

DESIGN AND FABRICATION OF EDDY CURRENT BRAKING SYSTEM WITH REGENERATIVE FOR BICYCLE

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in

Electrical and Electronics Engineering

by

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INSTITUTE OF SCIENCE AND TECHNOLOGY (

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ABSTRACT

Traditional braking systems in the automotive industry rely on mechanical mechanisms, which can cause skidding and excessive wear on cars. And at high speeds, these brakes might not stop you at all. This study provides a novel approach to overcoming these problems by introducing the "Eddy Current Braking System." By leveraging the opposing effects of eddy currents, this technology provides a non-abrasive type of braking that may be used with a wider range of vehicles, from bicycles to trains. Energy is lost as a result of eddy currents, which are whirling currents induced within a conductor by a varying magnetic field.

The Eddy Current Brake consists of an electromagnet placed next to a conductive, non-ferromagnetic metal disc (rotor) attached to the back axle of the bicycle wheel. The disc is set up in such a way that the electromagnet's magnetic field may easily permeate it. It is possible to overcome the shortcomings of conventional braking systems by regulating the electromagnet's braking force.

In addition, a regenerative part has been built into the bike to make it more Eco-friendly and efficient. A dynamo is attached to the bicycle wheel and uses the kinetic energy created by the wheel's rotation to generate electricity. This electricity is then stored in a battery for later use, whether to power additional devices. This innovative device does more than just revolutionise brake technology; it also helps make transportation more sustainable and efficient. To promote greater safety, performance, and environmental responsibility in the field of bicycle transportation, this project investigates the design and production of such a comprehensive system.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL BACKGROUND

There is a constant effort to make vehicles safer, more efficient, and less harmful to the environment in the dynamic field of transportation. At the heart of this effort is the research and development of improved braking systems to address the drawbacks of traditional methods, such as mechanical blockage that can cause skidding, excessive wear and tear, and a lack of efficiency at high speeds. As more and more people require better stopping methods, it's clear that cutting-edge innovations are required.

This work introduces a novel concept to tackle these issues: the "Eddy Current Braking System" combined with regenerative abilities. It's a radical departure from conventional braking systems, with the potential to revolutionise not just bicycles but also larger vehicles like trains by being non-abrasive, energy-efficient, and flexible.

The Eddy Current Braking System relies on eddy currents, which are whirling currents created within a conductor when it comes into contact with a changing magnetic field, as its primary mechanism. These currents dissipate energy because they are at odds with the magnetic field that generates them. Using this principle, the Eddy Current Brake provides an alternative method of slowing down that avoids the problems associated with conventional mechanical brakes.

This cutting-edge device is built around a conductive, non-ferromagnetic metal disc (the rotor) that is fastened to the bicycle's rear axle. An electromagnet is placed nearby, but not in touch, with the disc. The disc is permeable to the generated magnetic field in this setup, resulting in a brake force that can be precisely adjusted. The Eddy Current Braking System allows users to adjust the braking force according to their own preferences, improving both the safety and comfort of the ride.

But that's not the end of the creative thinking. This design includes a regenerative mechanism to further improve the bicycle's energy efficiency and environmental friendliness. The kinetic energy created by the wheel's revolution when the rider applies brakes is captured by a dynamo cleverly placed within the wheel.

This mechanical energy is efficiently converted into electrical power and stored in a battery, making it available for use in a wide range of contexts, from running on-board electronics to boosting the vehicle's thrust. Incorporating regenerative qualities into Eddy Current Braking not only promises a step forward in safety and performance, but also fits in nicely with the worldwide push for greener forms of transportation. By pursuing this project, we set out on a path to investigate the design and construction of this entire system, which will push the limits of braking technology and help create a more environmentally friendly and sustainable transportation system in the future.

1.2 MOTIVATION FOR THE SELECTION OF PROBLEM

The motivation for selecting the design and fabrication of an eddy current braking system with regenerative charging stems from the pressing need for sustainable transportation solutions. With the escalating concerns surrounding environmental degradation and the depletion of fossil fuels, there's an urgent call for innovative technologies that reduce carbon emissions and promote energy efficiency. Eddy current braking systems offer a promising avenue for enhancing vehicle safety and energy conservation by utilizing electromagnetic principles to slow down vehicles while simultaneously harnessing kinetic energy through regenerative charging. By addressing these dual challenges of safety and sustainability, this project aims to contribute to the ongoing effort towards greener transportation alternatives, thereby fostering a cleaner and more sustainable future for generations to come.

1.3 OVERVIEW

Design and Fabrication of eddy current braking system with regenerative charging for bicycle Provides a comprehensive examination of the design and fabrication process for an eddy current braking system with regenerative charging. It outlines the motivation behind the project, the objectives pursued, the methodology employed, and the results achieved. Additionally, key components of the system design, such as material selection, electromagnetic principles, and integration of regenerative charging technology, are discussed in detail. Furthermore, the report delves into the testing procedures conducted to evaluate the performance and efficiency of the braking system. Through this overview, readers will gain insight into the scope and significance of the project, as well as the subsequent sections that delve into specific aspects of the design and fabrication process.

CHAPTER 2

LITERATURE SURVEY AND PROBLEM IDENTIFICATION

2.1 LITERATURE SURVEY

Sirumalla Gnana Prakash et.al(2022),"DESIGN AND FABRICATION OF EDDY CURRENT BRAKING SYSTEM FOR BICYCLE", International Research Journal of Engineering and Technology (IRJET) e-ISSN:2395-0056 Volume:09 Issue:10 | Oct2022 www.irjet.netp-ISSN:2395-0072.

In Automotive Industry many traditional brakings which are used now a days by the concept of mechanical blocking. It results in skidding and wear and tear on the vehicle. And if the vehicle's speed is very high, the brake can't deliver that high braking force and it will cause problems. These disadvantages of ordinary brakes can be overcome by a simple and effective braking mechanism called 'Eddy Current Brake'. It is a method without abrasion for braking vehicles, including trains. It makes use of the opposite tendency of eddy current. Eddy current is the swirling current produced within a conductor, which is subject to a change of magnetic field. Due to the tendency of eddy currents to be oppositional, eddy currents lose energy. Eddy current brake consists of a conductive non-ferromagnetic metal disc (rotor) attached to the rear axle of the bicycle wheel, with an electromagnet located with its poles on the disk without contact, so the magnetic field by the electromagnet passes through the disk. The electromagnet makes it possible to vary the braking force.

Hashim Iqbal; Byung Ju Yi (2018), "A New Design of Spherical Electro-Magnetic Brake System", Published in: 2018 15th International Conference on Ubiquitous Robots (UR) Date of Conference: 26-30 June 2018 Date Added to IEEE Xplore: 23 August 2018.

Magnetic brakes are the popular means to provide efficient damping to the motion of manipulators to avoid any damages. Commercially available magnetic brakes are either single degree of freedom electro-magnetic brakes or spherical brakes being

operated by permanent magnet. Fully controlled braking in multi-DOF has only been explored using MR fluid but the risk of fluid leakage limits its application in human sensitive operations. This paper proposes a new design of a spherical electro-magnetic brake (SEMB) system that utilizes the solid friction surfaces to provide controlled braking torque in 3 DOF. The mathematical model of the SEMB has been derived. The design of SEMB is then optimized for maximizing the magnetic forces. The experimental results are compared with FEM simulation results and analytical model.

Benzhen Guo et al. (2022), "Analysis on a Novel Eddy current-magnetic track composite brake for high-speed train", Published in: 2022 IEEE 5th International Electrical and Energy Conference (CIEEC) Date of Conference: 27-29 May 2022 Date Added to IEEE Xplore: 11 August 2022.

An novel eddy current-magnetic track composite brake (EC-MTB) for high-speed trains is first proposed in this paper. As a non-adhesive braking device, the brake can effectively make up for braking force shortage results due to adhesion coefficient decrease of a high-speed train. The brake, consisting of alternating permanent magnet (PM) braking sections and electromagnetic braking sections, can work under eddy current braking and magnetic track braking modes. The function of excitation can be turned on and off by rotating the upper PM in the PM brake. Alternating or isotropic magnetic fields can be generated on the rail by changing the current direction in the electromagnetic brake. The paper firstly introduces the structure and working principle of the composite brake and then investigates characteristics of static and transient magnetic fields as well as braking performance through 3D finite element simulation (3D-FEM), which proves that the brake can lead to a deceleration of not less than 0.1 m/s^2 for a 60T carriage in the magnetic track mode and generate around 1000N braking force under the eddy current mode.

Hashim Iqbal; Byung Ju Yi (2017), "An optimal design of a two-layered magnetic brake", Published in: 2017 14th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI) Date of Conference: 28 June 2017 - 01 July 2017 Date Added to IEEE Xplore: 27 July 2017. Magnetic brakes are the popular means to provide efficient damping to seize the motion of manipulators to avoid any damages.

Commercially available magnetic brakes being used in an on-off fashion consume most of their power to overcome the restoring force of plate springs during engaging the brake. Thus, the range of the available braking force is very limited. This paper proposes a new design of a two-layered magnetic brake (TLMB) system that can provide large range of available braking force. The mathematical model of the TLMB has been derived. The design of TLMB is then optimized for maximizing the braking forces at the expense of minimum input power dissipation while limiting the core volume to certain bounds.

Igor V. Bochkarev et al. (2022), "Researching Dynamic Processes in Electromechanical Braking Devices with Massive Magnetic System", Published in: 2022 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM) Date of Conference: 16-20 May 2022 Date Added to IEEE Xplore: 09 June 2022

The authors review the key specifics of electromagnetic wave penetration in a solid ferromagnetic core of the brake-

release solenoid when its coil is powered by the DC current. The obtained experimental time dependencies for the magnetic inductance in various parts of the core in the transient modes showed that eddy current excitation can be represented as a result of the crossing of core layers with a magnetic field moving at a certain speed from the internal border towards the center line. The field movement in the core is characterized by a significant unevenness of

magnetic inductance with respect to coordinate. The analysis of experimental data helped obtain simplified formulae allowing to calculate the eddy current value induced in the core during transient operation modes. The formulae are based on a number of common assumptions. The authors demonstrate that when coefficient σ depending on the core material is inserted in the calculation formulae, we can achieve a satisfactory alignment of the mean inductance curve with the experimental dependence $B_m(t)$. The authors also describe the practical calculation of σ using the experimental data. The obtained analytical dependencies help calculate the coil data for the brake-release solenoid and the brake response parameters taking into account the demagnetizing action of the eddy current by summing its value with the magnetomotive force of the coil determined while calculating the magnetic circuit.

U Ubaidillah et.al(2020), "Magnetic flux distribution and braking torque of a grooved eddy current brake", Published in: 2020 2nd International Conference on Computer and Information Sciences (ICCIS) Date of Conference: 13-15 October 2020 Date Added to IEEE Xplore: 24 November 2020

Motorcycles generally require an optimal braking system, eddy current brake (ECB) can be used as an alternative to conventional braking systems. Design unipolar axial ECB with an electromagnet used in this research. ECB performance can be influenced by some factor, one of them is changing the form of the surface of a conductor. On this research will discuss the performances of the ECB when the form of the surface of a conductor be varied. Methods used are finite element method (FEM) to view the braking torque and changing magnetic flux, the design and the size of the ECB based on a conventional hydraulic braking system. A flat plate (uniform) will be a reference for comparison to see the braking characteristics of the ECB if the surface is given a groove. Groove variations include half-circle, square, triangular, and sawtooth, which will run at speeds of 150 to 750 rpm. The result on the half-circle variation has a different trend from the others, sawtooth has the highest average braking torque, while the triangular is lowest.

Cunxiang Liu et.al(2022), "Design and performance test of motor braking and friction braking integrated system", Published in: 2022 IEEE 6th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC) Date of Conference: 03-05 October 2022 Date Added to IEEE Xplore: 09 November 2022

In terms of vehicle braking and energy saving, the traditional mechanical friction brake relies on frequent or long-term mechanical friction. In the process of friction braking, it will not only produce a large amount of toxic dust, but also cause the overheating of brake drum (disc) and friction plate (brake lining), resulting in the decline of braking efficiency and even braking failure. Therefore, an integrated system of motor braking and friction braking and its control method are proposed. When the vehicle is braked, the friction braking device works independently, while the motor braking device further realizes the braking of the vehicle according to the slip rate of the wheel; When the motor braking device works, it uses the kinetic energy of the vehicle to drive the brake disc and the permanent magnet firmly connected with it to rotate, so as to generate alternating magnetic field on the coil around the permanent magnet and generate electricity, and store its electric energy in the battery. The

st

shows that the motor braking and friction braking integrated system can effectively integrate the two braking devices, and combined with the wheel slip rate, can reliably ensure the vehicle braking effect and achieve the purpose of energy storage.

Shivam Pandey et.al(2018), "Design, Fabrication and Parametric Analysis of Electromagnetic Braking System", Published in: 2018 4th International Conference for Convergence in Technology (I2CT) Date of Conference: 27-28 October 2018 Date Added to IEEE Xplore: 09 April 2020

The aim of this practical study was testing as well as an 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 braking is caused by the influence 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 stator flux which causes braking of the rotating element. The variations in the braking torque due to change of various electrical and mechanical parameters has been practically studied through a 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.

Bowen Chen et.al(2018), "Design Optimization of Friction Disc-Based Electromagnetic Brakes for Higher Braking Torque", Published in: 2018 21st International Conference on Electrical Machines and Systems (ICEMS) Date of Conference: 07-10 October 2018 Date Added to IEEE Xplore: 29 November 2018

This paper proposes an optimization scheme for friction disc-based electromagnetic (EM) brakes, which can achieve higher braking torque at constant volume by maximizing the magnetic circuit utilization. Firstly, the magnetic equivalent circuit is calculated, then the initial dimensions are designed for the EM brakes according to the torque requirement. Secondly, the EM field results are analyzed in the two-dimensional (2-D) and three-dimensional (3-D) finite element method (FEM) environment, respectively. Thirdly, to generate higher braking torque for the EM brakes, the area ratio of inner suction annulus and the outer suction annulus is optimized to make full use of the magnetic circuit characteristics. In order to validate the effectiveness of the proposed braking torque increasing scheme, FEA simulations are carried out in ANSYS/Maxwell.

Christoph Holtmann (2021), "Eddy Current- and Friction Brake Fusion by a Disc-Spring to a Hybrid- Brake", Published in: 2021 24th International Conference on Mechatronics Technology (ICMT) Date of Conference: 18-22 December 2021 Date Added to IEEE Xplore: 01 February 2022

This paper shows the concept and design method of a hybrid brake. The magnetic attraction force between rotor and stator of an eddy current brake can be used to generate an additional mechanical friction torque. By using a disc spring between rotor and stator, the eddy current brake is extended to a so-called hybrid brake. In particular, the design method of the disc spring is the focus of this work. Using a system model that includes the electromagnetic and mechanical domains, the wear reduction compared to a conventional friction brake and the dynamic behaviour depend on the spring parameters are investigated. Finally, a disc spring is designed in FEM with the desired force-displacement curve.

2.2 PROBLEM IDENTIFICATION

Traditional mechanical braking systems provide significant problems and constraints for cyclist safety and environmental sustainability, making them an unacceptable choice for modern bicycle transportation. One major issue is that regular brake softening causes sliding, which is especially dangerous for bikers in slippery circumstances or when stopping suddenly. In addition, at higher speeds, the effectiveness of these mechanical brakes decreases, increasing the risk of accidents and decreasing the

enjoyment of the ride. Furthermore, typical braking systems waste vital energy resources by converting momentum into heat. Brake pads and discs, for example, wear out over time, resulting in routine maintenance that is both time-consuming and inconvenient for bicycle owners. Last but not least, relying solely on mechanical braking systems results in increased carbon emissions and energy consumption, both of which are harmful to the environment. In response to these critical issues, this project seeks to design and fabricate a transformative solution in the shape of a bicycle-specific Eddy Current Braking System equipped with regenerative capabilities. To make a greener and more sustainable means of transportation, this system aims to revolutionise bicycle brake technology by providing a braking experience that is less abrasive, more adjustable, and uses less energy.

2.3 DISADVANTAGES OF EXISTING SYSTEM

Cost: Implementing eddy current braking systems can be expensive due to the need for specialized materials and components. This cost factor can limit their adoption, especially in applications where cost-effectiveness is a priority.

Complexity: These systems can be complex to design and integrate, requiring precise engineering to ensure optimal performance. This complexity can lead to challenges during installation, maintenance, and troubleshooting.

Limited Application Range: Eddy current brakes are most effective at high speeds, making them less suitable for low-speed applications. Additionally, their effectiveness may be limited in certain conditions such as wet or oily surfaces, which can reduce the generation of eddy currents and compromise braking performance.

Power Consumption: Eddy current braking systems typically require electrical power to operate. While they can provide precise control over braking force, this reliance on power means they are not suitable for use in environments where power availability is limited or where energy efficiency is a significant concern.

2.4 IEEE STANDARDS FOLLOWED

IEEE (Institute of Electrical and Electronics Engineers) Standards are a set of guidelines and protocols that help ensure the safety, reliability, and interoperability of technologies used in various industries. In the case of eddy current braking systems, the following IEEE standards may be relevant:

1. IEEE 1596.1-1996 Eddy braking can be relevant for the communication protocol between Disc and the eddy current brake with other components of the prototype
2. IEEE 1068-1998 - Standard for Portable Electric Tools: This standard provides guidelines for the safe use of portable electric tools, which may also be applicable to a prototype using a motor and conductor.
3. IEEE 1652-2018-Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Commercial Applications: This standard provides guidelines for the design, installation, and maintenance of electrical resistance trace heating systems, which may be useful for designing and testing the conductor used in the eddy current braking system prototype.
4. IEEE 117-1974: This standard specifies the methods and equipment to be used for testing the electrical performance of electromagnetic brakes.
5. IEEE 1415-2006: This standard specifies the methods for testing and evaluating the performance of eddy current brakes used in aviation.

These standards provide guidelines for the design, testing, and operation of eddy current braking systems, ensuring that they meet certain performance, safety, and reliability standards. Adhering to these standards helps to ensure that eddy current braking systems are safe, efficient, and effective in their intended applications.

2.5 CONSTRAINTS

Economic Constraints

Budgetary Limitations: The project budget imposed constraints on the procurement of materials, equipment, and labor costs. Cost considerations influenced decisions regarding the selection of components and manufacturing processes to optimize the use of

resources while meeting project objectives.

Cost-Effectiveness: Achieving a balance between performance and cost was essential to ensure the project remained economically viable. Cost-effective design and fabrication approaches were pursued to maximize the value proposition of the braking system with regenerative charging.

Performance Constraints:

Performance Requirements: Constraints imposed by the desired performance characteristics of the braking system, including braking force, efficiency, and energy regeneration efficiency, guided the design and fabrication process. Meeting performance requirements was paramount to achieving the desired functionality and effectiveness of the system.

Reliability and Durability: Constraints related to the reliability, durability, and service life of the braking system influenced design decisions to enhance robustness and mitigate potential failure modes. Emphasis was placed on ensuring the system's reliability and durability under operational conditions.

2.6 TRADEOFF

Braking Efficiency vs. Regenerative Charging Efficiency: Increasing the braking efficiency may reduce the efficiency of regenerative charging and vice versa. A system optimized for higher braking force may generate less electricity during braking, while a system optimized for regenerative charging may compromise braking performance.

Size and Weight vs. Portability: Designing a compact and lightweight system may enhance portability and ease of installation but could potentially sacrifice braking force or regenerative charging capacity. Conversely, prioritizing larger and heavier components may improve system performance but could limit its applicability in certain contexts where space and weight are critical factors.

Environmental Impact vs. Performance: Incorporating eco-friendly materials or manufacturing processes may align with sustainability goals but could come at the expense of system performance or cost-effectiveness. Balancing environmental considerations with performance requirements is crucial in achieving a sustainable and efficient braking system with regenerative charging.

Maintenance Requirements vs. Longevity: Designing a system with low maintenance requirements may simplify operation and reduce downtime but could potentially compromise long-term durability or lifespan. Conversely, implementing more robust components and maintenance protocols may extend the system's longevity but could require more frequent maintenance and upkeep.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 AIM OF THE PROJECT

The aim of this project is to design and fabricate an eddy current braking system with regenerative charging capabilities. Our goal is to create an innovative solution for braking applications that not only enhances safety but also promotes energy efficiency and sustainability. This involves developing a novel design concept that optimizes braking efficiency while integrating regenerative charging to capture and store kinetic energy during braking events. The system will be designed to maximize performance, reliability, and durability while ensuring cost-effectiveness. Through comprehensive testing and validation, we aim to demonstrate the effectiveness of our solution in contributing to a more sustainable transportation future. Additionally, we aim to explore new avenues in sustainable transportation by integrating cutting-edge technologies into the braking system. Our project seeks to address the growing demand for energy-efficient solutions in the automotive sector while aligning with global efforts to reduce carbon emissions and promote environmentally friendly practices.

3.2 SCOPE OF THE PROJECT

Conducting a comprehensive literature review and research on eddy current braking systems and regenerative braking technologies. Analyzing the specific requirements and challenges associated with implementing these technologies in a bicycle braking system. Developing conceptual designs and prototypes for the eddy current braking system with regenerative capabilities tailored specifically for bicycles. Considering factors such as system size, weight, power requirements, efficiency, and compatibility with existing bicycle components.

Creating detailed engineering designs, schematics, and specifications for each component of the braking system, including magnets, conductive materials, sensors, controllers, and energy storage units. Performing simulations and analyses to optimize the design for performance, safety, and reliability. Procuring or

manufacturing the necessary components based on the detailed engineering designs. Assembling the components into functional prototypes of the eddy current braking system with regenerative capabilities. Conducting initial testing and validation of the prototypes to assess functionality and performance. Conducting comprehensive testing of the braking system prototypes under various conditions, including different speeds, loads, and environmental factors. Collecting data on braking performance, energy efficiency, heat dissipation, durability, and user experience. Iteratively optimizing the design based on test results and feedback to improve overall performance and reliability. Ensuring seamless integration of the braking system with standard bicycle components such as wheels, frames, brakes, and drivetrains. Addressing compatibility issues and making necessary adjustments to ensure proper functionality and safety during operation. Adhering to relevant industry standards, regulations, and safety requirements for bicycle braking systems, electromagnetic devices, and electrical systems. Obtaining necessary certifications or approvals to demonstrate compliance with regulatory standards.

Documenting the design process, fabrication procedures, test results, optimizations, and lessons learned throughout the project. Generating comprehensive technical documentation, user manuals, maintenance guides, and performance reports for stakeholders. Identifying opportunities for future enhancements, upgrades, or modifications to the braking system design. Exploring potential applications of the technology beyond bicycles and assessing scalability for mass production or commercialization.

3.3 OBJECTIVE

Develop a detailed design of the Eddy Current Braking System, including the selection of materials, dimensions, and positioning of key components such as the rotor, electromagnet, and control unit. Fabricate the designed Eddy Current Braking System, ensuring precision and reliability in the assembly of components and integration with the bicycle's wheel and frame. Integrate a dynamo into the bicycle's wheel to capture kinetic energy during pedalling, rectify the generated electricity, and efficiently store it in a battery for future use. Conduct comprehensive testing and evaluation of the

EddyCurrentBrakingSystemundervariousconditions,includingdifferentspeeds,loads,and

terrain types, to assess its safety, efficiency, and effectiveness. Optimize the braking system and regenerative component based on testing results to maximize braking efficiency and energy recovery.

3.4 METHODOLOGY

Eddy current braking technology with regenerative capabilities is a first of its kind solution to bicycle braking systems, and this complete methodology aids the understanding and implementation of this technology. First, a thorough understanding of the fundamentals is required, specifically that electromagnetic induction is more effective than conventional friction and kinetic energy in causing a controlled slowdown. Recognising Lenz's Law, which describes how eddy currents produce opposing magnetic fields and thus the system's electromagnetic reaction, is fundamental to this approach. It is essential to recognise the benefits of eddy current brakes over their mechanical counterparts, such as their low cost, ease of use, and innovative ability to regenerate energy as they are applied. Its physical, monetary, and environmental benefits have led to its widespread adoption in industrial and manufacturing contexts. As we delve deeper into the system, we see that the non-ferromagnetic, electrically conducting disc that rotates vertically within a toroidal magnetic field plays a crucial role in this setup. By catching kinetic energy during braking and converting it into electricity for storage, a dynamo connected with the bicycle wheel adds a novel dimension to the process of energy regeneration. Braking efficiency and energy captured during regenerative braking are both affected by the system's magnetic fields, which may be adjusted thanks to electromagnets. Even while eddy current brakes are quite effective, they may be missing a crucial safety feature—the holding torque. They are used in conjunction with standard mechanical brakes to combat this issue.

This approach summarises the complex relationship between the ideas, benefits, and parts of eddy current braking technology that can be used to generate energy. It highlights the system's complex function in enabling accurate deceleration and harvesting kinetic energy, leading to improvements in performance, sustainability, and safety in the field of bicycle braking systems.

3.5 PROPOSED BLOCK DIAGRAM AND EXPLANATION

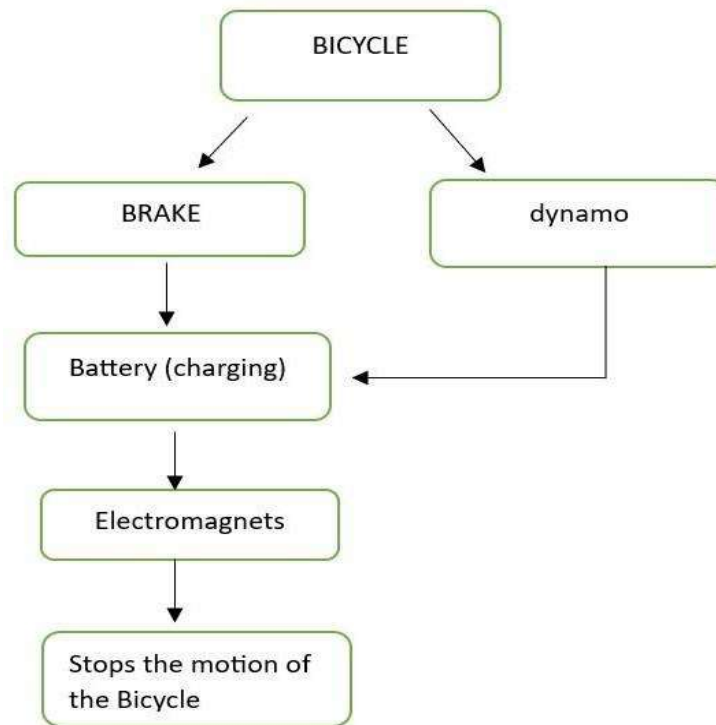


Figure 3.1: proposed system block diagram

WORKING PRINCIPLE

Figure 3.1 shows the Eddy Current Braking System with regenerative capabilities leverages electromagnetic induction, as explained by Faraday's law, to slow down and halt a bicycle without relying on traditional friction-based mechanisms. As the bicycle is in motion, a conductive metal disc (known as the rotor) attached to the rear axle passes through a changing magnetic field generated by an adjacent electromagnet. This interaction induces the formation of eddy currents within the rotor, leading to the creation of magnetic fields that oppose the original magnetic field, following

Lenz's law. These opposing magnetic fields generate a resistance force that acts as a brake, progressively reducing the bicycle's speed in a controlled manner. Concurrently, the system incorporates a dynamo, cleverly coupled with the bicycle wheel, which captures the kinetic energy produced while pedalling. The dynamo efficiently converts this mechanical energy into electrical power, which is then rectified into direct

current(DC)andstoredinabatteryforfutureuse.Thisinnovativesystemrevolutionizes

braking technology by offering precise control, reducing wear and tear, and enhancing safety while also promoting energy regeneration and environmental sustainability, making it an ideal solution for modern bicycle transportation.

3.6 ADVANTAGES

Energy Efficiency: The regenerative charging feature allows the system to capture and store kinetic energy during braking, which can be used to power other vehicle systems or stored for future use. This enhances overall energy efficiency and reduces reliance on traditional fuel sources.

Environmental Sustainability: By harnessing kinetic energy that would otherwise be dissipated as heat, the system reduces energy wastage and contributes to lower carbon emissions. This aligns with efforts to mitigate climate change and promote sustainable transportation solutions.

Extended Battery Life: The regenerative charging function helps to prolong the life of batteries by reducing the frequency of charging cycles. This can result in cost savings for vehicle owners and reduce the environmental impact associated with battery disposal.

Improved Braking Performance: Eddy current braking systems offer smooth and precise braking control, resulting in enhanced vehicle safety and driver comfort. The system's ability to generate braking force without mechanical contact reduces wear and tear on brake components, leading to longer service life and reduced maintenance costs.

3.7 APPLICATIONS

Some of the major applications of eddy current braking systems are

1. Gym equipment
2. Rider and roller coasters
3. High-speed trains
4. Industrial equipment
5. Recreation equipment

3.8 PROPOSED SYSTEM VS EXISTING SYSTEM

The integration of eddy current braking with regenerative charging represents a promising avenue for advancing energy-efficient braking systems across various sectors. Ongoing research and development efforts continue to refine these systems for enhanced performance and broader adoption.

Existing Systems

In traditional eddy current braking systems, a conductive material (usually a metal disc or drum) rotates within a magnetic field generated by an electromagnet.

As the conductor moves through the magnetic field, eddy currents are induced in the conductor, generating resistive force and causing deceleration. Regenerative braking is a method of slowing down a vehicle by converting its kinetic energy into a form that can be stored or reused later. In electric and hybrid vehicles, regenerative braking systems capture the kinetic energy during braking and convert it into electrical energy, which is then stored in the vehicle's battery for later use.

Proposed Systems

Integration of Eddy Current and Regenerative Braking: The proposed system integrates the principles of both eddy current braking and regenerative braking to maximize energy efficiency and braking performance. This integration involves using the eddy current braking mechanism to generate resistive force for deceleration while simultaneously capturing the kinetic energy and converting it into electrical energy through regenerative braking.

Design Optimization: Engineers and researchers are constantly working on optimizing the design of the system components such as the conductive material, electromagnets, control algorithms, and energy storage systems to improve efficiency, reliability, and performance.

Advanced Control Algorithms: Proposed systems often incorporate advanced control algorithms to precisely manage the transition between eddy current braking and regenerative braking modes based on factors such as vehicle speed, deceleration rate, battery state of charge, and road conditions.

Material Selection and Efficiency Improvement: Research focuses on selecting high-performance materials for the conductive elements to minimize energy loss due to heat dissipation and maximize the efficiency of energy conversion during braking.

Applications: Eddy current braking with regenerative charging is particularly relevant in electric vehicles, where it helps improve overall energy efficiency and extend driving range by recovering and reusing energy during braking.

This technology is also applicable in trains and mass transit systems, where it can enhance braking performance, reduce wear on braking components, and contribute to overall energy savings. In industrial applications, such as cranes and elevators, eddy current braking with regenerative charging can offer precise control over deceleration, energy efficiency, and maintenance cost reduction.

CHAPTER 4

HARDWARE AND PROJECT DESCRIPTION

4.1 EDDY CURRENT

In the realm of electromagnetism, eddy currents, also known as Foucault's currents, are loops of electric current that are induced within conductors either by a changing magnetic field in the conductor according to Faraday's law of induction or by the relative motion of a conductor while it is in a magnetic field which can be seen in Figure 4.1. Eddy currents can also be caused by the motion of a conductor while it is in a magnetic field. Within conductors, eddy currents move in closed circuits along planes that are perpendicular to the direction of the surrounding magnetic field. They can be induced inside neighbouring stationary conductors by a time-varying magnetic field provided, for example, by an AC electromagnet or transformer, or by the relative motion of a magnet and a nearby conductor. Another way they can be induced is by relative motion between a magnet and a nearby conductor. The size of the current flowing through a particular loop is proportional to the intensity of the magnetic field, the area of the loop, and the rate at which the flux is changing. On the other hand, the magnitude of the current is inversely related to the resistivity of the material. These circular currents within a piece of metal have a graph that looks a little bit like eddies or whirlpools in a liquid when viewed from above. Eddy current brake. The North magnetic pole piece (top) in this drawing is shown further away from the disk than the South; this is just to leave room to show the currents. In an actual eddy current brake the pole pieces are repositioned as close to the disk as possible. Eddy currents cause a reaction on the part of the source of the magnetic field because, according to Lenz's law, they produce a magnetic field that is in opposition to the change in the magnetic field that caused them to form in the first place.

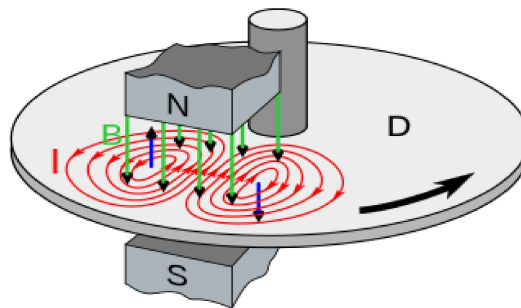


Figure 4.1 Eddy Current

Because a moving magnetic field causes eddy currents to flow in a nearby conducting surface, for instance, a nearby conductive surface will impose a drag force on a moving magnet that is in opposition to the motion of the magnet. This phenomenon is utilized in eddy current brakes, which are utilized to quickly bring to a stop the rotation of rotating power tools when the tools are turned off. The flow of current through the resistance of the conductor causes the material to generate heat, which is another form of energy loss. As a result, alternating current (AC) inductors, transformers, electric motors and generators, and other AC gear all suffer from the effects of eddy currents, which necessitate the adoption of specialized construction techniques, such as laminated magnetic cores or ferrite cores, to reduce their impact. Eddy currents have a number of applications, including the heating of things in induction heating furnaces and equipment, as well as the detection of cracks and other faults in metal components using eddy-current testing tools.

4.2 ELECTROMAGNETIC BRAKING

To slow down or stop a moving item, eddy current brakes utilise the drag force caused by eddy currents. There is no mechanical wear because the brake shoe or drum never makes contact. Eddy current brakes can be used in tandem with mechanical brakes, such as on overhead cranes, because they cannot produce a "holding" torque. Some roller coasters use this principle to move the car, which is made of steel, by moving heavy copper plates between pairs of very strong permanent magnets. The kinetic energy of the car is lost due to the dragging effect caused by the electrical resistance within the plates, which is similar to friction. This is the same principle behind electromagnetic brakes on trains and the rapid stopping of saw blades and other power tool blades.

Electromagnets, in contrast to permanent magnets, allow the magnetic field intensity to be modified, allowing for a more or less dramatic shift in the braking action.

Working Principle

Electromagnetic force, as opposed to friction and kinetic energy, is what typical mechanical brakes rely on to slow down the movement of an object. Eddy current brakes, on the other hand, use electromagnetic force. Eddy currents are formed when a conductor is moved through a magnetic field while simultaneously producing an opposing force that causes the conductor to spin internally. According to Lenz's Law, eddy currents are the inverse reaction to a magnetic field. This is because eddy currents generate a magnetic field that is perpendicular to the magnetic field that is causing them to occur. Because of this electromagnetic force response, it is feasible to decelerate in an environmentally friendly manner. The cutting-edge technology of eddy current braking offers various advantages over the more conventional method of stopping through mechanical means. Eddy current brakes are an excellent choice for a wide variety of applications because they do not include any moving components and require very no maintenance. Manufacturers frequently make use of eddy current braking because to the numerous economical and physical benefits that it offers. As a means of producing an eddy current brake, a disc that is non-ferromagnetic and electrically conductive is made to rotate vertically within a toroidal magnetic field. When the disc spins, it causes the conductor to become subject to eddy currents. The force is then distributed throughout the disc, which results in the generation of a braking torque. Electromagnets are frequently used in place of permanent magnets in eddy current braking applications. This is due to the fact that the intensity of the magnetic field (and, consequently, the braking effect) may be modified with electromagnets. The primary issue with eddy current brakes is that they do not have sufficient holding torque, which is an essential safety element. Due to the fact that this is the case, they are typically deployed in conjunction with standard mechanical brakes. In order to calculate the amount of power that is lost per unit of mass for a thin sheet or wire as a result of eddy currents under specific conditions (such as uniform material, uniform magnetic field, absence of skin effect, etc.), the following equation can be utilized.

4.3 MATERIALS REQUIRED FOR THIS PROJECT

- Bicycle
- Dynamo 12v
- Battery 12v 7A
- Electromagnets 12v
- Press-Switch 12v 7A
- MS-disc
- Wires
- Square Rod
- Bolts and Nuts

BICYCLE



Figure 4.2: Bicycle

Figure 4.2 shows that the Bicycles are two-wheeled, human-powered vehicles that serve multiple purposes. It's a straightforward and effective means of transportation. Bicycles have a lightweight Aluminium, steel, or carbon fiber frame, which serves as the main structural component. It holds everything else together like a framework. Bicycles have two rubber-tired wheels that are roughly the same size. The bike's steadiness, velocity, and maneuverability are all affected by the wheels' size and material. Tires for bicycles can be found in a wide variety of shapes and sizes, each one optimized for a specific task like commuting, racing, or mountain biking. They give you traction and comfort, and you can change the pressure to fit the road conditions. The brakes of a bicycle serve to slow down or stop the rider. Disc brakes, which employ a rotor and caliper system, are more common than rim brakes, which simply grab the rim of the wheels. A gear shifter allows the rider to change between

different ratios on bicycles with several gears. A bicycle with gears can be ridden with less effort up hills and at a faster pace on flat ground or when traveling downhill. A cyclist's feet rest on pedals, which are fastened to the bike's crankset. Different types exist, such as flat pedals, clipless pedals (which require specialized cycling shoes), and cage pedals.

The bike's rider directs and controls the bike via the handlebars. Drop bars, flat bars, and mountain bike bars all provide unique riding postures and degrees of control, but each serves a different purpose. The rider sits on the saddle, often known as the bike's seat. There is a wide variety of saddles available to meet the needs of riders of all sizes and preferences. Pedal power is transferred from the crankset to the rear wheel via the chain and drivetrain. The chain connects the pedals to the back wheel, allowing the rider to generate forward motion simply by pedaling. Derailleurs and other gearshifting mechanisms could be a part of the drivetrain. Fenders (to deflect water and mud), lights (to be seen), racks (to transport items), and water bottle holders are just a few of the many accessories available for bicycles.

DYNAMO 12V



Figure 4.3: Dynamo

As shown in figure 4.3, a 12V dynamo, this type of electrical generator is frequently installed in bicycles, motorbikes, small vehicles, and portable power systems. When the dynamo is rotated, mechanical energy is transferred into electrical energy using the principle of electromagnetic induction. Because of their ability to transform mechanical energy into electrical power, dynamos (also known as electrical generators) have played a crucial role in the development of the modern world. This abstract delves into the background and relevance of dynamos as they relate to the creation of electrical power. Electromagnetic induction is the basis of dynamos, which generate electricity when a magnetic field interacts with a revolving

conductor. The magnetic field is created by stationary magnets (stators), and the electron flow in the wire coils is induced by a spinning magnet (rotor or armature) that cuts across the magnetic lines of flux. Through the use of commutators or slip rings, dynamos can produce either direct current (DC) or alternating current (AC).

Early in the 19th century, Michael Faraday and Joseph Henry discovered electromagnetic induction, which paved the way for the development of dynamos. Pioneers like Charles F. Brush and Zenobe Gramme helped pave the way for modern, high-quality dynamos. Although Thomas Edison's direct current (DC) system gained initial traction, alternating current (AC) systems developed in Europe and ultimately triumphed due to their superiority in long-distance power transmission. Further progress was made in the realm of electrical power generation through the creation of polyphase AC generators and the theoretical contributions of scientists like Charles Steinmetz. Three-phase alternating current (AC) power became the norm, which was a watershed moment in the history of electrification. To commercialize electricity and enable its broad use for lighting, industry, and transportation, dynamos and generators were crucial components. They were the backbone of the modern electrical grid and are now vital parts of many modern technologies, from stationary power plants to portable ones.

Key features and components of a Dynamo 12V include:

- **Housing:** The dynamo is protected from the elements by a strong housing. The internal components are shielded from the elements and any damage by this housing.
- **Coils:** Inside the dynamo, there are coils of wire wound around a core. These coils play a crucial role in generating electricity through electromagnetic induction.
- **Magnet:** A permanent magnet is located close to the dynamo's coils and rotates in tandem with the rotor. An electric current is induced in the coils as the magnet travels relative to them.
- **Shaft:** The dynamo is often attached to the shaft of a moving object like a wheel or an engine. This part, when in motion, spins the shaft of the dynamo, which in turn spins the generator.

- **Voltage Output:** An intended result of the construction of a Dynamo 12V is a constant electrical output of 12 V. Batteries can be charged, lights can be powered, and other 12V electrical appliances can be used at this voltage.
- **Regulation:** To maintain a constant voltage regardless of changes in rotating speed, several Dynamo 12V versions incorporate voltage regulating systems.
- **Mounting:** These dynamos typically include mounting brackets or methods for sturdily attaching them to the intended application, be it a bicycle frame or a vehicle's engine.

BATTERY 12V7A

In isolated systems away from the grid, figure 4.4 shows the diagram of batteries which are used for storage of excess solar energy converted into electrical energy. The only exceptions are isolated sunshine loads such as irrigation pumps or drinking water supplies for storage. In fact for small units with output less than one kilowatt, batteries seem to be the only technically and economically available storage means. Since both the photo-voltaic system and batteries are high in capital costs. It is necessary that the overall system be optimized with respect to available energy and local demand pattern.

LEAD-ACID WET CELL:

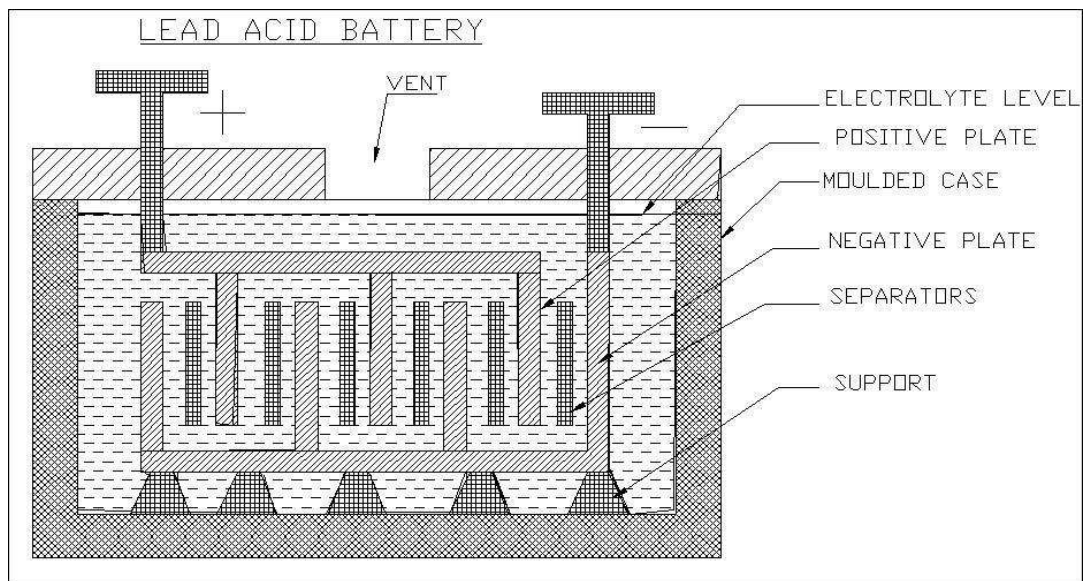


Figure 4.4: Lead acid battery diagram

To be economically attractive the storage of solar electricity requires a battery with a particular combination of properties:

- Lowcost
- Longlife
- Highreliability
- Highoverallefficiency
- Lowdischarge
- Minimummaintenance
 - (a) Amperehourefficiency
 - (b) Watthourefficiency

We use lead acid battery for storing the electrical energy from the solar panel for lighting the street and so about the lead acid cells are explained below. Where high values of load current are necessary, the lead-acid cell is the type most commonly used. The electrolyte is a dilute solution of sulfuric acid (H_2SO_4). In the application of battery power to start the engine in an automobile, for example, the load current to the starter motor is typically 200 to 400 A.

One cell has a nominal output of 2.1 V, but lead-acid cells are often used in a series combination of three for a 6-V battery and six for a 12-V battery. The lead acid cell type is a secondary cell or storage cell, which can be recharged. The charge and discharge cycle can be repeated many times to restore the output voltage, as long as the cell is in good physical condition. However, heat with excessive charge and discharge currents shortens the useful life to about 3 to 5 years for an automobile battery. Of the different types of secondary cells, the lead-acid type has the highest output voltage, which allows fewer cells for a specified battery voltage.

CONSTRUCTION:

Inside a lead-acid battery, the positive and negative electrodes consist of a group of plates welded to a connecting strap. The plates are immersed in the electrolyte, consisting of 8 parts of water to 3 parts of concentrated sulfuric acid. Each plate is a grid or framework, made of a lead-antimony alloy. This construction enables the active material, which is lead oxide, to be pasted into the grid. In the manufacturing process, the active material in the positive plate is changed to lead peroxide (PbO_2). The negative electrode is spongy lead (Pb). Automobile batteries are usually shipped dry from the manufacturer. The electrolyte is put in at the time of installation, and

then the battery is charged to from the plates. With maintenance-free batteries, little or no water need be added in normal service. Some types are sealed, except for a pressure vent, without provision for adding water.

ELECTROMAGNETS 12V

Electromagnets usually consist of wire wound into a coil. A current through the wire creates a magnetic field which is concentrated in the hole, denoting the center of the coil. The magnetic field disappears when the current is turned off. The wire turns are often wound around a magnetic core made from a ferromagnetic or ferrimagnetic material such as iron; the magnetic core concentrates the magnetic flux and makes a more powerful magnet. The main advantage of an electromagnet over a permanent magnet is that the magnetic field can be quickly changed by controlling the amount of electric current in the winding. However, unlike a permanent magnet that needs no power, an electromagnet requires a continuous supply of current to maintain the magnetic field.

SPECIFICATIONS

Voltage	12V
No of turns	500 tons
Force	8kgf
Power	40A

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

PRESS SWITCH 12V/7A

A push-button switch is a fundamental mechanical device used for controlling electrical circuits. It operates through manual actuation, where an operator applies physical force to a button or actuator. This action triggers an internal switching mechanism, resulting in the opening or closing of an electrical circuit. Push-button switches come in various types,

including momentary, toggle, and latching switches, each with specific functionalities. They can have different configurations, such as single-pole, single-throw (SPST) or double-pole, double-throw (DPDT), to suit various switching requirements. These switches are employed in diverse applications, ranging from control panels and machinery to automotive systems and industrial equipment. They are often designed for safety and convenience, with options for illumination to indicate their operational status, making them essential components in electrical.

MSDISC

The building, manufacturing, and industrial industries make extensive use of mild steel plates because of their strength and versatility (not because of their aesthetic appeal). These plates are made from flat steel. When referring to the depth of mild steel, the unit of measurement that is considered to be standard is the inch.

SQUARERODS

Iron and carbon are the two primary elements that make up structural steel, which is a type of ferrous metal. It's a material that can be used in a wide variety of standard technical applications, and it doesn't cost very much. The low carbon content in mild steel belies the remarkable magnetic characteristics of the material. Because of this property, the substance in question is known as a "ferromagnetic" material.

Iron and carbon are the two primary elements that make up structural steel, which is a type of ferrous metal. It's a material that can be used in a wide variety of standard technical applications, and it doesn't cost very much. The low carbon content in mild steel belies the remarkable magnetic characteristics of the material. Because of this property, the substance in question is known as a "ferromagnetic" material.

4.4 PROJECT PROTOTYPE

3-D Design of Eddy Current Braking System

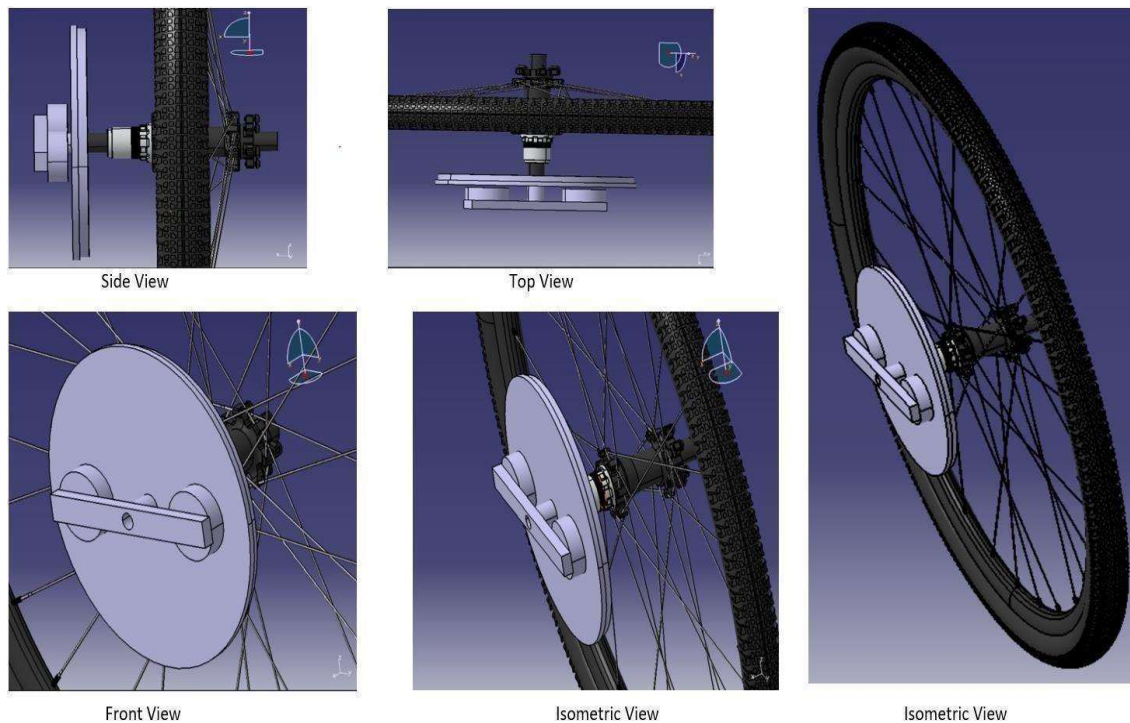


Figure 4.5: overview of electromagnets

Figure 4.5 shows the, Design and Fabrication of Eddy Current Braking System for Bicycle project involved the use of 3D design to create a detailed and accurate representation of the braking system. The 3D design helped the team to visualize and optimize the design, ensuring that the final product met the required standards. Here are some of the different views of the 3D design of the braking system:

Front view: The front view of the 3D design shows the eddy current braking system attached to the front wheel of the bicycle. The design includes a disc-shaped rotor attached to the wheel, which rotates inside the stator, creating eddy currents that generate braking force. The front view also shows the mounting bracket, which attaches the braking system to the fork of the bicycle.

Side view: The side view of the 3D design shows the eddy current braking system in relation to the bicycle's frame and components. The design includes a detailed view of the rotor and stator, highlighting the position of the magnets and coils that generate the braking force. The side view also shows the placement of the mounting bracket and the wiring that connects the system to the power source.

Top view: The top view of the 3D design shows a bird's eye view of the eddy current braking system, providing a detailed view of the rotor, stator, and mounting bracket. The top view also shows the position of the power source and the wiring that connects the system to the bicycle's electrical system.

4.5 DESIGN VIEW OF PROTOTYPE

The prototype design integrates eddy current braking with regenerative capabilities for efficient energy conversion in cycling.

A push button activates the electromagnets, strategically positioned at the disc's center within the wheel, enabling eddy current braking. Concurrently, a dynamo is affixed to the cycle wheel, harnessing kinetic energy during braking to generate electricity. This energy is then channeled to a battery, discreetly located at the cycle's rear, facilitating regenerative braking and subsequent power storage.

Side View:



Figure 4.6: Side view

From the figure 4.6 of side view, the integrated motor, comprising electromagnets, is clearly depicted. These electromagnets are strategically positioned adjacent to the disc, located at the center of the wheel. When activated, the electromagnets induce eddy currents within the rotating disc, generating a braking force that slows down the wheel's rotation. Additionally, the setup includes a dynamo attached to the wheel, responsible for harnessing kinetic energy during braking for subsequent regeneration.

TopView:

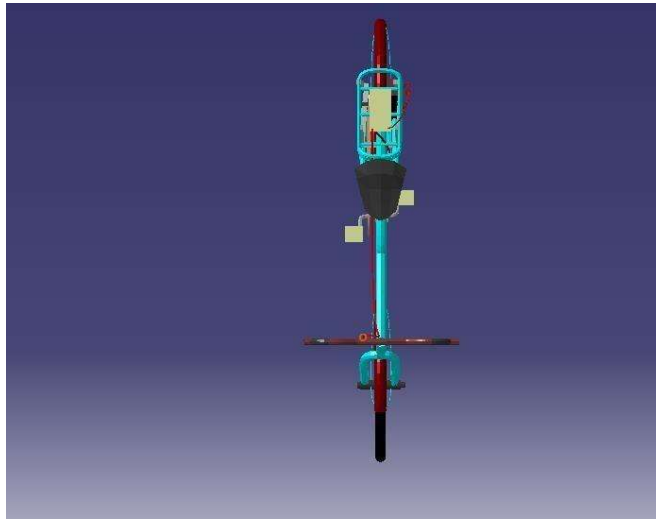


Figure4.7Topview

Figure4.7showsthetopviewprovidesacomprehensivelayoutofthesystem,illustratingthe arrangement of components such as the electromagnets, disc, and dynamo. Thisperspectiveoffersinsightintothespatialrelationshipbetweentheseelements,facilitatinga betterunderstandingofthe system'sdesignandfunctionality.

IsometricView:

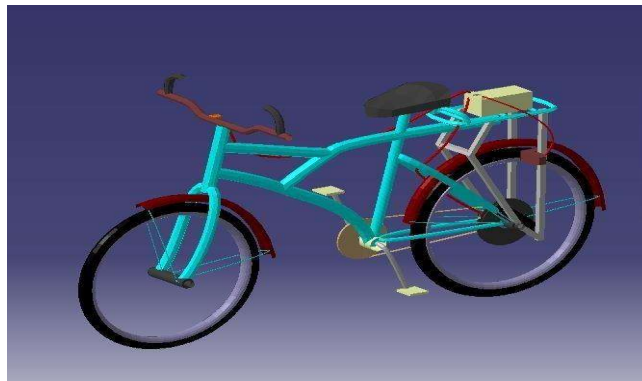


Figure4.8: Isometricview

Figure 4.8 shows that the isometric view, the three-dimensional structure of the eddycurrentbrakingsystemisrevealed.Thisperspectiveshowcaseshowtheelectromagn ets, disc, and dynamo are interconnected to form a cohesive unit. Itallows for a holistic examination of the system's configuration and highlights itsintegrationintotheoveralldesignof thevehicle ormachine.

HARDWARESETUP

Figure 4.9 shows the implemented prototype design seamlessly integrating an eddy current braking system with regenerative capabilities, showcasing innovative engineering for enhanced energy efficiency. The design features electromagnets strategically positioned adjacent to a centrally located disc within the wheel assembly. When activated by a push button control mechanism, the electromagnets induce eddy currents within the rotating disc, generating a braking force that efficiently slows down the wheel's rotation. Additionally, a dynamo is seamlessly integrated into the wheel assembly, leveraging kinetic energy during braking to generate electricity. This regenerated energy is then stored in a battery located at the rear of the cycle, providing a sustainable power source for various applications.

Figure 4.9 Prototype model



Dynamoview:



Figure 4.10: Dynamoview

Figure 4.10 shows that a 12V dynamo is an electrical generator that produces direct current (DC) electricity using a commutator. It operates on the principle of electromagnetic induction, where a rotating coil of wire within a magnetic field generates electricity. The 12V rating indicates the voltage output of the dynamo, suitable for powering various low-voltage applications. Dynamos are commonly used in small-scale power generation systems, such as bicycles, hand-cranked chargers, and portable electronics. The 12V dynamo's compact size and efficiency make it ideal for applications where space and power requirements are limited. It typically consists of a coil of wire wrapped around an iron core, mounted within a magnetic field produced by permanent magnets or electromagnets. As the coil rotates, it cuts through magnetic lines of force, inducing an electromotive force (EMF) that generates electricity. The commutator ensures that the output current remains direct by periodically reversing the direction of the current flow. Dynamos are versatile and can be used in various environments, including off-grid power generation, emergency lighting systems, and hobby projects. The 12V dynamo's reliability and simplicity make it a popular choice for applications requiring continuous or intermittent electrical power.

Electromagnets View:



Figure 4.11: Electromagnets

Figure 4.11 shows the electromagnets are pivotal components, with two electromagnets utilized, each comprising 500 turns. These electromagnets play a multifaceted role in the system's functionality. Firstly, they generate magnetic fields when

electric

current

flowsthroughthem,inducingeddycurrentswithintheconductivematerialofthebicyclewheel.

These induced currents create a resistive force, effectively slowing down the rotation of the wheel and providing the necessary braking action. Through precise control of the current flowing through the electromagnets, the strength of the magnetic field—and consequently, the braking force—can be finely adjusted, ensuring optimal braking performance and rider safety. Additionally, the electromagnets facilitate the regenerative aspect of the braking system. During braking, kinetic energy from the bicycle's motion is efficiently converted into electrical energy through electromagnetic induction principles. This harvested energy can then be stored for future use, enhancing the overall efficiency and sustainability of the braking system. Moreover, the utilization of two electromagnets allows for a balanced distribution of braking force and ensures uniform braking performance across the wheel. Careful design and calibration of these electromagnets are essential to achieving smooth and responsive braking action, providing cyclists with a reliable and intuitive braking experience. In conclusion, electromagnets serve as integral components in realizing the objectives of the project, contributing to both effective braking functionality and energy regeneration in bicycle systems.

4.6 EDDY CURRENT LOSSES PER UNIT MASS

$$P = \frac{\pi^2 B_p^2 d^2 f^2}{6k\rho D}$$

Equation: Eddy current losses per unit mass
Where,

- P is the power lost per unit mass (W/kg),
- B_p is the peak magnetic field (T),
- d is the thickness of the sheet or diameter of the wire (m),
- f is the frequency (Hz),
- k is a constant equal to 1 for a thin sheet and 2 for a thin wire,
- ρ is the resistivity of the material (Ωm), and
- D is the density of the material (kg/m^3).

This equation is only correct when applied in the so-called quasi-static conditions, which are those in which the frequency of magnetisation does not result in the skin effect; in other words, when the electromagnetic wave fully penetrates the material.

CHAPTER 5

REALTIME IMPLEMENTATION

5.1 RESULTS

To stop a moving vehicle or to prevent it from moving while stopped, braking is used. Brakes work by generating friction between a stationary component and a disc or drum that spins in tandem with the wheels. Friction generates the stopping force by transforming the kinetic energy of the moving vehicle into heat, which is then dissipated into the surrounding air. Frictional forces are affected by the kind of contacting surfaces, the forces acting on those surfaces, and the speed at which the surfaces are moving past one another. The amount of effort required to slow down is directly related to the frictional force between the lining and the drum and the amount of pressure applied by the band or shoe. In contrast, if the force exerted exceeds a particular threshold, more force is wasted when the brakes lock up and the wheels slide over the pavement. So, the adhesion between the tyre and the road determines the greatest braking effect that can be achieved, which in turn is determined by the load on the wheel upon which the brake operates and the coefficient of friction between the tyre and the road. A comprehensive overview of the outcomes obtained from the design and fabrication of the eddy current braking system with regenerative charging is essential. The results highlight both quantitative and qualitative findings, providing a clear understanding of the system's performance and functionality.

Quantitatively, data regarding the efficiency of energy conversion from kinetic to electrical energy, as well as the charging rate of the regenerative system, are presented. This includes measurements of energy output under various braking conditions and charging rates achieved during different testing scenarios. Additionally, quantitative assessments of system reliability and stability over extended operation periods are provided.

Qualitatively, observations regarding the system's responsiveness, noise levels, and overall user experience are detailed. Any unexpected behaviors or operational issues encountered during testing and evaluation are also documented. Furthermore, photographs or diagrams illustrating the physical construction and components of the system may complement the textual results, offering a visual representation of the project's outcomes.

Overall, the results section serves to objectively present the findings of the design and fabrication process, providing valuable insights into the performance, functionality, and practicality of the developed eddy current braking system with regenerative charging.

5.2 DISCUSSION

Design and fabrication of eddy current braking system with regenerative charging demonstrates notable efficiency in converting kinetic energy into electrical energy, thereby offering potential for significant energy savings and reduced environmental impact. The regenerative charging feature enables the storage or immediate utilization of generated electricity, enhancing overall system effectiveness. Despite these advantages, certain limitations were encountered during the design and fabrication process. Challenges such as optimizing the system's efficiency under varying operating conditions and ensuring compatibility with different vehicle types warrant further investigation. Additionally, addressing safety concerns and optimizing the system's integration with existing infrastructure are crucial for widespread adoption. Comparative analysis with conventional braking systems highlights the potential benefits of our innovation, including improved energy efficiency and reduced brake wear. Furthermore, discussions on the scalability and adaptability of the system across diverse industries underscore its versatility and market potential. While our eddy current braking system with regenerative charging represents a significant advancement in braking technology, further research and development are necessary to address existing challenges and maximize its practicality and impact.

5.3 PERFORMANCE ANALYSIS

Eddy current braking systems offer various advantages that make them a compelling choice for applications such as bicycles. They operate by generating a magnetic field around a conductive, non-ferromagnetic metal disc (rotor) attached to the rear axle of the bicycle wheel. As the rotor spins through the magnetic field, eddy currents are induced in the rotor, which creates a magnetic field opposing the original field. This interaction generates a braking force that slows down the rotor and consequently the bicycle.

A major benefit of eddy current brakes is their non-contact operation, which reduces wear and tear on the brake components. This results in a more durable and long-

lasting braking system with lower maintenance requirements. Additionally, the smooth, consistent braking provided by eddy current brakes enhances riders' safety and comfort.

In terms of performance, eddy current braking systems can offer precise control over the braking force, which can be adjusted by varying the strength of the magnetic field. The system's ability to provide strong braking without direct contact with the disc also helps reduce the risk of skidding and improves overall braking performance.

One potential drawback of eddy current brakes is heat generation, which needs to be managed effectively to maintain performance and reliability. However, with proper heat dissipation, these systems can perform reliably across a range of operating conditions.

Overall, eddy current brakes provide excellent performance with high reliability, making them an attractive choice for various applications, particularly in situations where durability and safety are paramount.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

An eddy current braking system with regenerative capabilities for bicycles is a sophisticated braking technology that harnesses the principles of electromagnetic induction to slow down and stop the bicycle while also recovering energy that would otherwise be lost during braking. Here's a summary of how this system works.

When the rider applies the brakes, instead of using friction pads like traditional braking systems, the eddy current braking system generates a magnetic field around a metal disc or wheel rim. As the metal disc passes through this magnetic field, eddy currents (localized circulating currents) are induced in the metal, creating resistance and slowing down the rotation of the wheel. In addition to slowing down the bicycle, the eddy current braking system is designed to capture some of the kinetic energy that would be dissipated as heat in traditional braking systems. This captured energy is converted into electrical energy through a generator or dynamo integrated into the braking system. The electrical energy generated during braking is then stored in a battery or capacitor system onboard the bicycle. This stored energy can be used to power various electrical components of the bicycle, such as lights, electronic shifting systems, or even assistive electric motors for propulsion, depending on the design of the bike. By recovering and reusing energy that would otherwise be lost as heat during braking, eddy current braking systems with regenerative capabilities contribute to increased energy efficiency and sustainability in electric bicycles. They also offer smoother and more controlled braking compared to traditional friction-based systems.

Overall, eddy current braking systems with regenerative features represent a cutting-edge technology that combines efficient braking performance with energy conservation, making them a promising option for eco-friendly and technologically advanced bicycles.

6.2 CONCLUSION

The discovery and development of new technologies play a crucial role in the search for transportation solutions that are safer, more efficient, and more environmentally

friendly. This project set out to create a regenerative Eddy Current brakes System, which would be a major technological advance in the world of bicycle brakes.

Electromagnetic concepts, in particular the creation of eddy currents within a conductor as it flows through a magnetic field, have been used to completely reimagine bicycle braking, with significant advantages above their mechanical predecessors.

The non-abrasive and adjustable deceleration provided by eddy current braking technology has the potential to significantly improve bicycle security and comfort. Its regenerative qualities help the environment by turning the energy lost into usable electricity via the ingenious incorporation of a dynamo within the bicycle wheel. This eddy current braking technology has the functionings solve the problems of skidding, maintenance, and energy waste that plague conventional brakes.

Understanding electromagnetic fundamentals, Lenz's Law, and the benefits of eddy current brakes over mechanical systems were crucial to the approach taken on this project. It outlined the crucial parts of the system and stressed the importance of safety concerns, which typically call for the use of conventional mechanical brakes to supplement eddy current ones.

As we wrap up this project, we hope for a future in which bicycles are not only more practical and less dangerous, but also help make the world a better, more sustainable place. With its regenerative qualities, the Eddy Current Braking System has the potential to improve not only the riding experience but also to fit in with the growing trend towards greener modes of transportation worldwide. By expanding its use beyond bicycles, this technology has the potential to revolutionise the field of environmentally friendly city transportation.

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