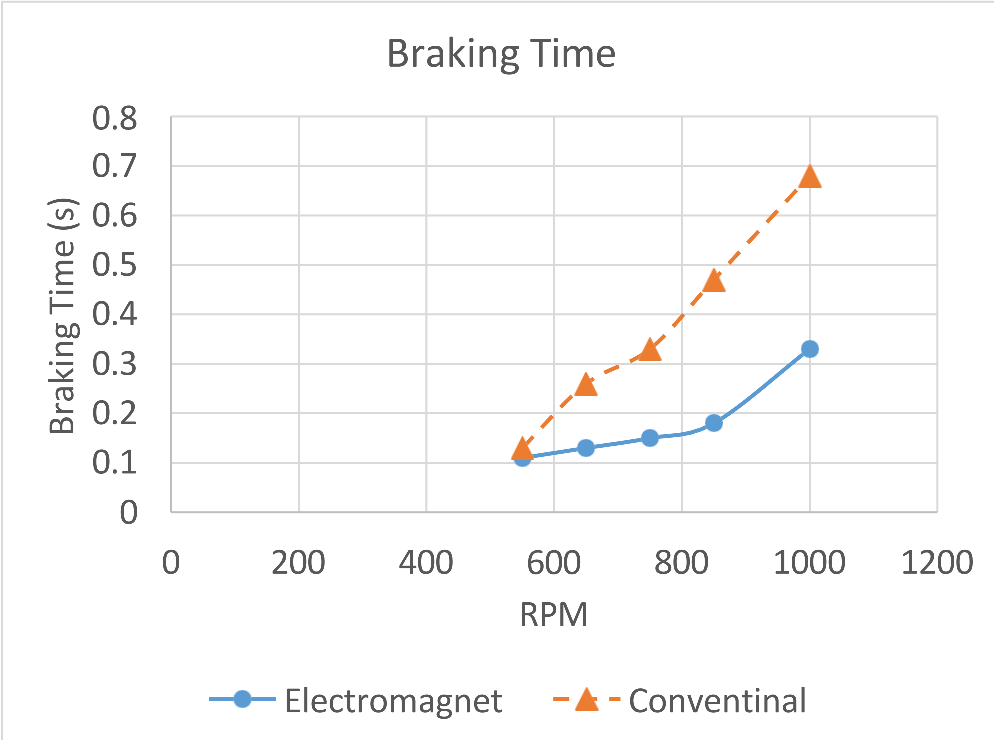


Figure 4-3: Braking Time of Electromagnetic v/s Conventional Braking

As obvious from and from the result concluded from as soon as the braking time increases the braking distance or in other words the distance at which the vehicle intended to stop also increases as soon as the RPM increases. Here the phenomenal difference between the conventional braking and electromagnetic braking also shows the electromagnetic braking is quite effective in stopping the vehicle at a much smaller distance than the conventional braking. This not only reduce the frictional effect of brakes but due to non-contact braking behavior wear and tear with much effective results can be a prone of the electromagnetic braking system.

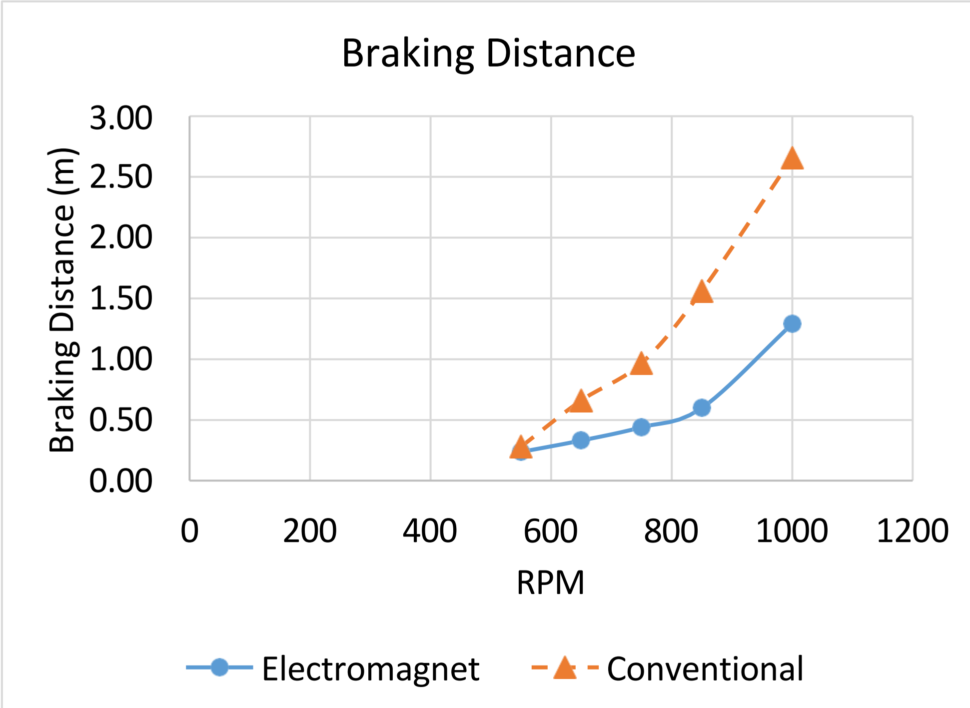


Figure 4-4: Braking Distance of Electromagnetic v/s Conventional Braking

4.6 Comparative Results

The comparative analysis overall results are shown in table between the Electromagnetic Braking System and Conventional Braking System

Table 4-4: Comparative Analysis between the Electromagnetic Braking System and Conventional Braking System

Parameter	Electromagnetic Brakes	Conventional Brakes	Percentage Difference
Braking Time	0.18 s	0.37 s	51%
Braking Distance	0.57 m	1.19 m	52.1%

4.7 Safety Precautions

- Follow the recommended maintenance schedule provided by the manufacturer for the Electromagnetic system

- Conduct routine inspections of electrical connections, and mechanical components to identify and address any safety concerns
- Ensure proper installation and secure mounting of the system components to prevent accidents or damage.
- Follow safety guidelines when assembling, disassembling, or adjusting any mechanical parts

Chapter 5

Environment and Sustainability

5.1 Effect on Environment

5.1.1 Reduce Wear & Tear:

Electromagnetic braking systems rely on electromagnetic forces rather than friction to slow down or stop a moving object. This results in significantly reduced wear and tear on braking components such as brake pads and discs. As a result, there is less particulate matter generated, contributing to a cleaner environment.

5.1.2 Lower Emissions:

In applications where electromagnetic braking systems are used as regenerative brakes, such as in electric vehicles and hybrid vehicles, they contribute to lower emissions. The regenerative braking process captures and converts kinetic energy into electrical energy, which can be stored in batteries. This means that less energy is wasted as heat, and the vehicle's overall energy efficiency improves. As a result, there is reduced reliance on fossil fuels and decreased greenhouse gas emissions.

5.1.3 Noise Reduction:

Electromagnetic braking systems tend to produce less noise compared to traditional friction-based braking systems. The absence of continuous physical contact and rubbing between brake components reduces the generation of noise pollution in urban environments and residential areas.

5.1.4 Enhanced Safety:

Electromagnetic braking systems often provide smoother and more controlled braking, which can contribute to enhanced safety. The reduced risk of sudden stops or skidding helps prevent accidents and decreases the wear on road surfaces, leading to safer and more sustainable transportation.

5.1.5 Energy Recovery:

In certain applications like trains and electric vehicles, electromagnetic braking systems can recover and reuse energy that would otherwise be lost as heat during braking. This energy recovery not only improves efficiency but also reduces the overall energy demand, leading to a more environmentally friendly operation.

5.1.6 Lower Air Pollution:

The reduction in wear-related particulate matter, as well as the potential for decreased fossil fuel consumption in regenerative braking systems, can contribute to lower levels of air pollution, which is especially important in urban areas with air quality concerns.

5.1.7 Decreased Heat Generation:

Traditional braking systems can generate substantial heat during braking, which can contribute to localized heating of surrounding components and infrastructure. Electromagnetic braking systems generate less heat, reducing the potential for heat-related damage to nearby components and infrastructure.

5.2 Existing Problem

5.2.1 Reduction of Friction-Related Issues:

Traditional friction-based braking systems are prone to wear and tear due to the constant contact and rubbing of brake pads against discs or drums. This can lead to frequent replacement of components and increased maintenance costs. Your electromagnetic braking system, which relies on electromagnetic forces rather than friction, significantly reduces wear-related issues and the associated maintenance requirements.

5.2.2 Improved Energy Efficiency:

In applications like electric vehicles, your electromagnetic braking system serves as a regenerative brake, converting kinetic energy into electrical energy. This recovered energy can be stored and used to power the vehicle, reducing the overall energy consumption and increasing the vehicle's range. This addresses the problem of energy wastage during braking in conventional systems.

5.2.3 Heat Dissipation and Cooling Challenges:

Traditional braking systems can generate substantial heat during braking, which may require complex cooling mechanisms to prevent overheating. Your electromagnetic braking system generates less heat, mitigating the need for elaborate cooling solutions and reducing the risk of heat-related component damage.

5.2.4 Noise Pollution Reduction:

Conventional braking systems can produce significant noise due to the friction between braking components. Your electromagnetic braking system produces less noise, contributing to a quieter and more comfortable environment, particularly in urban areas.

5.2.5 Component Longevity and Maintenance:

The reduced wear and tear in your electromagnetic braking system translates to longer component lifespans and decreased maintenance frequency. This addresses the challenge of frequent component replacements and associated downtime in conventional systems.

5.2.6 Energy Recovery in Transportation:

In applications like trains or hybrid vehicles, your electromagnetic braking system's regenerative capabilities address the energy wastage issue during braking, making transportation more energy-efficient and reducing the reliance on external power sources.

5.2.7 Adaptability to Various Applications:

Your electromagnetic braking system's versatility in different applications, from industrial machinery to transportation, addresses the need for adaptable braking solutions that can be tailored to specific requirements.

5.3 Reliability and Sustainability

Reliability

- **Robust Design:**

Describe how your electromagnetic braking system has been designed with reliability in mind. Highlight factors such as the selection of durable materials, appropriate component sizing, and consideration of potential failure points.

- **Testing and Validation:**

Discuss the extensive testing and validation processes your system has undergone. This includes simulations, laboratory tests, and possibly field trials to ensure that the system performs consistently under various conditions.

- **Maintenance Strategies:**

Explain any built-in features that enhance reliability, such as self-monitoring capabilities or predictive maintenance algorithms. These features can help identify and address issues before they lead to system failures.

- **Redundancy and Fail-Safe Mechanisms:**

If applicable, detail any redundancy or fail-safe mechanisms integrated into the system. These mechanisms can provide backup solutions in case of unexpected failures, contributing to system reliability.

- **Longevity:**

Highlight how the reduced wear and tear of your electromagnetic braking system leads to extended component lifespans. This reduces the need for frequent replacements and maintenance, enhancing the overall reliability of the system.

Sustainability

- **Energy Efficiency:**

Emphasize the energy efficiency of your electromagnetic braking system, particularly in regenerative braking applications. Explain how energy that would otherwise be wasted as heat is captured and repurposed, contributing to sustainability by reducing energy consumption.

- **Reduced Emissions:**

Discuss how the energy-efficient operation of your system translates into reduced emissions, especially in applications like electric vehicles and trains. This aligns with sustainability goals and contributes to environmental preservation.

- **Minimized Resource Consumption:**

Describe how the extended component lifespans and reduced maintenance needs of your system lead to minimized resource consumption. Fewer replacements and repairs result in less demand for raw materials and energy-intensive manufacturing processes.

- **Lifecycle Assessment:**

Explain any lifecycle assessments you've conducted to evaluate the environmental impact of your system from production to disposal. Highlight any areas where your system outperforms traditional braking systems in terms of sustainability.

- **Noise Reduction:**

Address how your electromagnetic braking system's quieter operation contributes to reduced noise pollution. This can have a positive impact on both human well-being and environmental sustainability.

- **Adaptability and Scalability**:

Discuss how your system's adaptability and scalability make it suitable for a range of applications. This versatility can contribute to sustainable design practices by offering a single solution for multiple contexts.

- **Alignment with Regulations:**

If your system aligns with or exceeds regulatory requirements related to emissions, noise, or energy efficiency, highlight how this demonstrates its commitment to sustainability.

Chapter 6
Conclusion & Future Recommendations

6.1 Conclusion

This report presented the performance of an electromagnetic braking system which includes various components with efficient methodologies to utilize the supplied energy. The electromagnetic braking system depends upon the various parameters that affect the braking torque and braking distance of the system which results depicted the efficiency of the EMB. With the application of an effective and strong electromagnet, we can have a greater efficient braking system. In this report, mathematical modeling was used for the parametric analysis and development of the prototype model. Air Gap, induced current, number of electromagnetic turns, and disc thickness were the major parameters that majorly affected the braking torque and RPM reduction of an automobile. The electromagnetic braking system was found to be reliable with the advantage of about 46.6% over the conventional system and proved to be efficient. However, the percentage difference observed of about 51% in braking time and 52.1% in braking distance. The braking time and braking distance were calculated at various RPMs of the vehicle and compared with the hydraulic wire type conventional braking system. It was shown in Table 6.2 that the electromagnetic braking system was efficient and had less wear and tear and maintenance requirements. Also, the braking time and braking system parameters proved to be best performing in the case of the electromagnetic braking system.

6.2 Future Scope

- Conventional system is less efficient in terms of heat dissipation and has more frictional losses.
- Conventional braking system uses hydraulic system in which crude oil is used as hydraulic fluid. Crude oil is a finite energy source so it will end soon. So, electromagnetic systems are a good alternative to it.
- Electromagnetic brakes are used in regenerative braking systems in hybrid and electric cars.

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