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REGENERATIVE BRAKING CONTROLLER FOR ELECTRIC VECHILE

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ABSTRACT - *This project explores the design and implementation of a flywheel regenerative braking system for a vehicle. The system utilizes a flywheel to store kinetic energy during braking, which can then be released to assist in acceleration. The project aims to evaluate the effectiveness of this system in terms of energy efficiency and braking performance. The design process involves selecting appropriate materials and components and developing control algorithms to manage the energy flow. The system will be tested under various driving conditions to assess its performance, and the results will be analyzed to determine the potential for practical application in the automotive industry.*

Keywords: Flywheel Regenerative Braking, Kinetic Energy Recovery, Energy Efficiency, Braking Performance, Control Algorithms, Material Selection.

I. INTRODUCTION:

Regenerative braking is a technology that has revolutionized the way we think about energy efficiency in transportation. Traditional braking systems rely on friction between brake pads and rotors to slow down a vehicle, which results in the dissipation of kinetic energy as heat. Regenerative braking systems, on the other hand, capture this kinetic energy and convert it into electrical energy that can be used to power other vehicle systems or stored for future use. This technology has the potential to significantly reduce the amount of energy wasted during braking, making transportation more efficient and sustainable.

Regenerative braking systems work by using an electric motor to slow down the vehicle. During braking, the electric motor is turned into a generator, and the kinetic energy of the vehicle is converted into electrical energy. This energy is then either used to power the vehicle's electric systems, such as the lights and air conditioning, or stored in a battery for later use. In hybrid and electric vehicles, regenerative braking is an essential component of the powertrain. In these vehicles, the electric motor is used to both propel the vehicle forward and slow it down during braking. The captured energy is then used to recharge the battery, extending the range of the vehicle and reducing the need for external charging. The primary advantage of regenerative braking is the energy savings it provides. By capturing and reusing kinetic energy that would otherwise be lost as heat, regenerative braking systems can significantly reduce the energy consumption of vehicles. This leads to reduced fuel consumption, lower emissions, and increased range for hybrid and electric vehicles.

Regenerative braking systems also offer smoother and more consistent braking performance than traditional braking systems. Because the system is able to precisely control the amount of braking force, it can provide a more comfortable and predictable braking experience for passengers. While regenerative braking is a promising technology, there are still some challenges that must be overcome to fully realize its potential. One of the main challenges is the limited amount of energy that can be captured during braking. Because the system relies on the deceleration of the vehicle to generate energy, it is most effective at low speeds and during frequent stops and starts. At higher speeds and during prolonged braking, the system may not be able to capture enough energy to make a significant impact on fuel economy. Another challenge is the cost and complexity of the system.

Regenerative braking systems require specialized components, such as electric motors and control systems, which can add to the cost of the vehicle. Additionally, integrating these components into the vehicle's powertrain can be complex and require significant engineering expertise. Regenerative braking is a promising technology that has the potential to significantly improve the energy efficiency of transportation. By capturing and reusing kinetic energy during braking, regenerative braking systems can reduce fuel consumption, lower emissions, and extend the range of hybrid and electric vehicles. While there are still challenges to overcome, the benefits of regenerative braking make it an important area of research and development in the automotive industry.

II. LITERATURE SURVEY:

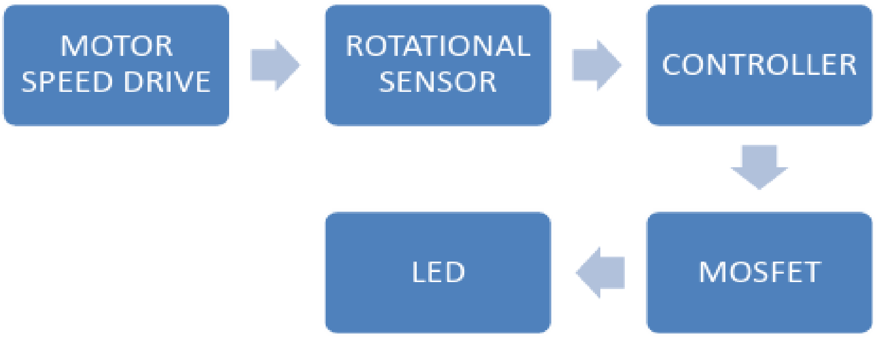
II.1. Regenerative Braking of Road Vehicles ,Andrew J.Day:

This book covers the fundamentals of brakes and braking, Braking of Road Vehicles covers car and commercial vehicle applications and developments from both a theoretical and practical standpoint.

II.2 Electric and Hybrid Vehicles: Technologies, Modelling and control A Mechatronic Approach , Amir Khajepour et al:

It is based on the authors' current research in vehicle systems and will include chapters on vehicle propulsion systems, the fundamentals of vehicle dynamics, EV and HEV technologies, chassis systems, steering control systems, and state, parameter and force estimations

III. BLOCK DIAGRAM:



IV. METHODOLOGY:

During braking, the kinetic energy of the vehicle undergoes a transformation, becoming the rotational energy of a flywheel. This flywheel is intricately connected to an electric motor/generator, serving as the conduit for converting the rotational energy into electrical energy.

The electrical energy produced during braking finds a home in either a battery or capacitor, awaiting its call for future utilization. The quantity of energy stowed away hinges upon the dimensions and capabilities of the flywheel, as well as the efficacy of the electric motor/generator.

Upon re-engagement of acceleration, the electrical energy housed within the battery or capacitor steps forward, empowering the electric motor/generator to spring into action, this time as a motor, propelling the vehicle forward with renewed vigor.

The flywheel, acting as a steadfast ally, also lends its hand, contributing energy to the electric motor/generator's endeavor to hasten the vehicle's pace. To orchestrate this ballet of energy with finesse, a control system takes the reins, diligently monitoring the speed and torque of both the flywheel and the electric motor/generator.

This vigilant control system orchestrates a delicate balance, maneuvering the power flow between the flywheel and the electric motor/generator with precision, all in pursuit of the holy grail of energy recovery and storage optimization.

V. PROPOSED SYSTEM:

A regenerative braking system using a flywheel is a type of energy storage system that captures the kinetic energy of a vehicle during braking and stores it in a high-speed spinning flywheel. The stored energy can then be released to assist in vehicle acceleration. Flywheel-based systems are lightweight, have a long lifespan, and can operate in a wide range of temperatures. However, they can be expensive and require complex control algorithms to ensure safe operation. The use of flywheel-based regenerative braking systems has the potential to improve the energy efficiency of vehicles and reduce their environmental impact. The flywheel can then be used to assist in vehicle acceleration. Flywheel-based systems are lightweight and can provide quick energy transfer, making them suitable for use in sports cars and other high performance vehicles. However, they are expensive and require complex control algorithms to ensure safe operation. These flywheels based regenerative braking systems are mostly used in sports cars and high performance vehicles, but these can be used even in electric bikes and cars. Which enables high distance travel in the EVs. This achieved just by assuming wheels as a flywheel however the output will slightly less than what we expect in flywheel. Flywheel regenerative braking offers several advantages over battery storage for energy recovery in vehicles:

1. High Power Density: Flywheels can store and deliver energy much faster than batteries, making them well-suited for high- performance applications such as motorsports.

2. Longer Lifespan: Unlike batteries, flywheels do not degrade over time and have a much longer lifespan, making them more cost- effective in the long run.

3. Lightweight: Flywheels are typically much lighter than batteries, making them ideal for use in vehicles where weight is a critical factor.

4. Environmentally Friendly: Unlike batteries, flywheels do not contain toxic chemicals and are easier to recycle at the end of their lifespan, making them a more environmentally friendly option.

5. Higher Efficiency: Flywheels have higher energy conversion efficiency compared to batteries, meaning more energy can be recovered during braking and reused during acceleration.

6. Faster Charge Time: Flywheels can be charged much faster than batteries, which is particularly important in high-performance vehicles where quick acceleration is required.

Overall, flywheel regenerative braking offers several advantages over battery storage, particularly in high-performance applications where fast, efficient energy storage and recovery are critical factors. However, there are still technical and cost challenges that need to be addressed for flywheel systems to become more widely adopted in mass-market vehicles.

VI. OBJECTIVE OF THE PROJECT:

1. Design and development of a flywheel-based regenerative braking system: The project should focus on designing a flywheel-based regenerative braking system that can convert the kinetic energy of a moving vehicle into potential energy, which can be stored in the flywheel. The system should be able to automatically engage when the vehicle brakes, and disengage when the vehicle accelerates.

2. Optimization of the flywheel: The flywheel should be optimized to store as much energy as possible in a limited amount of space, and to have minimal energy losses due to friction or other factors. This could involve selecting the right materials, designing the flywheel's shape and size, and calculating the ideal rotational speed.

3. Integration with the vehicle's existing braking system: The flywheel based regenerative braking system should be designed to integrate seamlessly with the vehicle's existing braking system. This will ensure that 8 the system operates smoothly and does not interfere with the vehicle's overall performance.

4. Testing and evaluation: The project should include extensive testing and evaluation of the flywheel-based regenerative braking system, both in laboratory settings and on real-world roads. This will help to identify any issues or limitations with the system and ensure that it is safe and reliable.

5. Cost analysis: The project should also include a cost analysis of the flywheel-based regenerative braking system, including the cost of materials, manufacturing, and installation. This will help to determine the economic feasibility of the system and its potential for widespread adoption.

Overall, the objectives for a project on regenerative braking using a flywheel should focus on designing and developing a system that is safe, reliable, efficient, and cost- effective, and that can be integrated seamlessly with existing vehicles.

VII. BASIC LAWS BEHIND REGENERATIVE BRAKING:

Regenerative braking is a process of recovering the energy that would normally be lost during braking and converting it into electrical energy, which is stored in a battery for later use. The laws of physics that govern regenerative braking are:

1. Conservation of Energy: This law states that energy cannot be created or destroyed, only converted from one form to another. During regenerative braking, the kinetic energy of the vehicle is converted into electrical energy, which is stored in the battery.

2. Newton's Second Law of Motion: This law states that the force acting on an object is equal to the mass of the object multiplied by its acceleration. During regenerative braking, the braking force is applied to the vehicle, which slows down the vehicle and converts its kinetic energy into electrical energy.

3. Faraday's Law of Electromagnetic Induction: This law states that a changing magnetic field induces an electromotive force (EMF) in a conductor. During regenerative braking, the rotation of the electric motor creates a changing magnetic field, which induces an EMF in the conductors of the motor.

4. Ohm's Law: This law states that the current flowing through a conductor is directly proportional to the voltage applied and inversely proportional to the resistance of the conductor. During regenerative braking, the electrical energy generated is stored in a battery, which has a certain amount of resistance. Ohm's law governs the flow of current into and out of the battery during charging and discharging.

By understanding and applying these laws, engineers can design and optimize regenerative braking systems to recover as much energy as possible and improve the efficiency of electric vehicles.

VIII. COMPONENTS:

VIII.1. MICROCONTROLLER:

A Microcontroller is a compact Integrated Circuit designed to govern a specific operation within an embedded system. Typically, a Microcontroller integrates a processor, memory, and Input/Output peripherals onto a single chip. These versatile devices find application in a myriad of systems and devices, often collaborating with multiple microcontrollers to collectively manage various tasks within a device.

At the heart of a Microcontroller lies its Processor (CPU), akin to the brain of the device. The Processor executes diverse instructions, directing the microcontroller's function, including basic arithmetic, logic, and I/O operations. Memory plays a crucial role, storing data received by the processor and facilitating its response to programmed instructions. Microcontrollers encompass two primary memory types: Program and Data Memories.

Input and Output peripherals serve as the interface between the processor and the external world. Input peripherals receive information and transmit it to the processor in binary form. Supporting elements of a Microcontroller include the Analog to Digital Converter (ADC), which converts analog signals to digital, enabling interaction with external analog devices like sensors. Conversely, the Digital to Analog Converter (DAC) allows the processor to communicate outgoing signals to external analog components. The System Bus serves as the interconnected wire linking all components of the microcontroller together.

Microcontroller processors vary by application, ranging from simple 4-bit, 8-bit, or 16-bit processors to more complex 32-bit or 64-bit variants. They utilize both volatile and non-volatile memory types, such as Random Access Memory (RAM), flash memory (EEPROM or EPROM), catering to diverse storage requirements.

Microcontrollers find application across various industries and domains, including home and enterprise building, automation, manufacturing, robotics, automotive, lighting, smart energy, communication, and IoT development.

In this project, an Arduino UNO is utilized. The Arduino Uno, based on the Atmega328P microcontroller, is a popular choice among hobbyists, students, and professionals alike. Featuring a user-friendly design with input/output pins, analog to-digital converters, timers, and other peripherals, the Arduino Uno facilitates easy programming using the Arduino Integrated Development Environment (IDE). Its support for a simplified version of the C++ programming language makes it accessible even to beginners.

The Arduino Uno's versatility allows it to control a wide range of sensors, motors, and devices, facilitating connections through digital and analog pins, serial communication, and wireless interfaces.

Being open-source, the Arduino Uno encourages collaboration and innovation, with its hardware design and software code freely available for modification and distribution. This fosters a vibrant community of users who share projects, ideas, and knowledge online. In summary, the Arduino Uno's flexibility, ease of use, and affordability make it an ideal choice for individuals delving into microcontrollers and electronics, from basic LED projects to intricate robotics systems.

VIII.2. 360 DEGREE ROTATIONAL SENSOR:

A 360 degree rotational encoder is a device that measures the rotational position and direction of a shaft or motor. It typically consists of a disc with evenly spaced notches or holes around its perimeter, and a sensor that detects the changes in the disc's pattern as it rotates. There are two main types of rotational encoders: absolute and incremental. Absolute encoders provide a unique digital output for each possible position of the shaft, while incremental encoders provide a series of pulses that indicate the change in position from a reference point. A 360 degree rotational encoder can be used in a variety of applications, such as robotics, industrial control systems, and motion control systems. By accurately measuring the rotation of a shaft or motor, it allows for precise control of position, speed, and direction. Some common features of a 360 degree rotational encoder include:

- High resolution: A higher resolution encoder provides more precise position information.
- Incremental or absolute output: Depending on the application, either type of output may be required.
- Multiple channels: Some encoders may have multiple output channels for additional information, such as speed ordirection.
- Quadrature output: Quadrature output provides both A and B channel signals that are 90 degrees out of phase with each other, allowing for precise measurement of direction.

Overall, a 360 degree rotational encoder is a useful device for measuring the rotation of a shaft or motor, and is an important component in many control and automation systems.

Rotational Encoder DATA SHEET OF THE SENSOR:

Product Name: AEDR-8400-14-TX60 Encoder Type: Reflective Optical Encoder Resolution: 60 pulses per revolution

Output Signal: Quadrature (A, B channels) with index pulse Supply Voltage: 3.3V to 5V DC

Operating Temperature Range: -40°C to +85°C Mechanical Features:

- Shaft diameter: 6mm
- Maximum shaft speed: 6,000 RPM
- Encoder size: 20mm diameter, 10mm thick
- Shaft load: 2N axial, 3N radial Electrical Features:

- Current consumption: 14mA typical, 20mA maximum
- Output voltage: 0.4V to 5V
- Rise/fall time: 2 microseconds maximum
- Duty cycle: 45% to 55% Environmental Features:
- Shock resistance: 50G (11ms half-sine wave)
- Vibration resistance: 10G (10 to 2000Hz)

VIII.3. MOSFET:

The IRFZ44N is a commonly used power MOSFET for switching applications in electronic circuits. Here are some of its key specifications:

Maximum Drain-Source Voltage (Vds): 55V

Maximum Continuous Drain Current (Id): 49A

Maximum Power Dissipation (Pd): 94W

Gate-Source Voltage (Vgs) Range: +/- 20V

Threshold Voltage (Vth): 2V to 4V 22

On-Resistance (Rds(on)): 17.5mΩ at Vgs = 10V

Some important features of the IRFZ44N include its low on- resistance and high current-carrying capability, which make it suitable for use in high power switching applications. Its gate-source voltage range also allows for flexibility in controlling the MOSFET, while its maximum power dissipation rating ensures reliable operation under heavy loads.

When using the IRFZ44N in a circuit, it is important to ensure that the gate voltage is within the specified range and that proper heat sinking is employed to dissipate any excess heat generated by the MOSFET. Additionally, proper current limiting and protection measures should be implemented to prevent damage to the MOSFET and other components in the circuit.

VIII.4. PMDC 775 MOTOR:

The PMDC 775 motor is a type of permanent magnet DC motor that is commonly used in a variety of applications, including power tools, robotics, and electric vehicles. Here are some of its key specifications:

- Voltage: 12V to 24V DC
- No-load speed: 12,000 RPM to 24,000 RPM
- No-load current: 1.5A to 3.0A
- Stall current: 80A to 120A
- Stall torque: 3.0 Nm to 5.5 Nm
- Shaft diameter: 5mm
- Shaft length: 17mm
- Motor body length: 66mm
- Motor body diameter: 42mm

Some important features of the PMDC 775 motor include its high torque output, compact size, and ease of control using PWM signals or other 24 methods. It is also capable of operating over a wide range of voltages, making it versatile and suitable for a range of applications. When using the PMDC 775 motor in a project, it is important to ensure that the voltage and current requirements are compatible with the power source and any controlling circuits or devices. Additionally, proper heat sinking and cooling measures should be employed to prevent overheating and prolong the lifespan of the motor.

VIII.5. PWM MOTOR SPEED CONTROLLER:

A DC motor speed controller is a device that allows you to control the speed of a DC motor. There are several methods to control the speed of a DC motor, including voltage control, current control, and pulse-width modulation (PWM). The voltage method of speed control is commonly used and involves adjusting the voltage that is applied to the motor to control its speed. Pulse-width modulation (PWM) is a technique used to reduce the average power delivered to the motor by quickly switching the power on and off. A microcontroller or dedicated PWM controller chips is used to generate a square wave signal with a fixed frequency and variable duty cycle to control the average voltage delivered to the motor. Potentiometers can be used as voltage dividers to adjust the voltage level from 1V to 12V, and the output voltage is fed into the microcontroller to generate the PWM signal. Overall, a DC motor speed controller provides precise control over the speed of a motor and can be useful in a variety of applications. This speed controller will be used as throttle for the motor as in E-bike.

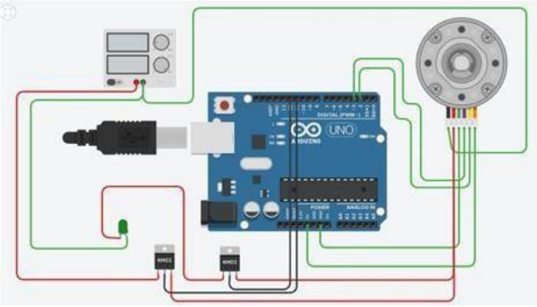
PWM (Pulse Width Modulation) is a popular technique used for DC motor speed control. PWM involves controlling the duty cycle of a square wave signal that is applied to the motor, where the duty cycle represents the percentage of time that the signal is high (on) compared to the total time of the signal. By varying the duty cycle of the square wave signal, the average voltage applied to the motor can be controlled, which in turn affects the motor speed.

PWM DC motor speed control provides several advantages, including high efficiency, low power consumption, and smooth operation. The control over the motor speed is very precise and allows for fine-tuning of the motor's behaviour. A microcontroller or dedicated PWM controller chip can be used to generate the PWM signal, which can be adjusted in real-time to control the motor speed. PWM DC motor speed control is commonly used in robotics, automation, and other applications where precise control over the motor speed is necessary. The effectiveness of regenerative braking depends on the speed of the vehicle and the amount of braking force applied. If the vehicle is moving at a high speed and the braking force is high, a lot of energy can be recovered. However, if the vehicle is moving slowly and the braking force is low, very little energy can be recovered. This is where speed control becomes important. By controlling the speed of the vehicle during regenerative braking, the amount of energy that can be recovered can be maximized. For example, if the vehicle is moving at a high speed, the speed can be reduced gradually to increase the amount of energy that can be recovered. On the other hand, if the vehicle is moving at a low speed, the speed can be maintained or increased slightly to maintain the efficiency of the regenerative braking system.

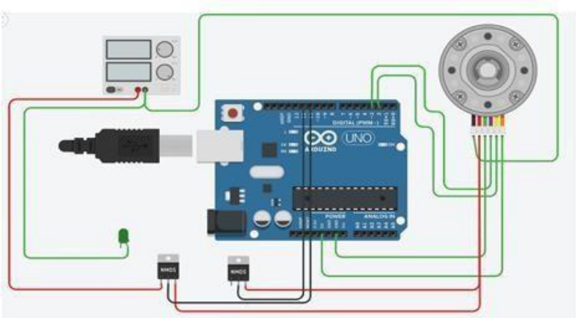
In summary, speed control is necessary in regenerative braking to maximize the amount of energy that can be recovered from the vehicle during braking. By controlling the speed of the vehicle, the efficiency of the regenerative braking system can be improved, leading to greater fuel efficiency and a longer range for electric and hybrid vehicles.

IX. CIRCUIT DIAGRAM:

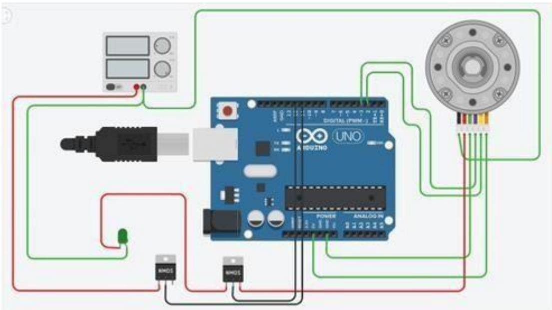
IX.1. BASIC CIRCUIT DIAGRAM:



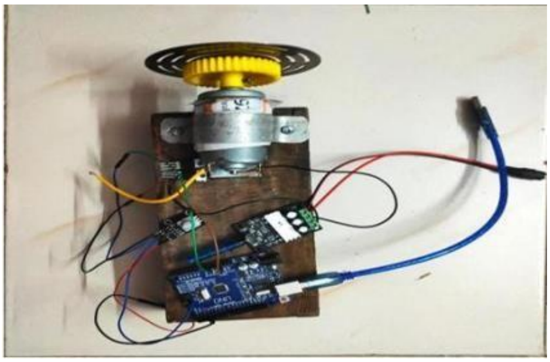
IX.2. CIRCUIT DIAGRAM RUNNING AS MOTOR:



IX.3. CIRCUIT DIAGRAM RUNNING AS GENERATOR:



IX.4. HARDWARE IMPLEMENTATION:



X. CONCLUSION AND FUTURE ENHANCEMENT:

Flywheel regenerative braking presents a host of advantages over battery storage for energy recovery in vehicles:

1. High Power Density: Flywheels boast the ability to store and deliver energy at a much faster rate than batteries, making them particularly suitable for demanding applications such as motorsports where rapid power delivery is essential.

2. Longer Lifespan: Unlike batteries, flywheels do not undergo degradation over time, leading to a significantly longer operational lifespan. This inherent durability translates to enhanced cost-effectiveness over the long term.

3. Lightweight: With their comparatively lower weight profile compared to batteries, flywheels offer an attractive option for vehicles where weight reduction is critical, contributing to improved overall efficiency and performance.

4. Environmentally Friendly: Flywheels lack the toxic chemicals found in batteries and are easier to recycle at the end of their service life, aligning with sustainability goals and minimizing environmental impact.

5. Higher Efficiency: Flywheels exhibit superior energy conversion efficiency when compared to batteries, resulting in more effective energy recovery during braking and subsequent reuse during acceleration, thereby maximizing overall vehicle efficiency.

6. Faster Charge Time: The rapid charging capability of flywheels is particularly advantageous in high-performance vehicles, where swift acceleration is a key requirement, ensuring minimal downtime between energy recovery and usage.

In summary, flywheel regenerative braking holds several advantages over battery storage, especially in demanding applications necessitating swift and efficient energy storage and retrieval. However, despite these benefits, there exist technical and cost-related challenges that require resolution for wider adoption in mass-market vehicles.

In conclusion, the utilization of flywheel-based regenerative braking demonstrates considerable promise in enhancing vehicle efficiency and performance. By harnessing kinetic energy and storing it in a rotating flywheel, this technology facilitates energy recovery during braking, subsequently supplementing acceleration power. One notable advantage of flywheel-based regenerative braking lies in its independence from batteries, which are often cumbersome, costly, and possess limited lifespans. Additionally, high power densities of flywheels enable rapid energy storage and release, rendering them well-suited for demanding applications like motorsports. Nonetheless, challenges persist, notably concerning the technology's high initial cost and technical intricacies associated with flywheel design and integration. Future enhancements could focus on refining flywheel design through the use of lightweight materials and advanced bearings to optimize efficiency and minimize friction. Integration with other powertrain technologies, such as hybrid and electric drivetrains, holds potential for further efficiency gains and sustainability. Overall, the promising trajectory of flywheel-based regenerative braking underscores its potential to revolutionize vehicle efficiency and performance, with ongoing research and development poised to drive further advancements in the field.

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