UGC & Govt. Approved
Sonargaon University (SU)
সোনারগাঁও ইউনিভার্সিটি (এসইউ)

"Design & Implementation of a Contactless Electromechanical Braking System"

A report submitted to the Department of Mechanical Engineering, Sonargaon University of Bangladesh in fulfillment of the requirements for the Award of Degree of Bachelor of Science in Mechanical Engineering.

A Thesis

By

Mahmud Hasan Touhid	ID: ME2101023433
Abdullah Al Noman	ID: ME2101023432
Shariar Hossain Sunny	ID: ME2101023435
Rafat Ahammed	ID: BME1703013484
Ajam Hossain	ID: ME2101023344
Md. Naimur Rahman	ID: ME2101023077

Supervisor

G M Ismail Hossain

Lecturer

Department of Mechanical Engineering

Sonargaon University (SU)

Dhaka-1215, Bangladesh

September 2024

Approval

This is to certify that the project work entitle, "**Design & Implementation of a Contactless Electromechanical Braking System**" has been carried out by **Mahmud Hasan Touhid (ID: ME2101023433), Abdullah Al Noman (ID: ME2101023432), Shariar Hossain Sunny (ID: ME2101023435), Rafat Ahammed (ID: BME1703013484), Ajam Hossain (ID: ME2101023344), Md. Naimur Rahman (ID: ME2101023077)** thereby declared that the work presented here is original work done by me and has not been published or submitted elsewhere for the requirement of a degree of Bachelor of Science (B.Sc.) in Mechanical Engineering in the year of 2024 Program in the Department of Mechanical Engineering, Sonargaon University of Bangladesh (SU) has been carried out under by supervisor.

BOARD OF EXAMINERS

_____ (Supervisor)

G M Ismail Hossain
Lecturer
Department of Mechanical Engineering
Sonargaon University (SU), Dhaka -1215, Bangladesh.

_____

Prof. Md. Mostofa Hossain
Head of the Department
Department of Mechanical Engineering

DECLARATION

We do hereby solemnly declare that the work presented here in this project report has been carried out by us and has not been previously submitted to any University/ Organization for award of any degree or certificate

We hereby ensure that the works that has been prevented here does not breach any existing copyright.

We further undertake to indemnify the university against any loss or damage arising from breach of the foregoing obligation.

Signature of Students

Mahmud Hasan Touhid
ME2101023433

Abdullah Al Noman
ME2101023432

Shariar Hossain Sunny
ME2101023435

Rafat Ahammed
BME1703013484

Ajam Hossain
ME2101023344

Md. Naimur Rahman
ME2101023077

Signature of Supervisor

GM Ismail Hossain
Lecturer
Department of ME

ACKNOWLEDGEMENT

First, we started in the name of almighty Allah. This thesis is accomplished under the supervision of **GM Ismail Hossain,** Lecturer, Department of Mechanical, Sonargaon University. It is a great pleasure to acknowledge our profound gratitude and respect to our supervisor for this consistent guidance, encouragement, helpful suggestion, constructive criticism and endless patience through the progress of this work. The successful completion of this thesis would not have been possible without his persistent motivation and continuous guidance.

The authors are also grateful to **Prof. Md. Mostofa Hossain,** Head of the Department of Mechanical Engineering and all respect teachers of the Mechanical Engineering Department for their co-operation and significant help for completing the thesis work successfully.

[Authors]

Mahmud Hasan Touhid
Abdullah Al Noman
Shariar Hossain Sunny
Rafat Ahammed
Ajam Hossain
Md. Naimur Rahman

ABSTARCT

This project, an Electromechanical Braking System is developed following, drivers and other road users' safety and comfort. Most of the conventional braking systems like mechanical systems, hydraulic systems, and pneumatic systems have certain limitations. In mechanical brake systems, erosion of the mechanical pads is carried out by frictional force and requires periodic replacement of the bearing. and electromechanical braking system is used to respond to stoppages or slowing down of the vehicle quickly. This braking system has also been more efficient. This project aims to create an electromechanical braking system model capable of applying brakes without any friction loss and without losing the energy supplied. It uses two electromagnets which runs by the supply of power from the Battery. Also, there is a wheel which is attached to the motor so when the power is supplied, by the help of motor the wheel rotates. We tested some performance test to verify its performance. We tested input voltage (12V DC) to the electromagnet system and the current of motor (0.4A) and the electromagnet coil (5.5A). We also tested vibration (0 mm/s) of our system. We tested the temperature of the coil (39.7 ˚C) and the braking disc (34.2˚C) of the wheel. In our system, the wheel was running at a speed of 104 RPM. When we applied electromagnet brake, the wheel stopped within 0.9 second without any heat generation at brake disc.

TABLE OF CONTENTS

Approval	ii
Declaration	iii
Acknowledgement	iv
Abstract	v
Table of Contents	vi
List of Figure	viii
List of Tables	ix

CHAPTER 1 INTRODUCTION

1.1 Introduction	1
1.2 Application	2

CHAPTER 2 LITERATURE REVIEW

2.1 Literature Review	3

CHAPTER 3 MATERIALS REQUIRED AND CONSTRUCTION

3.1 Required Instrument	7
3.2 Electromagnetic Break	7
3.3 DC Gear Motor	7
3.4 Relay	8
3.5 SMPS	10
3.6 Push Button Switch	11
3.7 Wheel	12
3.8 Bicycle Speedometer	12
3.9 Proteus Software	13

CHAPTER 4 METHODOLOGY

4.1 Braking Principle of Operation 14

4.2 Braking System Functioning Principle 14

4.3 Design Methodology 15

4.4 Working Principle 16

4.4.1 Block Diagram 16

4.4.2 Circuit Diagram 17

CHAPTER 5 RESULT AND DISCUSSION

5.1 Result 18

5.2 Data Analysis 18

5.3 Braking Torque Calculation 19

5.4 Discussion 20

CHAPTER 6 CONCLUSION

6.1 Conclusion 21

6.2 Limitation 21

6.2 Future Scope 21

Reference 23

LIST OF FIGURES

FIGURE NO	FIGURE NAME	PAGE NO
1.1	Our Main Project View	1
3.1	Electromagnetic Brake	7
3.2	DC Gear Motor	8
3.3	Relay	8
3.4	Relay Module	9
3.5	Mains Voltage Construction	9
3.6	Pin Wiring	10
3.7	Push Button Switch	11
3.8	Wheel	12
3.9	Bicycle Speedometer	12
3.10	Proteus Software Interface	13
4.1	Block Diagram of our project	16
4.2	Schematic Circuit Diagram of the Project	17
5.1	Temperature Difference between Disc and Coil	18
5.2	RPM and Brake Response Time Curve	19

LIST OF TABLES

TABLE NO	TABLE NAME	PAGE NO
5.1	DATA ANALYSIS TEST PARAMETERS	18

CHAPTER 1
INTRODUCTION

1.1 Introduction:

Electromagnetic brakes have been used as supplementary retardation equipment in addition to the regular friction brakes on heavy vehicles. We outline the general principles of regular brakes and several alternative retardation techniques in this section. The working principle and characteristics of electromagnetic brakes are then highlighted. The principle of braking in road vehicles involves the conversion of kinetic energy into thermal energy (heat). When stepping on the brakes, the driver commands a stopping force several times as powerful as the force that puts the car in motion and dissipates the associated kinetic energy as heat. Brakes must be able to arrest the speed of a vehicle in a short period regardless of how fast the speed is. As a result, the brakes are required to have the ability to generate high torque and absorb energy at extremely high rates for short periods.

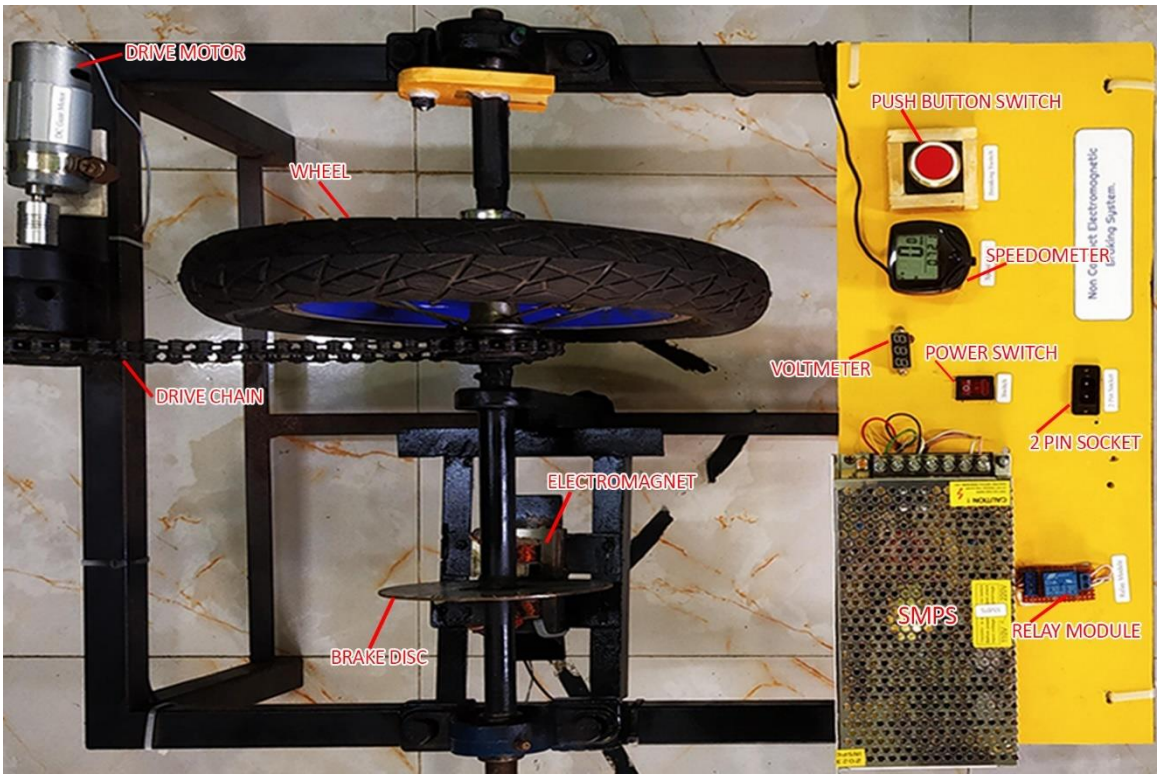


Figure-1.1: Our main project View.

Brakes may be applied for a prolonged period in some applications such as a heavy vehicle descending a long gradient at high speed. Brakes have to have the mechanism to keep the heat absorption capability for prolonged periods. In the electromagnetic brake, the coil or solenoid attracts a steel disc. The steel disc presses a brake disc made of sintered or asbestos material between itself and a stationary steel disc. The torque is thus 'grounded' and braking

action takes place. This type of brake is used in machines like lathes, presses, etc. In an electro-magnetic braking system, the electro-magnetic property is used due to this action of braking will be done. In this system, electromagnet iron plate, liners, tension spring, stud, and disc brake plate are used. The brake lines are attached with electromagnet and iron plate individually and both plates insert the disc plate, and this plate is rigidly attached with wheels. A battery of a minimum of 12 volts is used for the external power supply.

The electromagnet consists of a wire wound over a soft iron core. When current is passed through the coil, it produces a magnetic field that magnetizes the core into the bar magnet with the polarities. The strong magnetic field is obtained by high currents of large self-induction. High currents are not always feasible, which is why high self-induction is obtained by making a loop of wire in the shape of a coil, a so-called solenoid. More current and more turns produce a stronger magnetic field which results in a stronger electromagnet. When the current is switched OFF field disappears, and the iron core is no longer a magnet. This ability of an electromagnet provides a strong magnetic force of attraction. Shape geometry and material used in the construction of electromagnet decide the shape and strength of the magnetic field produced by it.

1.2 Application:

Some of the application areas of the project have been pointed out below:

i. Coaches
ii. Roller coasters
iii. Lifts
iv. Industrial Trucks
v. Aircraft and Ship
vi. High speed electric trains
vii. GYM Equipment

1.3 Objective:

The objectives of this project are followed:

I. to study about design & implementation of a contactless electromechanical braking system,
II. to test the performance of the constructed system,
III. to analyze the performance of the system.

CHAPTER 2
LITERATURE REVIEW

2.1 Literature Review:

Analytical modeling of eddy current brakes with the application of time varying magnetic fields" by Kerem Karakoca, Afzal Sulemana, Edward J. Parka, Eddy current brakes have a number of potential advantages, i.e. contactless operation, faster response, reduced number of components and easy implementation of various controllers. "Improved braking torque generation capacity of an eddy current brake with time varying magnetic fields: A numerical study" by Kerem Karakoc a, n, Edward J. Park a, b, Afzal Suleman Eddy current brakes (ECB) are electrically controlled and non-contact actuators used as assistive brakes in vehicles. ECBs exhibit insufficient generated braking torque at low speeds.

"An investigation on braking systems used in railway vehicles." By Mustafa Günay a, Mehmet Erdi Korkmaz The high safety and comfort expectations under varying conditions have required the development of brake systems in railway vehicles. The main factors affecting the performance and function of the brake system are braking force, mass and speed of the vehicles, stopping or braking distance, railway condition and environmental factors. "Brake Performance Analysis of ABS for Eddy Current and Electrohydraulic Hybrid Brake System " by Ren He,1 Xuejun Liu,1,2 and Cunxiang Liu2 This paper introduces an eddy current and electro-hydraulic hybrid brake system to solve problems such as wear, thermal failure, and slow response of traditional vehicle brake system. “An Analysis of Permanent Magnet Eddy Current Braking System" by Shivashankar. R, Dr. G. V. Naveen Prakash the developed brake is wear-free, less-sensitive to temperature than friction brakes, has fast and simple actuation, and has a reduced sensitivity to wheel lock.

Lei Zhang at el. Developed brake by wire for passenger cars. The three main development tendencies in the modern vehicle industry are electrification, networking, and intelligence. These trends aim to improve efficiency and safety while lowering emissions from the transportation system. The brake-by-wire (BBW) system, a crucial part of a wire-controlled chassis in passenger cars, enhances ride comfort, safety, and braking effectiveness. An exhaustive and methodical assessment of BBW and associated technologies for use in passenger cars is presented in this research. First, a detailed explanation of the primary BBW systems' structures and operating principles is given. Next, cutting-edge control approaches for BBW systems are discussed. Specifically, active safety control involving BBW is described. Ultimately, the outstanding issues and potential avenues for further research are

examined. A significant area of development for BBW is its integrated design, however there are still significant technological issues that need to be resolved for all BBW systems save the electro-hydraulic system. Furthermore, effective coordinated control of the X-by-wire chassis is still a mystery. A hotspot for study is the use of BBW in the X-by-wire chassis in particular.

Xiaoxiang Gong at el. Reviewed on the Development, Control Method and Application Prospect of Brake-by-Wire Actuator. Brake-by-wire (BBW) actuator development, important technologies, and applications are reviewed and summarized in this study. BBW represents the brake system of the future, focused on technology. The primary function of BBW is to employ cables and wires to transfer energy and signals in place of some of the traditional brake system's mechanical and hydraulic components. Outstanding benefits of BBW actuators include their small design, precise control, and quick response times. They fit very well with the regenerative braking systems of electric vehicles and are simple to incorporate with active safety features. This study first provides an overview of the BBW actuators' classification, features, performance, and architecture. As a result, the primary goal is thought to be the vehicle's braking process regulation, which is summed up by looking at two factors: actuator regulation and braking force distribution. The present study provides an analysis and summary of the state estimation and control algorithms utilized in these actuators. Additionally, the development trend, obstacles, and proposed schemes for the braking force distribution are discussed. Additionally examined and described are the advancement and research trends in braking force match techniques between the BBW system and the regenerative brake system. The braking force management and distribution method of BBW's further electrification and intelligence of vehicle demand must have greater control precision, greater robustness, and wider adaptability. Additionally, the effects on handling stability and comfort during braking need to be further explored.

This technique has not appeared in any production models because of the critical safety nature of the braking systems. However, it has undergone a broad search and testing. Compared to electro-hydraulic brakes, the EMB system has electronic components. Instead of using hydraulic-slave cylinders, the calipers contain electronic actuators, and everything is governed by a controller instead of using a master cylinder with high pressure. The EMB uses electromagnetic force to slow or stop motion These systems also need a set of additional equipment, such as clamp force, actuator position, and temperature sensors in each caliper.

The brake-by-wire applications is requiring high-quality motors with a high torque/size ratio, high dynamic capacity, low inertia, fast braking response, low torque pulsations, and low

radial forces [9, 10]. In this paper, a permanent magnet synchronous motor (PMSM) is considered an electrical drive for the EMB system. The braking force is generated by this motor in each wheel brake. These motors are controlled by an electronic control unit and are executed by signals coming from the electronic pedal module where the input of the driver is again received from a suitable sensor in a way similar way to the operation of the electrohydraulic system. Moreover, an actuator in the inputs such as the brake pedal would send a feedback signal to the driver. The EMB has many advantages over conventional brake [11] such as reducing mechanical parts, being nature friendly, and less maintenance.

The EMB mechanical part performs by transforming the motor rotational motion into linear displacement by which it controls the braking force. The electrical part processes feedback signals transmitted to the control chip via sensors to ensure optimal response time [12]. Some researchers in the literature focused on the issue of the EMB system and are interested in designing and improving its performance. Yang et al. [13] had designed an actuator and controller of EMB. Mat lab/Simulink was used to build the EMB model. The control unit design of the braking system had adopted control architecture with three successive loops, which are force loop, speed loop, and current loop. Computer simulations were performed based on three typical conditions for step input, pulse input, and half cosine input. Liao [14] analyzed the EMB system in detail.

The researchers introduced the theory of the EMB system and its advantages composition. They offered the Electronic Braking System (EBS) hardware and assessed the design of the electrical machine and electronic pedal of the EMB system. Eventually, they specifically analyzed the system software. This study has great meaning for the braking system researchers and maintainers of the automobile. Nayak et al. [15] had designed a new concept of an electromechanical parking-brake system with simple and low-cost characteristics. Traditional parking brake systems have been replaced by a fully electric component system. This brake is accomplished by replacing traditional links with electric units driven by an electric motor. The braking force of each wheel can be directly generated by using high-performance electric motors as well as gear reduction. Beak et al. [16] theoretically and experimentally evaluated the clamping force performance for an EMB in a high-speed train. A three-phase surface permanent magnet synchronous motor (SPMSM) is used for generating this force.

A Proportional Integral (PI) current control was applied to control motor torque. Moreover, an anti-windup fast current tracking controller was proposed to improve the torque output. It was found that the peak clamping force is enhanced by about 4.8% when the PI current

controller is combined with the anti-windup controller. An interior three-phase permanent magnet synchronous motor (IPMSM) was used to drive the EMB. A speed controller, position controller, and current controller based on the PI control were utilized for driving the motor. The control principle with maximum torque per ampere (MTPA) was implemented on the current controller for effective control performance. The experimental results showed that applying the MTPA control reduces the current consumption in the EMB system. At the same time, the clamping force reduced the total input power by ~40%.

Based on an electromagnet concept for a non-contact braking system, we have built an electromagnetic braking system for this project. This electromagnetic braking system has been integrated with a mechanical support structure and controller. Since it is more dependable than other braking systems, we provide the electromagnetic brake system with flux-controlled mechanism. It has been observed in the literature that about 80% of all electrically controlled braking applications use electromagnetic brakes.

CHAPTER 3
MATERIALS REQUIRED AND CONSTRUCTION

The materials required to construct this project as follows:

3.1 Required Materials:

The materials based on hardware that were employed in this project.

Hardware

IV. Electromagnetic Break
V. DC Gear Motor
VI. Relay
VII. SMPS
VIII. Push Button Switch
IX. Wheel
X. Bicycle Speedometer

Software

XI. Proteus Software

3.2 Electromagnetic Break:

Electromagnetic brakes (also called electro-mechanical brakes or EM brakes) slow or stop motion using electromagnetic force to apply mechanical resistance (friction). They were originally called "electro-mechanical brakes," but over the years the name changed to "electromagnetic brakes", referring to their actuation method. Since becoming popular in the mid-20th century, especially in trains and trams, the variety of applications and brake designs has increased dramatically, but the basic operation remains the same. We used 300 turns of wire to make a magnet coil.



Figure 3.1: Electromagnetic Break

3.3 DC Gear Motor: A DC motor is any motor within a class of electrical machines whereby direct current electrical power is converted into mechanical power. A 12v DC motor is small and inexpensive, yet powerful enough to be used for many applications.



Figure 3.2: DC Gear Motor

3.4 Relay:

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

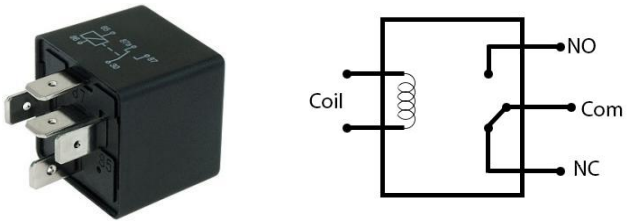


Figure 3.3: Relay

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

Magnetic latching relays require one pulse of coil power to move their contacts in one direction, and another, redirected pulse to move them back. Repeated pulses from the same input have no effect. Magnetic latching relays are useful in applications where interrupted power should not be able to transition the contacts. Magnetic latching relays can have either single or dual coils. On a single coil device, the relay will operate in one direction when power is applied with one polarity and will reset when the polarity is reversed. On a dual coil device, when polarized voltage is applied to the reset coil the contacts will transition.

AC controlled magnetic latch relays have single coils that employ steering diodes to differentiate between operate and reset commands.

The relay module is the one in the figure below.



Figure 3.4: Relay Module.

This module has two channels (those blue cubes). There are other varieties with one, four and eight channels.

Mains voltage connections

In relation to mains voltage, relays have 3 possible connections:

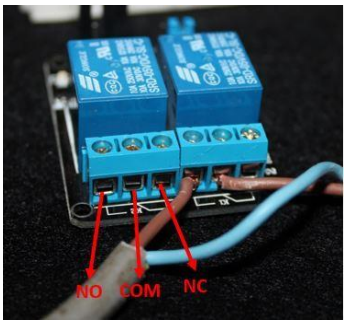


Figure. 3.5: Mains voltage connections.

- **COM**: common pin
- **NO (Normally Open):** there is no contact between the common pin and the normally open pin. So, when you trigger the relay, it connects to the COM pin and supply is provided to a load
- **NC (Normally Closed):** there is contact between the common pin and the normally closed pin. There is always connection between the COM and NC pins, even when the relay is turned off. When you trigger the relay, the circuit is opened and there is no supply provided to a load.

Pin wiring

The connections between the relay module and the Arduino are really simple:

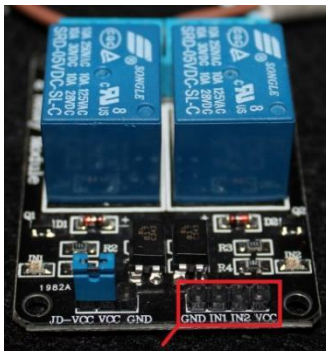


Figure 3.6: Pin Wiring

- **GND**: goes to ground
- **IN1**: controls the first relay (it will be connected to an Arduino digital pin)
- **IN2**: controls the second relay (it should be connected to an Arduino digital pin if you are using this second relay. Otherwise, you don't need to connect it)
- **VCC**: goes to 5V

Specification:

- Voltage: 12V DC
- Gear ratio: 1/31
- No-load speed: 200 RPM
- Rated Speed: 140 RPM
- Rated torque: 10 kg.cm
- Rated current: 2.5 Amp
- Length of Motor (including spindle): 106 mm/4.17″
- Diameter: 37 mm/1.45″
- Shaft length: 21 mm/0.82″
- Shaft diameter: 6 mm/0.24″

3.5 Switch Mode Power Supply (SMPS):

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycles). In contrast, a linear power supply regulates the output

voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.

3.6 Push Button Switch:

A push-button (also spelled push-button) or simply button is a simple switch mechanism to control some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal. The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, although many un-biased buttons (due to their physical nature) still require a spring to return to their un-pushed state.



Figure 3.7: Push Button Switch

Specifications:

1. Mode of Operation: Tactile feedback
2. Power Rating: MAX 50mA 24V DC
3. Insulation Resistance: 100Mohm at 100v
4. Operating Force: 2.55±0.69 N
5. Contact Resistance: MAX 100mOhm
6. Operating Temperature Range: -20 to +70 ℃
7. Storage Temperature Range: -20 to +70 ℃

Application:

In locomotives, a mechanical linkage transmits torque to an electromagnetic braking component. Trams and trains use electromagnetic track brakes where the braking element is pressed by magnetic force to the rail. They are distinguished from *mechanical* track brakes, where the braking element is mechanically pressed on the rail.

Electric motors in industrial and robotic applications also employ electromagnetic brakes. Recent design innovations have led to the application of electromagnetic brakes to aircraft applications. In this application, a combination motor/generator is used first as a motor to spin the tires up to speed prior to touchdown, thus reducing wear on the tires, and then as a generator to provide regenerative braking.

3.7 Wheel:

A wheel is a circular component that is intended to rotate on an axle bearing. The wheel is one of the key components of the wheel and axle which is one of the six simple machines. Wheels, in conjunction with axles, allow heavy objects to be moved easily facilitating movement or transportation while supporting a load, or performing labor in machines. Wheels are also used for other purposes, such as a ship's wheel, steering wheel, potter's wheel, and flywheel.



Figure 3.8: Wheel

3.8 Bicycle Speedometer:

A speedometer keep track the number of rotations your wheel makes. That is translated to distance traveled based on the diameter of your wheel. This wireless bicycle speedometer is an ideal companion for cyclists. It can read current time, average speed, riding time, total distance / total ODO, riding speed, max speed, riding distance, etc. It uses a wireless receiver device with steady transmission that is convenient and accurate. Also waterproof, superior for outdoor cycling on rainy days.



Figure 3.9: Bicycle Speedometer

Features:

1. Computer has LCD backlight.
2. Time display function
3. Anti-signal interference
4. Easy to read LCD display with large screen
5. Easy to install firmly with mounting accessories.
6. Small size and lightweight (2.36 in x 1.73 in)
7. Wireless receiver from hub to computer
8. Waterproof
9. Perfect for use when training, hiking, climbing, riding and other outdoor actives
10. Simple and easy installation

3.9 Proteus Software:

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronics design engineers and technicians to create schematics and electronics prints for manufacturing printed circuit boards. The first version of what is now the Proteus Design Suite was called PC-B and was written by the company chairman, John Jameson, for DOS in 1988. Schematic Capture support followed in 1990 with a port to the Windows environment shortly thereafter. Mixed mode SPICE Simulation was first integrated into Proteus in 1996, and micro-controller simulation then arrived in Proteus in 1998. Shape based auto routing was added in 2002 and 2006 saw another major product update with 3D Board Visualization. More recently, a dedicated IDE for simulation was added in 2011 and MCAD import/export was included in 2015. Support for high-speed design was added in 2017. Feature led product releases are typically biannual, while maintenance-based service packs are released as required.

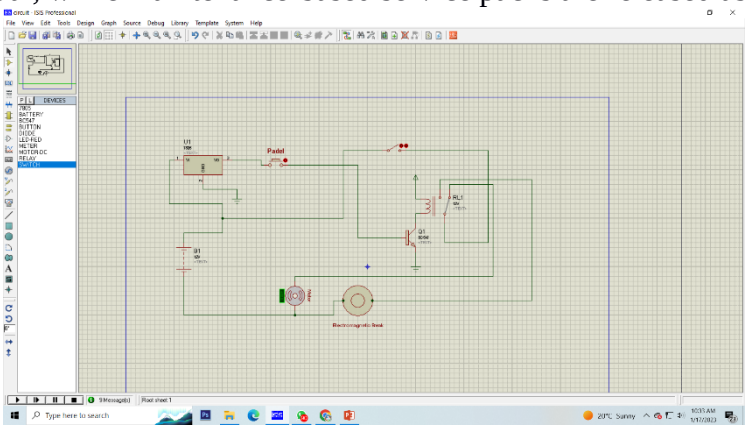


Figure 3.10: Proteus Software Interface

CHAPTER 4
METHODOLOGY

4.1 Basic Principle of Operation:

The braking system in vehicles operates primarily on the principles of **hydraulics and friction**. Here's a simplified explanation:

1. **Hydraulic System**: When you press the brake pedal, it pushes a piston in the master cylinder, which forces brake fluid through the brake lines to the slave cylinders at each wheel. This fluid is incompressible, so it effectively transmits the force from your foot to the brakes.

2. **Friction**: The brake pads or shoes press against the rotors or drums, creating friction. This friction converts the kinetic energy of the moving vehicle into thermal energy (heat), slowing down or stopping the vehicle.

3. **Force Multiplication**: The brake pedal and hydraulic system are designed to multiply the force applied by your foot, making it sufficient to stop the vehicle. This is achieved through mechanical advantage (leverage) and hydraulic force multiplication.

4.2 Braking System Functioning Principle:

The functioning principle of a braking system revolves around **hydraulics and friction**. Here's a detailed breakdown:

1. **Hydraulic Pressure**: When you press the brake pedal, it activates a piston in the master cylinder. This action forces brake fluid through the brake lines to the slave cylinders at each wheel. The incompressible nature of the brake fluid ensures that the force is transmitted effectively.

2. **Friction**: The brake pads or shoes are pressed against the rotors or drums, creating friction. This friction converts the kinetic energy of the moving vehicle into thermal energy (heat), which slows down or stops the vehicle.

3. **Force Multiplication**: The brake pedal and hydraulic system are designed to multiply the force applied by your foot. This is achieved through mechanical advantage (leverage) and hydraulic force multiplication, making it sufficient to stop the vehicle.

4. **Energy Conversion**: The primary principle behind braking is the conversion of kinetic energy into thermal energy. This process is crucial for reducing the speed of the vehicle or bringing it to a complete stop.

4.3 Design Methodology:

Designing an electromagnetic brake system involves several key steps and considerations. Here's a general methodology that we followed to build our system:

i. **Conceptual Design**:

- **Define Requirements**: Determine the braking force needed, the type of vehicle, and the operating conditions.
- **Select Materials**: Choose appropriate materials for the electromagnets and braking surfaces. Common materials include ferromagnetic metals for the core and copper for the coils.

ii. **Electromagnet Design**:

- **Core Design**: Design the core of the electromagnet, typically using a soft ferrous material to enhance magnetic properties. In this case we used two transformers core.
- **Coil Design**: Calculate the number of turns and the gauge of the wire needed for the coils. This involves using formulas related to electromagnetism to ensure sufficient magnetic field strength.

iii. **Power Supply and Control**:

- **Power Source**: Design a power supply that can provide the necessary current to the electromagnets. This often involves a DC power source.
- **Control System**: Implement a control system, often using microprocessors, to regulate the current and thus control the braking force. Sensors can be used to adjust the braking force based on speed and load.

iv. **Mechanical Integration**:

- **Mounting**: Design the mounting system to integrate the electromagnetic brakes with the vehicle's wheels or axles. Ensure that the system can handle the mechanical stresses involved.

4.4 Working Principle:

The working principle of an electromagnetic brake system is based on the use of electromagnetic force to create mechanical resistance, which slows down or stops the motion of a vehicle or machinery. Here's a detailed explanation:

1. **Electromagnetic Field Generation**:
- When an electric current passes through the coil of an electromagnet, it generates a magnetic field. This coil is typically made of copper and is wound around a ferromagnetic core.

2. **Magnetic Attraction**:
- The generated magnetic field attracts a ferromagnetic armature, which is connected to the rotating part of the system, such as a wheel or shaft.

3. **Friction Creation**:
- As the armature is pulled towards the electromagnet, it presses against a friction surface (like a brake pad or disc). This contact creates friction, which converts the kinetic energy of the rotating part into thermal energy, thereby slowing down or stopping the motion.

4. **Control and Regulation**:
- The braking force can be controlled by adjusting the current flowing through the electromagnet. More current increases the magnetic field strength, resulting in a stronger braking force.

5. **Release Mechanism**:
- When the current is cut off, the magnetic field dissipates, and the armature is released from the friction surface. This allows the rotating part to move freely again.

4.4.1 Block Diagram: The SMPS simply converts the 220V AC to a pure DC of 12V 20Amp. We will use this 12V DC output from the SMPS to run our controller, motor and other units.

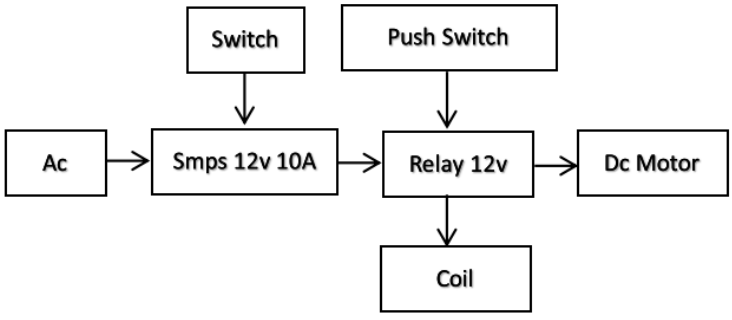


Figure 4.1: Block Diagram of Our System

4.4.2 Circuit Diagram:

The schematic diagram here is representing the electrical circuit and the components of the project. Here we have used standardized symbols and lines.

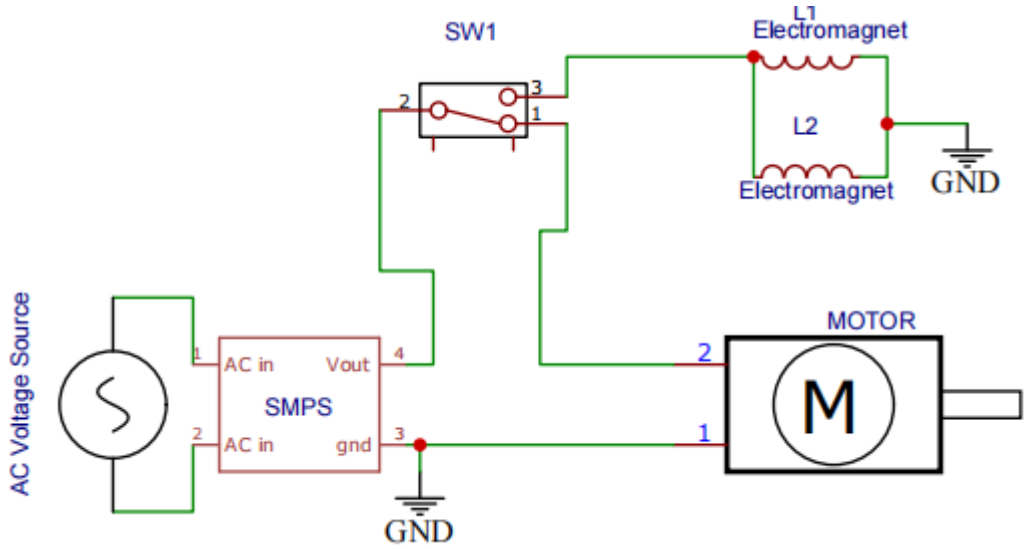


Figure 4.2: Schematic Circuit Diagram of the Project

CHAPTER 5
RESULT & DISCUSSION

5.1 Result:

After making our project we observe it very careful. It works as we desire. Our project give output perfectly and all equipment are work perfectly. We check how much it works and we get perfect output from this project.

- Firstly, when we press switch on then the project will be run,
- Then a switch will work to start the motor.
- When we press the pedal then relay will cut off the motor connection.
- Supply the current in electromagnet break.
- When it magnetized then wheel will be stop.

5.2 Data Analysis:

Test Parameter	Test-1	Test-2	Test-3	Test-4	Test-5	Test-6
Supply Voltage (V)	12	11.8	11.9	11.9	11.9	12
Current (Motor) (A)	0.42	0.4	0.45	0.42	0.4	0.43
Current (Coil) (A)	5.5	5.7	5.8	5.9	5.7	5.8
Coil Temperature (◦C)	39.7	38.5	41.1	42.5	42.0	42.2
Brake Disc Temp. (◦C)	34.2	34.1	34.2	34.4	34.5	34.5
RPM	103	105	104	105	104	104
Response / Stop Time (sec)	0.92	0.85	0.78	0.87	0.82	0.89
Braking Torque (N m)	0.00278	0.00347	0.00330	0.00299	0.00314	0.00289

Table 5.1: Data Analysis Test Parameters.

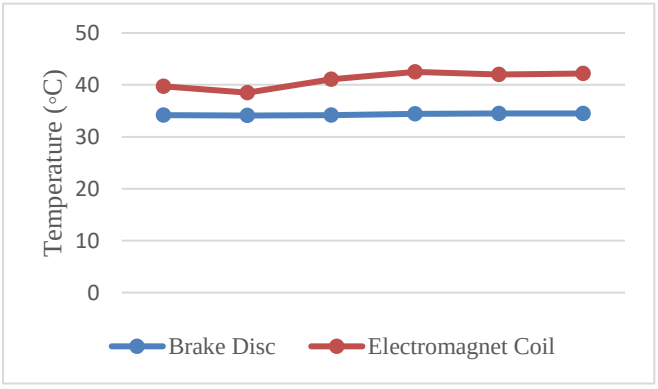


Figure 5.1: Temperature Difference between Disc and Coil.

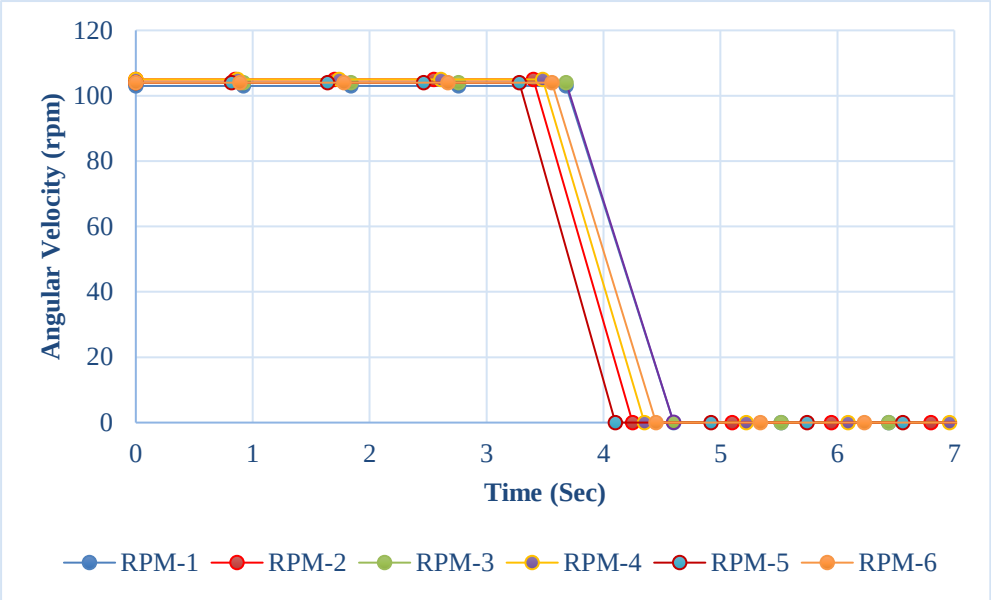


Figure 5.2: RPM and Brake Response Time Curve

5.3 Braking Torque Calculation:

$T = WK^2N/308t$

Where,

T=Torque (ft.-lb.)
W=Weight of Rotating Member (ft.)
K= Radius of Gyration of Rotating Member (ft.)
N=Speed of Rotating Shaft (RPM)
t=Stopping Time Required (Seconds)

The radius of gyration (K) for a disc brake is calculated using the moment of inertia (I) and the mass (m) of the disc. The formula is: $K = r/\sqrt{2}$

Data Values that we have:

W=0.25 lb.
N=105
t=0.9 s
r=0.21 ft

Now, K $= 0.21 / \sqrt{2}$
$= 0.15$

Again, T $= 0.25 \times (0.15)^2 \times 105 / 308 \times 0.9$
$= 2.131 \times 10^{-3}$

So, the braking Torque of our project is = 2.131×10^{-3} ft.-lb. / 0.002131 N m.

5.4 Discussion:

While working on our project, we did face some difficulties as it is a very complex system but the end results, we came up with were quite satisfactory. We have put the whole system through several tasks performance tests to validate our work and also have taken necessary notes for future improvements. Some future recommendations that we have involves improvement in system design and wiring, adding features for more efficient. We have seen that in our electromagnetic braking system project, there was no temperature rising issue at the brake disc for friction. There is no frictional loss in brake disc or brake pads as well. Here our electromagnets are acting like the brake pads but without direct contact with the brake disc. And we found our project's Braking Torque is 2.131×10^{-3} ft.-lb. / 0.002131 N m.

CHAPTER 6
CONCLUSION

6.1 Conclusion:

The Electromagnetic braking system is found to be more reliable as compared to other braking systems. In addition, it is found that electromagnetic brakes make up approximately 80% of all of the power applied brake applications. Electromagnetic brakes have been used as supplementary retardation equipment in addition to the regular friction of the brakes. This enhanced braking system not only helps in effective braking but also helps in avoiding the accidents and reducing the frequency of accidents to a minimum. Furthermore, the electromagnetic brakes prevent the danger that can arise from the prolonged use of brake beyond their capability to dissipate heat. ABS usage can be neglected by simply using a micro controlled electromagnetic disk brake system. For the brake distribution of the electromagnetic braking system, the abrasion, noise, harmful friction dust, and the risk of thermal failure in braking system were reduced obviously. These electromagnetic brakes can be used in wet conditions which eliminate the anti-skidding equipment, and cost of these brake are cheaper than the other types. The concept designed by us is just a prototype and needs to be developed more. It can not only be used in the field of automotives but also in the field of aeronautics. Hence the electromagnetic braking system can be a better technological revolution in the future application.

6.2 Limitations:

Though this project has many advantages, but it has some limitations as well and they are listed below:

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

6.3 Future Scope:

We are thinking about adding many features to our project in the future to get more desirable outcomes. Some of the steps that we are thinking about taking are given below:

i. In future, we are looking forward to improving our whole system design to make it more efficient.
ii. Braking system can be done depending on the speed and add some sensors. So that the accident will be reduced.
iii. Depending on the sensor, the automatic brake system can be done without pressing the pedal.
iv. The blend of swirl present and attractive powers makes this brake more successful.

REFERENCE

[1] Analytical modeling of eddy current brakes with the application of time varying magnetic fields" by Kerem Karakoca, Afzal Sulemana, Edward J. Parka,

[2] Improved braking torque generation capacity of an eddy current brake with time varying magnetic fields: A numerical study" by Kerem Karakoc a, n, Edward J. Park a, b, Afzal

[3] An investigation on braking systems used in railway vehicles." By Mustafa Günay a, Mehmet Erdi Korkmaz

[4] Brake Performance Analysis of ABS for Eddy Current and Electrohydraulic Hybrid Brake System " by Ren He,1 Xuejun Liu,1,2 and Cunxiang Liu2

[5] An Analysis of Permanent Magnet Eddy Current Braking System" by Shivashankar. R, Dr. G. V. Naveen Prakash

[6] S. B. McLaughlin, J. M. Hankey, S. G. Klauer, T. A. Dingus, Contributing Factors to Run-Off-Road Crashes and Near Crashes, U.S. Department of Transportation, National Highway Traffic Safety Administration Final Report, Jan. 2009.

[7] K. Pickerel, Today's technician classroom manual for automotive brake systems, 7th Edition, Today's technician, 2019.

[8] P. N. Amrish, Computer aided design analysis of disc brake rotors, Advances in Automobile Engineering, 2016

[9] A. Day, Braking of Road Vehicles, 1st Edition, Butterworth- Heinemann, 2014.

[10] K. Reif, Brakes, Brake Control Driver Assistance Systems: Function, Regulation and Components, 1st Ed., Bosch Professional Automotive Information, Springer Viewer, 2014.

[11] W. Xiang, P. C. Richardson, C. Zhao, S. Mohammad, Automobile Brake-by-Wire Control System Design and Analysis, IEEE Trans. Veh. Technol., 57 (2008) 138-145

[12] C. Martinez, E. Velenis, D. Tavernini, B. Gao, Modelling and estimation of friction brake torque for a brake by wire system, in IEEE, International Electric Vehicle Conference, (2014)

[13] R. Ahmed, M. Farag, J. Abdul-Kareem Mohammed, Design implementation of a single-side flat synchronous linear motor model, IOP Conf. Ser.: Mater. Sci. Eng., 765 (2020) 012018.

[14] R. Trifa, C. Martis, K. Biro, A. M. Gazdac, Design and analysis of a permanent magnet synchronous machine forautomotive electromechanical braking system, Prz. Elektrotech., 88 (2012) 141-144.

[15] F. Kalluf, C. Pompermaier , M. V . Ferreira . Luz , N . Sadowski, Braking torque analysis of the single-phase line-start permanent magnet synchronous motor, Int. Conf. Electr. Mach., (2010) 6-8.

[16] O. C. Emereole, M. C. Good, Comparison of the Braking Performance of Electromechanical and Hydraulic ABS Systems, Active Serial Memory Interface, Int. Mech. Eng., 79368 (2005) 319-328.

[17] C. Line, Modelling and control of an automotive electromechanical brake, Ph.D. dissertation., 2007.

[18] X.M. Liao, Design and Application of Electromechanical Brake System, Appl. Mech. Mater., 705 (2014) 152-156

[19] S.A. Nayak, G. Kiran, P.S. Kushal, B.V. Madhu, M.K. Ravishankar, Design and fabrication of electromechanical parking brake system, Int. Res. J. Eng.Technol., 3 (2014)

[20] S. K. Baek, H. K. Oh, S. W. Kim, S. I. Seo, A clamping force performance evaluation of the electromechanical brake using pmsm, Energies, 11 (2018) 2876.

[21] S. K. Baek, H. K. Oh, J. H. Park, Y. J. Shin, S. W. Kim, Evaluation of Efficient Operation for Electromechanical Brake Using Maximum Torque per Ampere Control, Energies, 12 (2019) 1869

[23] S. Aldeen. Saad Alkahim, F. M. Mohammed, Prototype Wireless Controller System Based on Raspberry Pi and Arduino for Engraving Machine, Proc. 2017 UK Sim-AMSS 19th Integrated Client and Case Management System, 2018