FABRICATION OF REGENERATIVE BRAKING SYSTEM USING ULTRASONIC SENSOR

A Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF TECHNOLOGY

in

MECHANICAL ENGINEERING

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LUCKNOW

May, 2023

DECLARATION

We hereby declare that this submission is our own work and that, to the best of our knowledge and belief, it contains no material previously published or written by any other person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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CERTIFICATE

This is to certify that the project report entitled "**Fabrication of Regenerative Braking System using Ultrasonic Sensor**" which is submitted by Mayank Gupta, Maitrei Tiwari, Kartikey Pandey and Kundan Yadav in partial fulfilment of the requirement for the award of degree B. Tech in Department of Mechanical Engineering of JSS Academy of Technical Education, Noida affiliated to Dr. A.P.J. Abdul Kalam Technical University, Lucknow is a record of candidate's own work carried out by them under my supervision. The matter embodied in this thesis is original and has not been submitted for the award of any other degree.

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ABSTRACT

This study focuses on the integration of a regenerative braking system with an automatic braking system using ultrasonic sensors for electric and hybrid vehicles. The proposed system uses ultrasonic sensors to detect obstacles and apply the brakes automatically to prevent collisions. Along with this automatic braking system, regenerative braking is employed to capture the kinetic energy of the vehicle during braking and convert it into electrical energy. The generated energy is then stored in the battery and used to power the electric motor, thereby increasing the vehicle's energy efficiency and reducing its dependence on traditional fuel sources.

To evaluate the performance of the proposed system, a simulation model was developed, and the results showed that the system could recover a significant amount of energy during braking, which can extend the vehicle's range. Additionally, the automatic braking system using ultrasonic sensors demonstrated high accuracy and response time, making it an effective safety feature.

The integration of regenerative braking with an automatic braking system using ultrasonic sensors has the potential to improve the energy efficiency and safety of electric and hybrid vehicles. However, further research could focus on developing a real-world prototype and evaluating its performance under various driving conditions. It should be noted that the implementation of this system in current working vehicles may cause discomfort to drivers as it requires some changes in driving style and may increase the mass of the vehicle, and occupy additional space. Therefore, the integration of regenerative braking should be considered with other braking systems, and drivers should be educated about eco-driving strategies to maximize the benefits of this system.

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

RBS	Regenerative Braking System
A.C.	Alternating Current
D.C.	Direct Current
EVs	Electric Vehicles
ABS	Anti-lock Braking System
IBS	Intelligent Braking System
BLDC	Brushless Direct Current Motor
IR	Infrared
M.S.	Mild Steel
LEDs	Light Emitting Diodes
PPE	Personal Protective Equipment
RPM	Revolutions Per Minute

E	Young’s Modulus	Gpa
ρ	Density	kg/m^3
I	Electric Current	A
D	Distance	m
V	Voltage	V

CHAPTER 1

INTRODUCTION

1.1 Overview

The number of automobile users has been increasing steadily over the years, as more people around the world are able to afford personal transportation. This trend is driven by a number of factors, including rising incomes, urbanization, and improvements in technology and manufacturing processes. The increasing number of automobile users has raised concerns about both the environment and road safety. The widespread use of automobiles has led to increased carbon emissions, air pollution, and other environmental issues, while the rise in accidents has led to serious injuries and fatalities. To address these concerns, governments and industry organizations are taking steps to promote more sustainable and safe transportation solutions. For example, many countries are promoting the use of electric and hybrid vehicles as a way to reduce carbon emissions and improve air quality. Similarly, the development of autonomous vehicles has the potential to significantly reduce the number of accidents by eliminating driver error.

Regenerative braking is a technology used in electric and hybrid vehicles to recapture energy that would otherwise be lost during braking and use it to recharge the vehicle's battery. During normal braking, a vehicle's kinetic energy is converted into heat and dissipated into the environment through the brakes. In contrast, regenerative braking systems use an electric motor as a generator to convert the kinetic energy of the moving vehicle into electrical energy. This generated electricity is then used to recharge the battery, which can then power the electric motor to accelerate the vehicle again.

The regenerative braking system works by using the electric motor in reverse mode when the brakes are applied. The motor generates electricity as the vehicle slows down, which is stored in the battery for later use. This technology helps to increase the efficiency of electric and hybrid vehicles, making them more energy-efficient and reducing the amount of energy wasted during braking.

During normal braking, the RBS captures the kinetic energy generated by the vehicle's motion and converts it into electrical energy, which can be stored in the vehicle's battery or used to power the electric motor. The traditional braking system, which typically uses hydraulic pressure to apply brake pads to the wheels, is used to provide additional stopping power when needed or when the RBS is unable to capture enough energy to bring the vehicle to a complete stop.

The combination of RBS and traditional braking system provides a highly effective and efficient braking solution for hybrid and electric vehicles. The RBS helps to reduce wear and tear on the traditional braking system, while also providing energy savings and reducing carbon emissions. At the same time, the traditional braking system provides the additional stopping power needed to ensure safe and effective braking in all driving conditions.

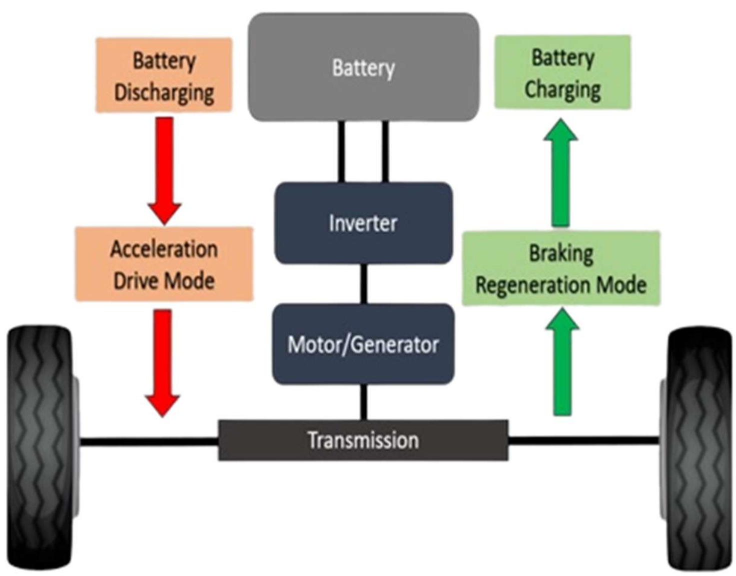

Fig. 1.1: Regenerative Braking

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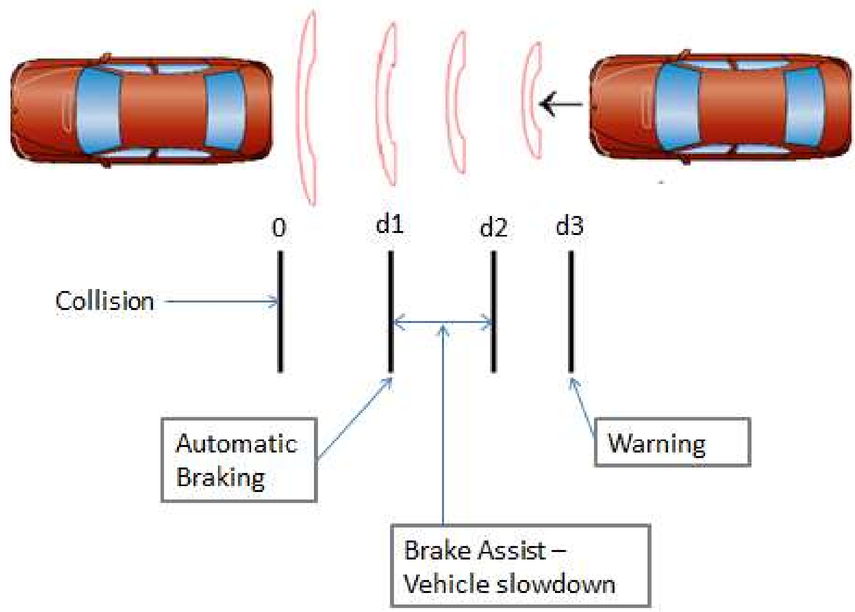

Fig. 1.2: Automatic Braking

Regenerative braking is often integrated with automatic braking systems in modern vehicles. An automatic braking system uses sensors and control systems to automatically apply the brakes when it detects an impending collision. When combined with a regenerative braking system, this allows the vehicle to recover more kinetic energy, since the automatic braking system can detect and respond to braking situations more quickly than a human driver.

In a typical scenario, when the automatic braking system detects an obstacle or another vehicle in front of the car and applies the brakes, the regenerative braking system kicks in to convert the kinetic energy of the moving vehicle into electrical energy, which is then stored in the battery. This way, the energy that would have been lost as heat in the brakes is used to recharge the battery.

Regenerative braking with automatic braking systems is becoming increasingly common in electric and hybrid vehicles and is an important technology for increasing the efficiency and range of these vehicles. By recovering energy that would otherwise be lost during braking, regenerative braking can help reduce the vehicle's reliance on traditional fuel sources and lower its overall carbon footprint.

By combining these two technologies with ultrasonic sensors, the system can detect obstacles or other vehicles in the vehicle's path and automatically apply the brakes to prevent a collision. The ultrasonic sensors use sound waves to detect objects in front of the vehicle, and the system can apply the brakes automatically to bring the vehicle to a stop.

Regenerative braking finds numerous applications in various industries. Here are some examples:

- **Metro Trains**: Many metro trains worldwide utilize regenerative braking systems, which allow for the recovery of approximately 25% of the electrical energy and return it to the power source.
- **Electric Trams**: Škoda Transportation produces electric trams equipped with regenerative braking systems. These trams are extensively used throughout Europe, contributing to energy efficiency and sustainability.
- **Electric Vehicles**: Regenerative braking is commonly employed in electric vehicles to improve energy efficiency and increase range. Some notable examples include:
  a. **TESLA**: The electric car manufacturer TESLA incorporates regenerative braking systems in most of its models, enabling efficient energy recovery during deceleration.
  b. **Audi E-TRON and BMW I8**: These electric vehicle models from Audi and BMW respectively utilize regenerative braking to enhance energy efficiency and extend driving range.
  c. **MG ZS EV and Hyundai Kona**: Both the MG ZS EV and Hyundai Kona electric vehicles feature regenerative braking systems to recover and utilize energy during braking.
  d. **Toyota Prius**: The Toyota Prius hybrid vehicle is equipped with regenerative braking technology, enabling the recovery of energy that would otherwise be lost during braking.

e. **Ford Fusion**: The Ford Fusion hybrid model utilizes regenerative braking to enhance fuel efficiency and reduce emissions.

The concept of regenerative brakes can be better understood by considering a bicycle equipped with a dynamo. When a dynamo, a small electricity generator, is fitted to power the bike's lights, pedaling becomes harder when the dynamo is engaged compared to when it is disengaged. This is because some of the energy from pedaling is used by the dynamo, which converts it into electrical energy for lighting.

If a bicycle traveling at a certain velocity stops pedaling and activates the dynamo, it will come to a stop more quickly than it would under normal circumstances without using the brakes. Now, envision a bicycle equipped with a larger and more powerful dynamo that includes a battery. This setup can bring the bike to a relatively quick halt by converting the kinetic energy into electricity, which can be stored in the battery. This basic principle forms the foundation of regenerative brakes.

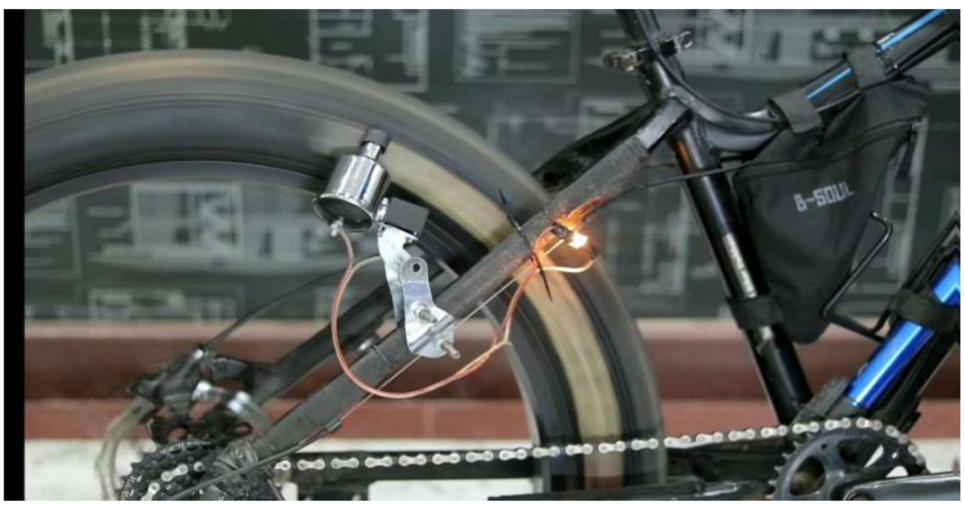

Fig. 1.3: A bicycle equipped with dynamo

Overall, a regenerative braking system with an automatic braking system using ultrasonic sensors has the potential to improve the safety and efficiency of vehicles on the road. By converting the kinetic energy of the vehicle into electrical energy during deceleration or braking and applying the brakes automatically in the event of an imminent collision, this system can help to reduce accidents and promote more sustainable transportation practices.

1.2 History of Regenerative Brakes

The concept of regenerative braking originated in the early 19th century with the development of electric vehicles (EVs). In 1832, Robert Anderson, a British inventor, created one of the earliest electric carriages that employed a basic form of regenerative braking. Anderson's design featured a crankshaft-driven dynamo that charged batteries during deceleration or downhill motion, enabling limited energy recovery.

Throughout the following decades, regenerative braking garnered increasing attention and research. Hungarian engineer Ányos Jedlik proposed an electromagnetic braking system for electric trams in the late 19th century. Jedlik's design involved using the tram motors as generators during braking to produce electrical energy, which could be fed back into the power grid. However, practical implementation and widespread adoption posed challenges for Jedlik's innovative concept.

In the early 20th century, regenerative braking gained traction, particularly in railway transportation. German engineer Karl Wittgenstein developed a regenerative braking system for electric trains in the 1900s. Wittgenstein's system utilized transformers and resistors to convert train kinetic energy into electrical energy, which was then fed back into the power grid. This development marked a significant milestone in the large-scale application of regenerative braking.

Regenerative braking gained popularity in the automotive sector during the latter half of the 20th century with the rise of hybrid electric vehicles (HEVs). The introduction of the Toyota Prius in 1997 played a crucial role in the widespread acceptance of regenerative braking in the automotive industry. The Prius utilized regenerative braking to capture energy during acceleration and store it in onboard batteries, reducing reliance on the internal combustion engine and improving fuel economy.

Advancements in power electronics, battery technology, and control systems have further enhanced the efficiency and effectiveness of regenerative braking. Modern regenerative braking systems employ sophisticated algorithms and sensors to optimize energy capture and conversion based on factors such as road conditions, battery charge levels, and driver preferences.

Regenerative braking has evolved from an option for hybrid cars to a standard feature in fully electric vehicles (EVs). It is also utilized in electric trains, trams, bicycles, and various other modes of transportation. Regenerative braking extends the range of EVs and enhances overall energy efficiency.

From its early conceptual stages, regenerative braking has become a crucial aspect of modern transportation systems. It has revolutionized the approach to energy efficiency in vehicles by harnessing energy that would otherwise be lost during braking. As technology advances and sustainability takes centre stage, regenerative braking is expected to play an even larger role in shaping the future of transportation.

1.3 Vehicles Utilizing Regenerative Braking

The amount of energy saved by regenerative brakes depends on the specific vehicle and its operating conditions. In general, larger and heavier vehicles that travel at higher speeds, such as electric trains, can achieve significant energy savings through regenerative braking. These vehicles accumulate a substantial amount of kinetic energy, which can be efficiently recovered during braking.

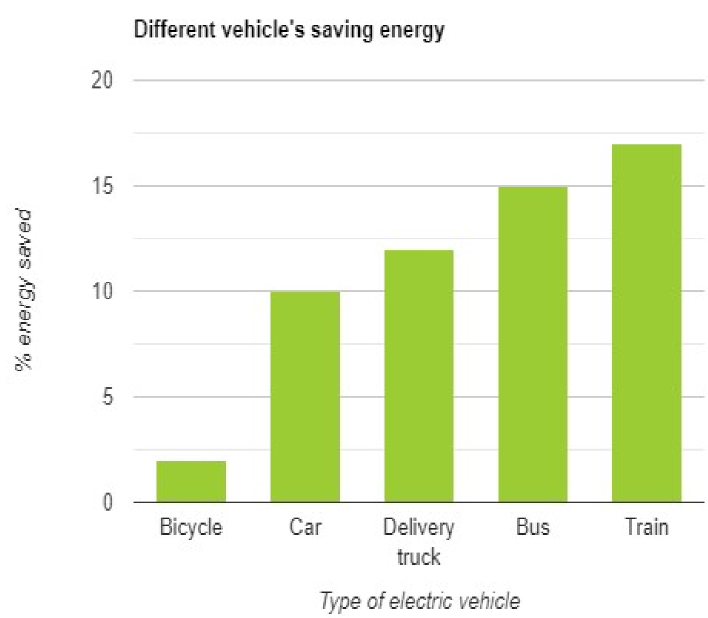

Fig. 1.4: Different vehicle’s saving Energy

Delivery trucks, despite being lighter and traveling at lower speeds, can also achieve notable energy savings through regenerative braking. This is particularly true for trucks that frequently start and stop during their routes.

For passenger cars, the energy savings achieved by regenerative brakes can vary. Typically, passenger cars can save around 8 to 15 percent of energy, depending on factors such as the specific car model, driving conditions (city traffic or open highway), and driving style.

On the other hand, electric bicycles, which are lightweight and generally operate at slower speeds, experience relatively less energy recovery through regenerative braking. The lower amount of kinetic energy generated during braking limits the energy-saving potential in electric bicycles.

Electric Buses: Buses have experimented with mechanical forms of regenerative braking since the 1940s, with concepts like flywheels or hydraulics. While these systems have shown promising energy-saving potential, they have not gained widespread adoption due to factors such as increased mass and complexity. However, advancements in regenerative braking technology for buses continue to be explored.

Electric Bicycles: Electric bicycles, due to their low mass and lower speeds compared to cars and trains, do not benefit significantly from regenerative braking. Cyclists often optimize their energy usage by coasting or freewheeling to a stop rather than relying heavily on braking. In most cases, regenerative brakes on electric bicycles provide minimal energy savings, and they may even consume more energy overall due to the need for the motor to be engaged continuously.

Electric and Hybrid Cars: In electric and hybrid vehicles, regenerative braking systems have a vital function in extending the vehicle's range between charging cycles. By converting the energy produced during braking into electrical energy, regenerative brakes facilitate the charging of the main battery pack, thereby improving the overall energy efficiency of the vehicle. This innovative technology enables electric and hybrid cars to recover and harness a substantial amount of the kinetic energy that would typically be dissipated and wasted during the braking process.

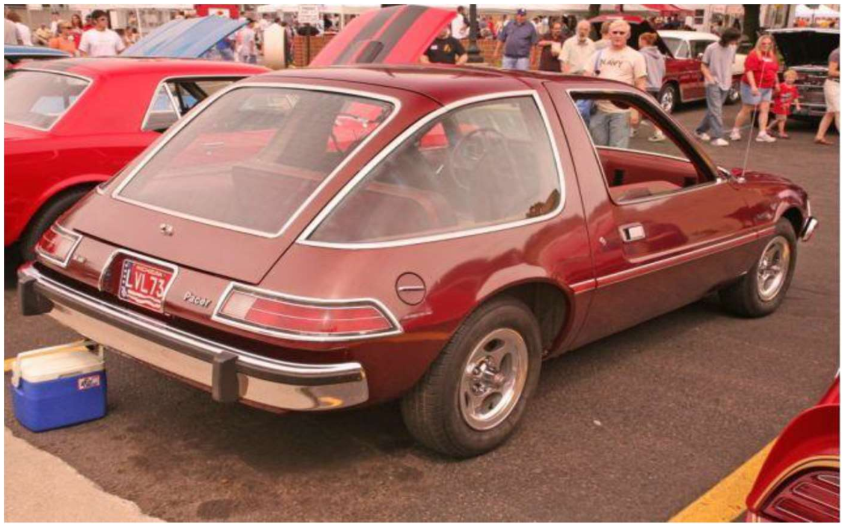

Fig. 1.5: Amitron car equipped with RBS

Electric Trains: Electric trains, which are powered by overhead or trackside powerlines, also utilize regenerative braking systems. Instead of storing the braking energy in batteries, electric trains return it back to the powerline. This approach enables the trains to save around 15-20 percent of their energy consumption by effectively utilizing regenerative braking.

Fig. 1.6: Delhi Metro equipped with Regenerative Brakes

Elevators: Elevators, although not typically thought of as electric vehicles, also benefit from regenerative braking technology. Leading elevator manufacturers have introduced regenerative elevators that can save up to 75 percent of the energy normally used. By feeding the braking energy back into the building's power system instead of dissipating it as heat, regenerative elevators significantly improve energy efficiency.

1.4 Problem statement

In the fast-paced world we live in, maintaining a safe distance between vehicles, especially at traffic signals, can be challenging. Vehicles often come to a stop in close proximity to each other, and if a driver loses control, collisions with other vehicles or objects, such as trees, can occur, resulting in loss of lives and vehicle damage.

Another common scenario is when one vehicle is following another or attempting to overtake it. If the leading vehicle suddenly applies brakes and slows down, the following vehicle may not maintain a proper distance and end up colliding with the leading vehicle.

To address these issues and promote safety, our objective is to develop a device that can prevent accidents and minimize vehicle damage while also generating electricity during braking.

The introduction of an intelligent braking system aims to enhance safety and driving comfort. This system is designed to prevent critical damage to vehicles during driving. Oftentimes, drivers struggle to accurately judge the appropriate distance between their car and obstacles. Therefore, an intelligent braking system can play a crucial role in ensuring car safety. It opens up new possibilities and concepts for the automobile industry.

Every time we apply the brakes in our cars, we are essentially wasting energy. According to the laws of thermodynamics, energy cannot be created or destroyed; it can only be converted from one form to another. When a car slows down, the kinetic energy that was propelling it forward is dissipated as heat, rendering it useless. This wasted energy, which could have been utilized to perform work, represents a missed opportunity.

1.5 Objective

The objective of our research of this project is to improve the efficiency and safety of the braking system in a vehicle. Specifically, the objectives of this system are:

- The primary objective is to develop a safety car braking system using ultrasonic sensor and to design a system with less human attention to driving.
- To develop an automated braking system to avoid frontal collision of the vehicle due to driver's inattentiveness. The working model comprises of automated braking system which includes ultrasonic sensor.
- The main aim is to recover, store and reuse some of the vehicle's braking energy to improve fuel efficiency or boost the range of electric and hybrid vehicles (FEV/HEV).

1.6 Working principle

The working principle of our research involves the integration of the sensor with the braking system of the vehicle to enable automatic detection and control of the braking process.

Here is a step-by-step explanation of the working principle:

1. **Ultrasonic Sensor Detection**: The ultrasonic sensor is positioned in a suitable location, typically at the front of the vehicle, facing forward. It emits ultrasonic waves, which travel in a cone-shaped pattern. If there is an obstacle or object in the path of the vehicle, the ultrasonic waves will bounce back after hitting the object.
2. **Distance Measurement**: The ultrasonic sensor receives the reflected waves and measures the time it takes for the waves to return. Based on the time of flight, the sensor calculates the distance between the vehicle and the obstacle. This distance measurement is crucial for determining the appropriate braking action.
3. **Object Detection and Analysis**: The distance data obtained from the ultrasonic sensor is processed by a controller or microcontroller unit. The controller analyses the distance readings and compares them to a predefined threshold or set of parameters to determine if there is a potential collision risk.

4. **Braking Signal Generation**: If the controller determines that the vehicle is too close to the detected object or that a collision is imminent, it generates a braking signal. This signal is then sent to the vehicle's braking system, which may include hydraulic, pneumatic, or electric components.
5. **Braking Activation**: Upon receiving the braking signal, the braking system is activated, applying the appropriate level of braking force to slow down or stop the vehicle. The amount of braking force applied may vary depending on the distance to the obstacle and the speed of the vehicle.
6. **Regenerative Braking**: In a regenerative braking system, when the brakes are applied, the kinetic energy of the vehicle is converted into electrical energy. This energy is stored in the vehicle's battery or capacitors for later use, such as powering the vehicle or recharging the battery.
7. **Monitoring and Feedback**: Throughout the braking process, the ultrasonic sensor continues to monitor the distance to the obstacle. If the distance increases and the obstacle is no longer a threat, the braking force is gradually reduced or released to allow the vehicle to resume normal operation.

1.6.1 Working of Regenerative Braking System

The working principle of a regenerative braking system involves the following steps:

1. When the driver applies the brakes, the kinetic energy of the moving vehicle is converted into heat energy through the friction between the brake pads and the brake disc or drum, which dissipates into the environment.
2. In a regenerative braking system, the kinetic energy of the moving vehicle is captured by an electric motor or generator installed in the vehicle.
3. When the driver applies the brakes, the motor or generator is activated, and it converts the kinetic energy of the vehicle into electrical energy.
4. This electrical energy is then stored in a battery or other storage device, such as a supercapacitor, for later use.
5. By capturing and reusing the kinetic energy that would otherwise be lost as heat, regenerative braking can improve the overall energy efficiency of the vehicle and increase the driving range.

6. In hybrid and electric vehicles, the stored electrical energy can be used to power the vehicle's electric motor, reducing the reliance on the combustion engine and increasing the fuel efficiency.

Overall, the regenerative braking system allows for the recovery of energy that would otherwise be lost during the braking process, making the vehicle more energy-efficient and eco-friendly.

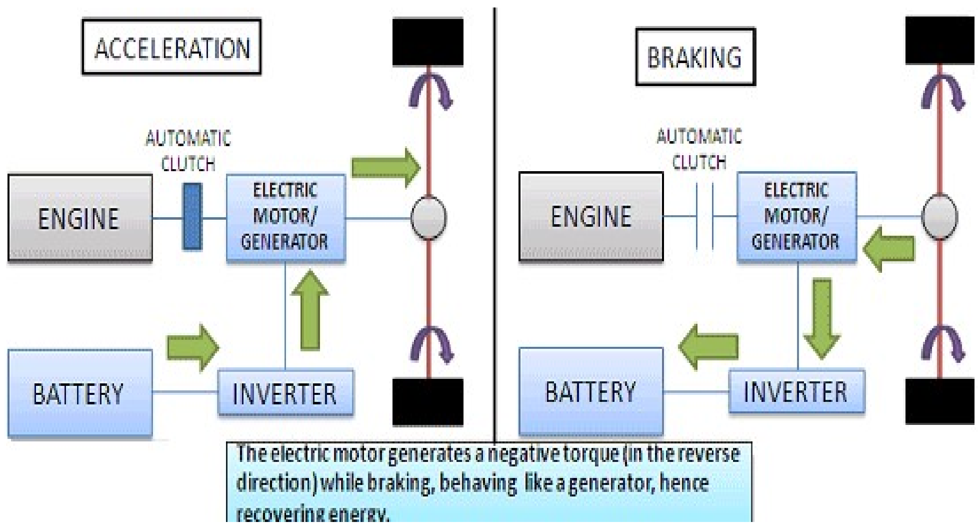

Fig. 1.7: Braking Circuit of RBS

1.6.1.1 Generating Electrical Energy From Kinetic Energy Through Motor Conversion:

The process of converting kinetic energy to electrical energy using a motor in RBS can be broken down into a few simple steps:

1. When the driver applies the brakes, the electric motor switches to generator mode, using the kinetic energy of the moving vehicle to turn the rotor.
2. As the rotor turns, it generates an electric current that is sent to the inverter, which converts the current from AC to DC.
3. Direct current is then sent to the battery, where it is stored for later use or used to power an electric motor.
4. As the vehicle comes to a stop, the traditional friction-based braking system may also be used to provide additional stopping power, if necessary.

1.6.2 Working of Ultrasonic Sensor

The ultrasonic sensor in the fabrication of a regenerative and automatic braking system works by emitting high-frequency sound waves that bounce off objects in front of the vehicle. The sensor then measures the time it takes for the sound waves to return to the sensor, which provides an estimate of the distance to the object.

In the context of a regenerative and automatic braking system, the ultrasonic sensor can be used to detect objects in front of the vehicle and automatically apply the brakes if the vehicle is too close. This system relies on the sensor to accurately detect the distance to objects in front of the vehicle and respond quickly to changes in the environment.

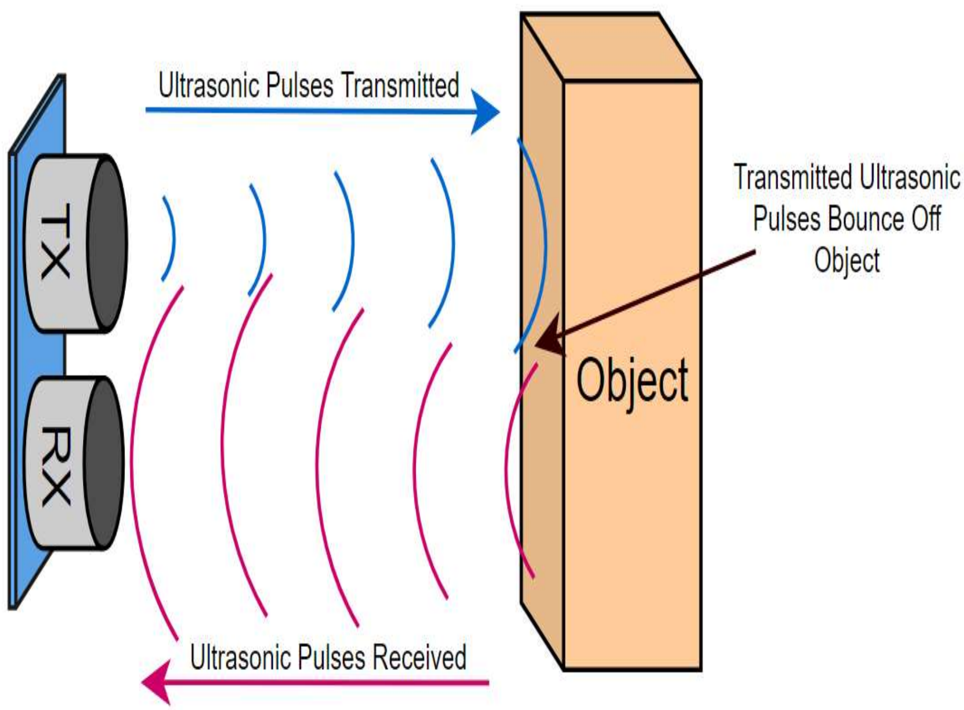

Fig. 1.8: Working of Ultrasonic Sensor

When an object is detected by the ultrasonic sensor, the signal is sent to a controller that analyzes the data and determines if the vehicle needs to slow down or stop. If the controller determines that the vehicle needs to stop, it will send a signal to the braking system, which will apply the brakes and bring the vehicle to a stop.

1.6.3 Working of Micro-Controller (Arduino Uno)

The Arduino Uno microcontroller plays a crucial role in the implementation of a regenerative and automatic braking system using an ultrasonic sensor. Here is a brief overview of how the microcontroller operates within this system:

1. **Sensing**: The ultrasonic sensor is used to detect the distance between the vehicle and an obstacle or another vehicle ahead. It emits ultrasonic waves and measures the time it takes for the waves to bounce back after hitting an object. This data is then sent to the Arduino Uno.
2. **Data Processing**: The Arduino Uno receives the distance data from the ultrasonic sensor and processes it using its built-in microcontroller unit (MCU). The MCU executes a predefined program or code that analyzes the received data and determines the appropriate action based on the braking requirements.
3. **Decision Making**: Based on the distance measurement, the Arduino Uno evaluates whether the vehicle needs to apply the brakes or initiate regenerative braking. If the distance between the vehicle and the obstacle is within a predefined safety range, the microcontroller initiate the braking system.
4. **Braking Control**: In the case of automatic braking, the Arduino Uno sends signals to the braking system of the vehicle, activating the brakes and bringing the vehicle to a stop. It ensures that the braking action is swift and efficient, enhancing safety.
5. **Regenerative Braking**: In the regenerative braking mode, the Arduino Uno coordinates with the powertrain system to activate the regenerative braking mechanism. It controls the electric motor or generator to convert the kinetic energy of the vehicle into electrical energy. This energy is then stored in a battery or used to power various vehicle systems, thereby increasing energy efficiency.
6. **Monitoring and Feedback**: The Arduino Uno continuously monitors the ultrasonic sensor readings and adjusts the braking action accordingly. It provides feedback to the driver or displays relevant information on a user interface, informing them about the braking status, distance measurements, and other relevant data.

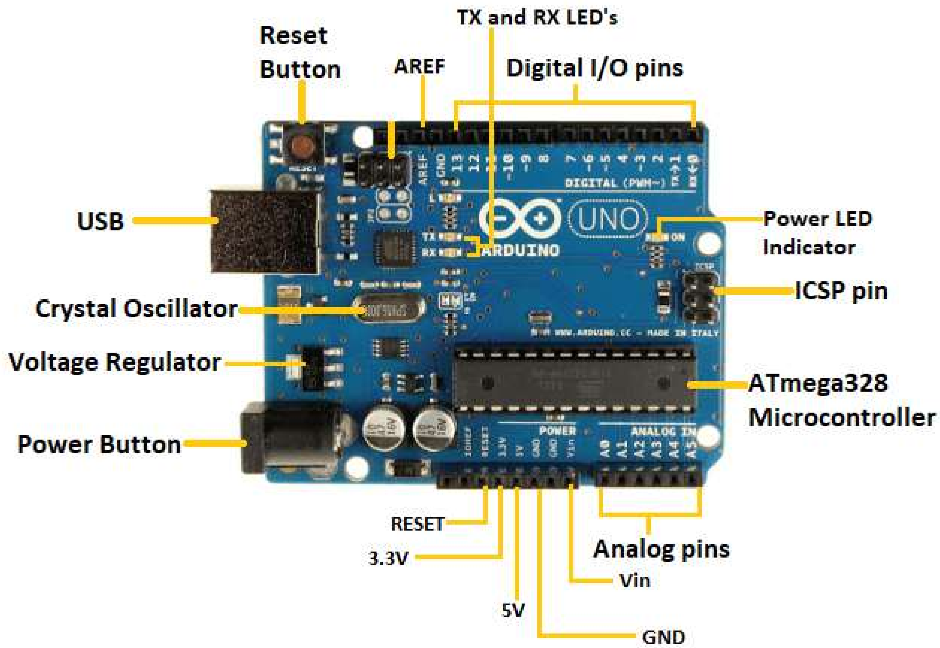

Fig. 1.9: Micro-controller (Arduino Uno)

The Arduino Uno acts as the central processing unit, receiving input from the ultrasonic sensor, processing the data, and issuing commands to control the braking system and regenerative mechanisms. Its flexibility and programmability make it a versatile component in designing and implementing advanced braking systems in vehicles.

1.6.3.1 Program Used For Micro Controller

```
#define trigPin1 A4

#define echoPin1 A5

#define m11  6

#define m12  7

#define relay  5

long duration, distance,sensor1,sensor2,sensor3,sensor4;

int onetime=0;
```

```
void setup()
{
  Serial.begin(9600);
  pinMode(trigPin1, OUTPUT);
  pinMode(echoPin1, INPUT);
  pinMode(m11, OUTPUT);
  pinMode(m12, OUTPUT);
  pinMode(relay, OUTPUT);
}
void loop()
{
 ultrasensor(trigPin1, echoPin1);
 sensor1 = distance;
 delay(10);
 Serial.print("sensor1=");
 Serial.println(sensor1);
 if(sensor1 <= 60)
  {
  digitalWrite(relay,HIGH);
  digitalWrite(m11,LOW);
  digitalWrite(m12,LOW);
```

```
}
else if(sensor1 >= 60 && sensor1 <= 150)
{
 if(onetime==0)
 {
  digitalWrite(m11,HIGH);
  digitalWrite(m12,LOW);
  delay(1000);
  digitalWrite(m11,LOW);
  digitalWrite(m12,LOW);
  onetime=1;
 }
}
else
{
 digitalWrite(relay,LOW);
 if(onetime==1)
 {
  digitalWrite(m11,LOW);
  digitalWrite(m12,HIGH);
  delay(1000);
```

```
  digitalWrite(m11,LOW);
  digitalWrite(m12,LOW);
  onetime=0;
 }
}
}
void ultrasensor(int trigPin,int echoPin)
{
 digitalWrite(trigPin, LOW);  // Added this line
 delayMicroseconds(2); // Added this line
 digitalWrite(trigPin, HIGH);
 delayMicroseconds(10); // Added this line
 digitalWrite(trigPin, LOW);
 duration = pulseIn(echoPin, HIGH);
 distance = (duration/2) / 29.1;
}
```

1.7 Types of Regenerative Braking System

Regenerative braking systems encompass various methods of energy conversion, including spring, flywheel, electromagnetic, hydraulic, and a recently developed electromagnetic-flywheel hybrid system. Each type of regenerative braking system employs a unique energy conversion or storage approach, resulting in diverse efficiencies and applications. Here are the different types:

- ❖ Electromagnetic Regenerative Braking
- ❖ Flywheel Regenerative Braking
- ❖ Electromagnetic Flywheel Regenerative Braking
- ❖ Spring Regenerative Braking
- ❖ Hydraulic Regenerative Braking

1.7.1 Electromagnetic Regenerative Braking

The electromagnetic regenerative braking system utilizes electromagnetic forces to transform the kinetic energy of a moving vehicle into electrical energy. As the vehicle decelerates or engages the brakes, the rotational motion of the wheels drives an electromagnetic generator. This generator efficiently converts the mechanical energy into electrical energy, which can be stored in a battery or directed back into the vehicle's electrical system.

1.7.2 Flywheel Regenerative Braking

Flywheel regenerative braking systems employ a rotating flywheel to capture and store kinetic energy during the deceleration phase. The flywheel is integrated into the drivetrain, and as the vehicle slows down, the energy is transferred to the flywheel, causing its rotational speed to increase. By effectively harnessing this stored energy, the flywheel can subsequently power the vehicle during acceleration, thereby alleviating the burden on the primary power source.

Fig. 1.10: Flywheel Based RBS

1.7.3 Electromagnetic Flywheel Regenerative Braking

The electromagnetic flywheel regenerative braking system integrates both electromagnetic and flywheel principles to maximize energy capture and storage. As the wheels rotate, an electromagnetic generator generates electrical energy, which is simultaneously transferred to a flywheel for storage. This enables the vehicle to harness and store the kinetic energy that would have otherwise been lost during deceleration. Later, during acceleration, the stored energy in the flywheel can be used to assist the vehicle, reducing the load on the primary power source and increasing efficiency.

1.7.4 Spring Regenerative Braking

Spring regenerative braking systems capitalize on the potential of mechanical springs to store and unleash energy during deceleration and acceleration. As the vehicle applies the brakes, the energy is transferred to the springs, resulting in their compression. Subsequently, during acceleration, the compressed springs efficiently release the stored energy, providing an additional boost to the vehicle's propulsion. This innovative approach maximizes energy utilization, contributing to improved overall efficiency and performance.

Fig. 1.11: Spring Based RBS

1.7.5 Hydraulic Regenerative Braking

Hydraulic regenerative braking systems harness the power of hydraulic fluid to efficiently store and release energy. When the vehicle engages the brakes, the hydraulic system converts the kinetic energy into potential energy by compressing the hydraulic fluid. This compressed fluid serves as a reservoir of energy, which can be strategically released to aid the vehicle during acceleration, resulting in reduced fuel consumption. By effectively converting and utilizing the vehicle's kinetic energy, hydraulic regenerative braking systems offer enhanced efficiency and contribute to sustainable energy utilization.

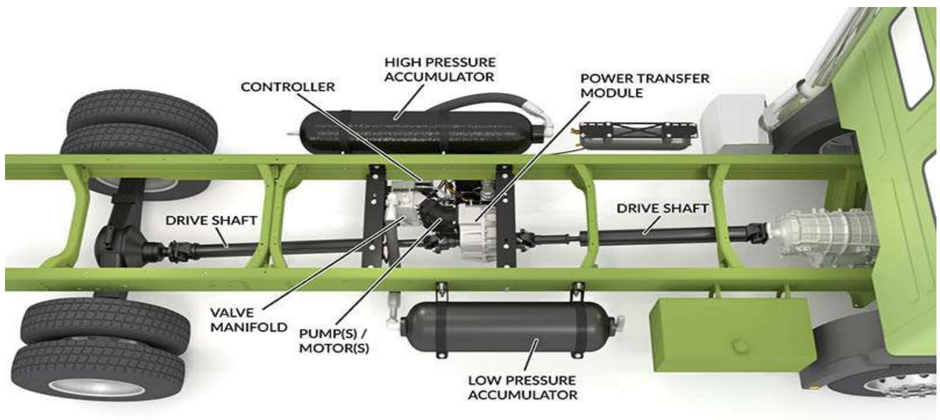

Fig. 1.12: Hydraulic Based RBS

1.8 Applications

- **Electric vehicles**: One of the primary applications of regenerative braking systems is in electric vehicles. These systems recover and store the kinetic energy of the vehicle during braking and reuse it to power the vehicle. This process reduces energy consumption and increases the driving range of the vehicle.
- **Hybrid vehicles**: Regenerative braking systems are also commonly used in hybrid vehicles. These vehicles use a combination of internal combustion engines and electric motors. The regenerative braking system helps to recover

the kinetic energy of the vehicle during braking and reuse it to power the electric motor.

- **Elevators**: Regenerative braking systems are used in elevators to reduce energy consumption. When an elevator goes down, the motor generates electricity that can be used to power other elevators or other electrical systems in the building.
- **Cranes and hoists**: Regenerative braking systems are also used in cranes and hoists to reduce energy consumption. These systems recover the kinetic energy of the load during braking and reuse it to power the motor during lifting.
- **Renewable energy**: Regenerative braking systems are also used in renewable energy systems, such as wind turbines and hydroelectric generators. These systems can use regenerative braking to recover the kinetic energy of the rotor during braking and reuse it to power the generator.

1.9 Advantages

- **Increased energy efficiency**: Regenerative braking systems convert the kinetic energy of the vehicle into electrical energy, which can be used to power the vehicle. By using ultrasonic sensors to optimize the regenerative braking system, more of the kinetic energy can be captured, resulting in increased energy efficiency and reduced fuel consumption.
- **Improved safety**: The automatic braking system can detect obstacles and pedestrians in front of the vehicle and automatically apply the brakes, reducing the risk of accidents. The use of ultrasonic sensors can enhance the accuracy of the braking system, enabling it to detect obstacles more effectively and provide a faster response time.
- **Reduced brake wear and tear**: The regenerative braking system can reduce the wear and tear on the vehicle's brake system by using the electric motor to slow down the vehicle, which reduces the need for the brake pads to do so. This can result in reduced maintenance costs and longer brake life.
- **Reduced emissions**: By capturing more of the kinetic energy of the vehicle, regenerative braking systems can reduce the amount of energy wasted during braking, resulting in reduced emissions and a smaller carbon footprint.
- **Improved driving experience**: The combination of regenerative and automatic braking systems with ultrasonic sensors can provide a smoother and more

comfortable driving experience, as the vehicle can decelerate more smoothly and predictably.

1.10 Limitations

- **Limited performance in certain driving conditions**: The regenerative braking system is most effective at recovering kinetic energy during stop-and-go driving, and less effective at high speeds. Additionally, the effectiveness of the ultrasonic sensors in detecting obstacles can be reduced in adverse weather conditions, such as heavy rain or snow.
- **Increased complexity and cost**: The combination of regenerative and automatic braking systems using ultrasonic sensors can increase the complexity of the vehicle's braking system, which can lead to increased maintenance costs and potential reliability issues.
- **Limited range of application**: The use of regenerative and automatic braking systems with ultrasonic sensors may not be suitable for all types of vehicles, such as heavy-duty trucks or off-road vehicles, which require different types of braking systems.
- **Driver acceptance and behaviour**: The success of automatic braking systems with ultrasonic sensors depends on the acceptance and behaviour of the driver. Some drivers may find the automatic braking system intrusive or distracting, leading them to disable or ignore the system, which can reduce its effectiveness.
- **Limited battery capacity**: Regenerative braking systems use the vehicle's battery to store the recovered kinetic energy. However, the battery capacity may not be sufficient to store all the recovered energy, which can limit the effectiveness of the system.

1.11 Future scope

- **Integration with other advanced safety features**: Regenerative and automatic braking systems using ultrasonic sensors can be integrated with other advanced safety features, such as lane departure warning, adaptive cruise control, and pedestrian detection, to provide a more comprehensive safety system.
- **Application in electric and hybrid vehicles**: Regenerative braking systems are particularly well-suited for use in electric and hybrid vehicles, where the

recovered kinetic energy can be used to recharge the battery and improve the vehicle's range.

- **Further development of sensor technology**: The use of ultrasonic sensors can be further developed to improve the accuracy and speed of the system. Other sensor technologies, such as lidar and radar, can also be explored to enhance the overall performance of the system.
- **Optimization for different driving conditions**: Regenerative and automatic braking systems can be optimized for different types of driving conditions, such as highway driving or off-road driving, to improve the efficiency and performance of the system in these scenarios.
- **Development of new control algorithms**: Advanced control algorithms can be developed to optimize the regenerative and automatic braking systems, taking into account the driving conditions, vehicle type, and sensor data to provide a more efficient and effective braking system.

CHAPTER 2

LITERATURE REVIEW

- (P Bhandari et al., 2017), author has emphasized in their work that the immense potential of regenerative braking as a means of energy conversion. They highlight that regenerative braking systems have the capability to convert a significant portion of energy into electrical energy, which can be efficiently stored for future use. With frequent braking events occurring during driving, the implementation of regenerative braking offers substantial opportunities for energy savings. Although current regenerative braking systems only convert a fraction of the total kinetic energy into mechanical or electrical energy, the authors state the importance of ongoing research and advancements in this field. They envision a future where regenerative braking systems become more efficient, playing a vital role in conserving non-renewable energy sources. This highlights the promising prospects of regenerative braking for enhancing energy efficiency and fostering sustainable transportation practices.
- In their publication titled "Review on Intelligent Braking System", (Milind S. Deotale et al., 2016), addressed the pervasive issue of road accidents and the significance of accident prevention. They emphasized that Indian vehicles commonly incorporate safety features such as ABS, traction control, and brake assist to ensure driver safety. Their study focused on the innovative 'Intelligent Braking System' (IBS), which utilizes a range of sensors to promptly respond to emergency conditions. The IBS includes an infrared wave emitter and receiver, enabling accurate detection of obstacle's distances. A microcontroller processes the received pulses and effectively engages the vehicle's brakes. This research highlights the potential of the IBS as an advanced approach to enhance road safety through intelligent sensor technology and responsive braking systems.
- In their publication titled "Intelligent Mechatronic Braking System" which addresses the need for advanced safety systems in vehicles, particularly in urban environments. The authors highlight the prevalence of active safety

systems like ABS, Traction Control, and Stability Control, which rely on sensors to monitor vehicle conditions and respond in emergencies. They propose the integration of ultrasonic sensors into the safety system to control vehicle speed. By utilizing an ultrasonic receiver, the system detects reflective ultrasonic waves, determining the distance to obstacles. With the aid of a microcontroller, the speed of the vehicle is then regulated by applying brakes through the manipulation of the brake pedal. This intelligent mechatronic braking system aims to enhance safety by providing precise speed control and efficient braking, mitigating risks for a safer driving experience (G.V. Sairam et al., 2013).

- (Soniya. K. Melodee et al., 2016), in their published paper titled "Investigation of Regenerative Braking in Electric Vehicles" emphasize the significance of regenerative braking in expanding the driving capabilities of electric vehicles. Regenerative braking plays a crucial role in preserving the vehicle's power and enhancing energy efficiency. Electric vehicles utilize a Regenerative Braking System to enhance the effectiveness of wheel roughness during deceleration. However, from an energy-saving perspective, conventional mechanical brakes dissipate a significant amount of energy as the kinetic energy of the electric vehicle is converted into thermal energy. The traditional hydraulic braking system employed in vehicles leads to substantial energy wastage due to the generation of unwanted heat during braking. The advent of regenerative braking has overcome these drawbacks and offers energy-saving benefits and improved efficiency for vehicles. The focus of this research lies in investigating the impact of brake energy regeneration and its usability. It is important to address the energy crisis that the world is currently facing.
- In their published paper titled "Regenerative Braking Systems (RBS) (FUTURE OF BRAKING SYSTEMS)", (P. Gupta et al., 2014), discuss and present two innovative methods for utilizing the kinetic energy that is typically wasted during braking. The authors propose using a flywheel to convert kinetic energy into mechanical energy and an electric motor to transform it into electrical energy. By integrating these approaches, the flywheel captures and stores the kinetic energy during deceleration, enabling its use during acceleration to assist the vehicle and improve overall energy efficiency.

Simultaneously, the electric motor acts as a generator, converting the kinetic energy into electrical energy, which can be stored or fed back into the vehicle's electrical system. These advancements in regenerative braking systems offer promising prospects for reducing energy consumption and enhancing sustainability in the automotive industry.

- In their published paper titled "Design and Fabrication of Intelligent Mechatronic Braking System", (M. Rajyalakshmi, et al., 2018), propose the use of ultrasonic sensors in a safety system to control the speed of a vehicle. The system utilizes a microcontroller to monitor the detection pulse information and apply the brakes to the vehicle if necessary to ensure safety. The proposed system aims to provide an intelligent mechatronic braking system that enhances the safety of the driver and passengers by avoiding collisions. The use of ultrasonic sensors ensures accurate and reliable detection of obstacles, and the microcontroller provides precise control over the braking system. The paper presents a detailed design and fabrication process for the proposed system and highlights its potential for future research and development in the field of automotive safety systems.
- In their published paper titled "Regenerative Braking System of BLDC Motor with Automatic Braking and Brake Fail Detection For Electric Vehicle", (Mr. Laxmikant et al., 2020), address the pressing need for energy conservation in electric vehicles. They emphasize the importance of reducing energy losses and present an innovative approach that combines regenerative braking, automatic braking, and brake fail detection systems. Their proposed system utilizes sensors to detect obstacles, enabling efficient automatic braking and enhancing safety. Additionally, the inclusion of a brake fail detection system provides real-time feedback and alerts to mitigate potential failures. Through their comprehensive research, the authors highlight the potential for enhanced energy efficiency, safety, and overall performance in electric vehicles, contributing to a sustainable and greener transportation future.
- In their published paper titled "Development of Automated Braking System for Collision Avoidance of Vehicles", (Jeyanthi S. et al., 2018), present a comprehensive study on the creation of an innovative automated braking system. Their objective is to address the issue of driver inattentiveness, which

often leads to frontal collisions. The authors propose an algorithm specifically designed for the automated braking system, enabling it to detect potential collision scenarios and initiate the appropriate braking action. Through rigorous experiments, the ultrasonic sensor used for distance measurement is validated, demonstrating an impressive accuracy with a minimal error rate of 3.31%.

- In their paper titled "Design and Fabrication of Regenerative Braking System", (Ajith S. et al., 2018), highlight the significance of regenerative braking systems in vehicles. This system effectively saves energy that would have been lost otherwise during braking, offering superior efficiency compared to conventional braking systems. It exhibits the ability to operate at high temperature ranges and presents an opportunity for further research to develop even more efficient systems capable of capturing additional energy and providing faster stopping capabilities. The implementation of such systems in all vehicles has the potential to yield substantial economic savings by harnessing the energy that would have otherwise been wasted during the braking process.
- (K. Warake et al., 2018), in their research paper titled "Design & Development of Regenerative Braking System at Rear Axle", presents a regenerative braking system that addresses the issue of energy loss during vehicle braking. The system effectively recovers a portion of the energy that would otherwise be dissipated as heat through friction brakes. By converting this energy into useful electrical charge, the regenerative braking system preserves battery charge that would otherwise go to waste. It is important to note that this system cannot serve as the primary braking mechanism for the vehicle, but rather complements the existing braking system. Experimental results demonstrate that the regenerative braking system can recover at least 11% of the battery energy, which would otherwise be lost as heat in the friction brakes. Implementation of this system in actual vehicles can increase the distance traveled between two consecutive charging requirements by approximately 10 to 15%.
- (S. K. Sheladia et al., 2018), in their paper titled "A Review on Regenerative Braking Methodology in Electric Vehicle", emphasize the potential energy

savings of up to 25% to 28% achieved through regenerative braking. To enhance these systems, advanced power electronic components such as ultra-capacitors, DC-DC converters (Buck-Boost), and flywheels are employed. Ultra-capacitors improve transient performance during startup, optimize battery charging, and enhance overall system efficiency. Buck-boost converters play a vital role in power management, particularly in boosting acceleration. Additionally, flywheels are utilized to enhance power recovery through the vehicle's wheels. By incorporating the recommendations and conclusions of previous research, the study aims to improve the practicality and efficiency of regenerative braking systems.

- (C. J. Vikram et al., 2018), in their paper titled "Fabrication of Regenerative Braking System" meticulously implemented the regenerative braking system according to prescribed measures, focusing on its significance in the automotive transportation industry. The study emphasized the need for future enhancements to be tailored to the specific requirements identified during the research. By effectively recovering and utilizing energy that would otherwise be wasted during braking, the regenerative braking system not only enhances braking performance but also contributes to overall efficiency and reduced environmental impact. The comprehensive fabrication process carried out in the study ensures the accuracy and reliability of the results, highlighting the importance of implementing regenerative braking for optimized performance in braking.
- In their research paper titled "Performance Improvement of Regenerative Braking System", (T. L. Patil et al., 2018), explores techniques to enhance the efficiency of regenerative braking systems. The study emphasizes the significance of reducing the weight of the automobile to improve performance, as lighter vehicles require less energy for acceleration and deceleration. Additionally, the incorporation of supercapacitors is proposed as a means to improve energy conversion rates within the regenerative braking system, leading to more efficient energy recovery. The paper also highlights the importance of compact vehicle design, which reduces the energy required for braking and improves overall system efficiency. By combining these techniques, such as weight reduction, supercapacitor integration, and compact

design, the efficiency of regenerative braking systems can be significantly improved, contributing to more sustainable and energy-efficient transportation solutions.

- (Khushboo Rahim and Mohd. Tanveer, 2018), present a comprehensive review paper titled "Regenerative Braking System: Review Paper", where they highlight the advantages of regenerative braking systems compared to conventional braking systems. The paper emphasizes that regenerative braking systems excel in high-temperature environments and exhibit superior efficiency when compared to traditional brakes. Furthermore, these systems prove to be more effective in situations involving higher momentum. Vehicles that frequently stop can benefit significantly from regenerative braking systems, as they allow for efficient energy conservation. Additionally, the authors note that large and heavy vehicles traveling at high speeds accumulate substantial kinetic energy, making regenerative braking an even more efficient means of energy conservation. The paper concludes by acknowledging the broad potential for further advancements in regenerative braking technology and the substantial scope for energy conservation in the future.
- In their paper titled "Design, Fabrication and Testing of Regenerative Braking Test Rig for BLDC Motor", (Sayed Nashit et al., 2016), present a test bench designed and fabricated to evaluate the regenerative braking capability of a Brushless DC Motor. The project aims to raise awareness among engineers about energy efficiency and conservation. The study concludes that while regenerative braking systems are more efficient at higher speeds, they cannot serve as the sole braking mechanism in a vehicle. However, the integration of regenerative braking systems in future automobiles holds promise for a sustainable and energy-efficient world, as it enables the recovery of power lost during braking. By converting this energy into usable form, regenerative braking systems contribute to reducing energy wastage. The findings emphasize the importance of developing and implementing efficient regenerative braking systems to enhance overall vehicle energy efficiency, thereby fostering a brighter and sustainable future in the automotive industry.
- In their groundbreaking and meticulously conducted study titled "Automatic Braking System Using Ultrasonic Sensor," (J.V. Sai Ram et al., 2017) provide

a comprehensive analysis of the integration of various sensors, particularly ultrasonic sensors, in the braking system. Their research aims to address the high fatality rate associated with road accidents by advancing automotive safety measures. By utilizing ultrasonic sensors, the automatic braking system is capable of detecting obstacles and making real-time decisions to apply the brakes when necessary. This transformative technology, known as the Automatic Braking System (ABS), offers a glimpse into the future of automotive safety and holds the potential to prevent accidents and save lives. The author's research provides valuable insights and contributes to the ongoing advancements in accident prevention technologies, emphasizing the critical role of sensor integration in enhancing both the performance and overall safety of vehicles.

- The paper titled "Automatic Braking System for Automobiles Using IR Sensor" (Hemalatha B. K. et al., 2016), addresses the growing demand for collision avoidance systems in automotive vehicles. The objective of the study is to design an intelligent and electronically controlled braking system, referred to as the "INTELLIGENT BRAKING SYSTEM," utilizing an IR sensor for obstacle detection. The system incorporates an IR transmitter and receiver circuit, a microcontroller, a motor, and a solenoid. When an obstacle is detected by the IR sensor, it sends a control signal to the microcontroller, which then instructs the motor and solenoid to stop the vehicle as programmed. The inclusion of an electromagnetic braking system further enhances the system functionality. This research contributes to automotive safety by presenting a practical approach to automatic braking using IR sensor technology, providing valuable insights for the development of collision avoidance systems in vehicles.
- (Mr. S. N. Sidek and Mr. J. E. Salami), conducted a study titled "Hardware Implementation of Intelligent Braking System" where they explored the efficiency of the TMS320LF2407 processor in controlling the intelligent braking system. The research concludes that the TMS320LF2407 processor is highly capable of handling the required tasks, with its onboard peripherals reducing the need for additional components. The architecture of the processor facilitates real-time control, ensuring optimal performance. To further enhance

the processor's capabilities, the inclusion of a special fuzzy logic instruction set within the software kernel is recommended. This would augment the processor's ability to handle complex control algorithms efficiently.

- (Pranav R. Khot et al., 2021), conducted a study titled "Design and Development of Regenerative Braking System" sheds light on the significance of this innovative approach. Unlike conventional braking systems that dissipate kinetic energy as heat through friction, regenerative braking converts a significant portion of this energy into electrical energy, which can be stored for future use. The paper emphasizes the need for alternative energy conversion methods, highlighting the capability of regenerative braking to play a vital role in energy conservation. The proposed design and development of a working model further illustrates the energy conversion process, showcasing the transformation from one form to another. With further research and advancements, regenerative braking has the potential to revolutionize the automotive industry, contributing to energy sustainability and reducing reliance on non-renewable sources.
- The development of intelligent braking systems using ultrasonic sensors has gained attention in recent research. In the paper "Intelligent Braking System Using Ultrasonic Sensor", (Manju Kumari et al., 2019), a mechatronic braking system is proposed to address the pressing issue of road accidents. The system is designed to automatically apply brakes when objects are detected by ultrasonic sensors, aiming to reduce accidents caused by poor infrastructure, lack of road protocols, and delayed driver reactions. By constantly monitoring the vehicle's conditions using a range of sensors, the system ensures prompt responses in emergency situations. The integration of an embedded system design facilitates seamless implementation, enabling real-time monitoring and efficient braking. This approach holds great potential for enhancing road safety, preventing accidents, and reducing human-related driving risks. Continued research and development in this field can lead to advancements in intelligent braking systems, contributing to safer and more secure driving experiences.
- (Balaji B et al., 2017), research titled "Design and Analysis of Regenerative Braking System and Automatic Braking Using Ultrasonic Sensor" explores the generation of electrical energy from a vehicle's braking system. The study

highlights the concept of regenerative braking, which converts the kinetic energy of the vehicle into usable energy instead of dissipating it as heat, as in conventional braking systems. Various methods of energy storage, such as electric motors, batteries, capacitors, and rotating flywheels, are discussed. The researchers emphasize the use of a rotating flywheel coupled with a permanent magnet DC generator to store electrical energy. Additionally, the study incorporates an automatic braking system utilizing an ultrasonic sensor for obstacle detection. This integration aims to enhance energy efficiency and improve vehicle safety.

- The paper titled "Design and Fabrication of Regenerative Braking System" (Milan Lamichhane et al., 2021) explores the concept of regenerative braking as an energy recovery mechanism for vehicles. In today's world, where energy crisis and resource depletion are significant concerns, the need for technologies that can recover wasted energy becomes crucial. The regenerative braking system discussed in the paper aims to convert the kinetic energy of a vehicle during braking into a usable form, such as electrical energy, thereby reducing energy waste. The converted kinetic energy can be stored for future use or fed back into the vehicle's power system, and the paper examines two methods of energy storage: using batteries or capacitors and employing a rotating flywheel. By transmitting the flywheel force as a torque opposing the forward rotation of a wheel upon braking, this innovative approach presents an energy-storing regenerative braking system. This research provides valuable insights into the design and fabrication of such systems, emphasizing the importance of energy recovery and paving the way for further advancements in this field.
- In the paper "Automatic Braking System", (Aakash Parmar's, 2022), the braking system in automobiles has undergone constant evolution as companies strive to enhance vehicle safety. Aakash Parmar's research focuses on an electronically controlled automatic braking system specifically designed for Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV). This system integrates regenerative braking, automatic control of braking forces for front and rear wheels, and wheel antilock function. By working together with sensors and an Electronic Control Unit (ECU), the system can autonomously engage the braking system in emergency situations when the driver is unable to apply

the brakes. This approach not only ensures prompt and effective response to unforeseen conditions but also facilitates the recovery and utilization of kinetic energy, contributing to improved energy efficiency. Parmar's research adds to the ongoing efforts in advancing vehicle safety and highlights the potential of such automatic braking systems in enhancing overall performance and sustainability.

- In recent studies, researchers have explored the development of advanced braking systems to address the increasing risks associated with road accidents. One such system is the automatic braking system utilizing ultrasonic sensors, which has shown promising results. (Naveen Navudu et al., 2021), proposed an effective mechatronic solution in their study. The system consists of key components such as an ultrasonic transducer, receiver, Arduino UNOR3 board with a PIC microcontroller, DC gear motor, servomotor, and mechanical braking arrangement. By emitting and receiving ultrasonic waves, the system detects obstacles and enables the microcontroller to control the vehicle's speed accordingly. This approach proves especially vital in preventing accidents caused by factors like brake failure, drunk driving, and delayed brake application. The integration of intelligent control mechanisms and the utilization of ultrasonic technology offer a promising path towards reducing the fatality rate caused by road accidents. Further research and development are necessary to refine the system's performance and ensure its widespread implementation in the automotive industry.
- (Kedar Bhanewad et al., 2021), hybrid electric vehicle technology has gained prominence in the automotive industry as a means to reduce environmental impact and fuel consumption. One key component of these vehicles is regenerative braking, which converts kinetic energy into electrical energy. However, the high cost of hybrid electric systems has limited their widespread adoption. To address this, researchers propose a cost-effective design for an electro-hydraulic braking system. This system enables independent control of the boost force generated by the brake booster, separate from the driver's braking force, ensuring a suitable time response and seamless blending of mechanical and regenerative braking torques. By optimizing the utilization of regenerative braking, the system efficiently harnesses the vehicle's kinetic

energy during deceleration. Their work highlights the need for improved braking efficiency and control mechanisms to enhance the performance and sustainability of hybrid electric vehicles, making them more accessible to consumers.

- (Siva Rama Krishna Movva et al., 2021), in recent research papers, various intelligent braking systems have been proposed to address the growing concern of high-speed catastrophes caused by advanced internal combustion engines. One such study focuses on the design of a low-speed intelligent Brake Assist system for vehicles. This system utilizes components such as an ultrasonic transmitter, ultrasonic receiver, Arduino UNO R3 board with PIC microcontroller, DC gear motor, servomotor, and a mechanical braking arrangement. By generating and analyzing ultrasonic waves, the system detects obstacles or potential collisions in front of the vehicle, triggering automatic braking actions. The integration of microcontroller-based control allows for precise modulation of the DC gear motor and servomotor, enabling efficient and reliable braking. This research contributes to enhancing vehicle safety by providing valuable insights into the design and implementation of a low-speed intelligent Brake Assist system, highlighting the potential for preventing accidents and mitigating risks associated with high-speed driving.

CHAPTER 3

METHODOLOGY

3.1 FABRICATION

Fabrication refers to the process of manufacturing or constructing a physical product or component. In the context of our research, fabrication involves the assembly and production of the necessary components and subsystems to create a functional braking system.

3.1.1 Fabrication Considerations

Regardless of the specific method of regeneration employed, regenerative braking systems necessitate certain fundamental requirements. These requirements are crucial for the successful implementation of regenerative braking. The key requirements include:

- Sufficient Momentum in the Vehicle
- Energy Storage System
- Controller

Regenerative energy can only be produced when the vehicle is in motion. Sufficient momentum in the axle is necessary to enable the system to capture and utilize this energy effectively. The electricity generated through regenerative braking should be either utilized immediately or stored in a battery for future use. This ensures efficient energy management and provides flexibility in utilizing the captured energy when needed.

A controller is essential to manage the process of regeneration. It controls when to turn the regeneration process on or off based on specific requirements and availability of the system. This enables optimal energy capture and management.

A provision for frictional braking should be available to stop the vehicle when regenerative braking alone is insufficient or during emergency situations. The presence of a frictional braking system ensures safety and provides a backup in case the regenerative braking system fails.

A regenerative braking system on its own may not meet the fundamental requirements of a braking system. This is primarily because it faces limitations in dissipating energy at very high power levels. The storage and generation systems may not be capable of operating effectively at such levels due to design constraints. Moreover, the critical safety considerations associated with the braking system raise concerns about the reliability of regenerative braking alone. Therefore, the coexistence of a frictional braking system alongside the electric regenerative braking system is necessary, forming a hybrid braking system.

3.1.2 Materials Employed in the Fabrication Process

Table 3.1: Materials Employed

Sr. No.	**Name of Components Used**	**Description**	**Quantity**
1.	Square Bar	(23*23) mm Hollow Bar	1 unit
2.	D.C. Motors/ Alternators	300 RPM	7 unit
3.	Arduino Uno	UNO R3	1 unit
4.	Ultrasonic Sensor	HC-SR04	1 unit
5.	Battery	12 V, 2.5 A	1 unit
6.	Relay Module	5 V	1 unit
7.	Motor Driver	5-35 V, 2A	1 unit
8.	Speed Controller	B100K	1 unit
9.	LEDs	Shows energy generation	2 unit
10.	Electric wires	Copper wire	6 m
11.	Brake Wheel	Outer Dia 10 cm	2 unit
12.	Wheel	Outer Dia 9.5 cm	4 unit

3.1.2.1 Square Bar

The fabrication process involved the use of specific elements to construct a sturdy frame. A solid bar, composed of mild steel, was selected as the primary material for the frame. The solid bar was carefully welded together to form a robust and reliable square frame structure. This method ensured the frame's durability and provided the necessary strength to support the intended load or application.

Fig 3.1: Frame/ Square Bar

The Mild Steel possesses the properties which has been shown in the following table-

Table 3.2: Properties of Mild Steel

Name of Material	**Young's Modulus (Gpa)**	**Density (kg/m^3)**	**Poisson's Ratio**
Mild Steel	210	7800	0.3

3.1.2.2 Alternators

The alternator, a vital component of the regenerative braking system, serves the purpose of converting mechanical energy into electrical energy. Specifically, during the braking process, the alternator captures the energy generated and transforms it into electrical energy. This electrical energy is subsequently stored in the vehicle's battery for future utilization. The alternator's significant role in the system lies in enhancing the overall energy efficiency of the vehicle, ensuring that the energy generated during braking is effectively harnessed and repurposed rather than being wasted. By enabling the conversion and storage of this energy, the alternator contributes to the optimization of the regenerative braking system's performance and the conservation of valuable resources.

3.1.2.3 D.C. Motors

D.C. motors play a fundamental role in the conversion of electrical energy into mechanical energy. In the context of a regenerative and automatic braking system, these motors find application in powering the vehicle's wheels, supplying the necessary mechanical power for vehicle movement. Additionally, D.C. motors can be employed in the alternator to generate electrical energy during the braking process, enabling the recovery and storage of energy that would otherwise be lost as heat. This dual functionality of D.C. motors facilitates energy conservation and enhances the overall efficiency of the braking system.

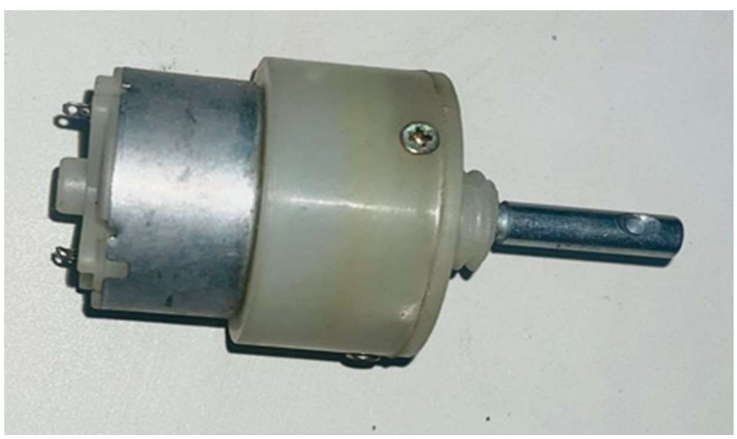

Fig. 3.2: D.C. Motors / Alternators

3.1.2.4 Arduino Uno

The Arduino Uno serves as the central microcontroller board, functioning as the system's core processing unit. It assumes the role of the system's 'brain' by executing programmed instructions. Specifically, it receives signals from various components such as the ultrasonic sensor and motor driver, enabling it to regulate the motor's operation and control the relay module. Moreover, the Arduino Uno's capabilities extend to the implementation of a fuzzy logic controller for the intelligent regenerative braking system. Through programming, it can apply fuzzy logic algorithms to optimize the braking process based on real-time data and make intelligent decisions. Thus, the Arduino Uno plays a pivotal role in coordinating and controlling the various components of the system, ensuring efficient and intelligent operation.

Fig 3.3: Arduino Uno

3.1.2.5 Ultrasonic Sensor

The ultrasonic sensor serves as a vital component within the system, functioning by emitting high-frequency sound waves and measuring the time it takes for the waves to return after reflecting off objects in the vehicle's vicinity. This sensor is specifically utilized to determine the proximity between the vehicle and potential obstacles along its path. By providing precise distance measurements, the ultrasonic sensor supplies essential input to the Arduino Uno microcontroller.

The Arduino Uno, upon receiving data from the ultrasonic sensor, utilizes this information to dynamically adjust the regenerative braking force. This adaptive control allows the system to optimize the energy efficiency of the vehicle. By analyzing the proximity readings, the Arduino Uno can make informed decisions on the appropriate level of regenerative braking required based on the detected obstacles or surroundings. This enables the vehicle to maximize energy recovery during braking while ensuring safe and efficient operation.

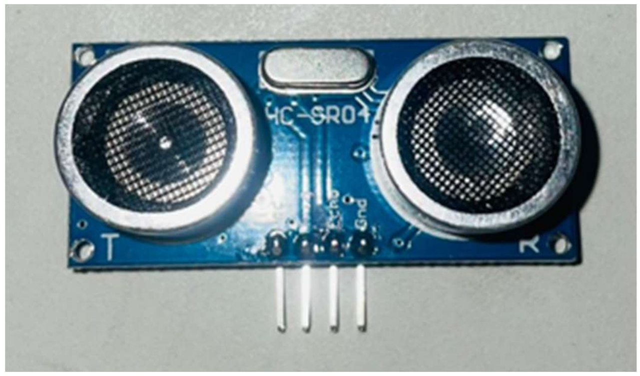

Fig 3.4: Ultrasonic Sensor

3.1.2.6 Battery

The battery holds a critical role in the system, as it serves as the primary source of electrical energy to power the various components. In the context of small electric vehicles and the regenerative braking system, a commonly used choice is a 12V, 2.5 ampere battery. This specific battery specification is selected due to its ability to supply sufficient power to ensure the effective operation of the system. By providing the necessary electrical energy, the battery enables the functioning of components such as the motor, microcontroller board, sensors, and other electrical systems within the vehicle. Thus, the battery's capacity and voltage rating are carefully considered to ensure optimal performance and reliable power supply throughout the vehicle's operation.

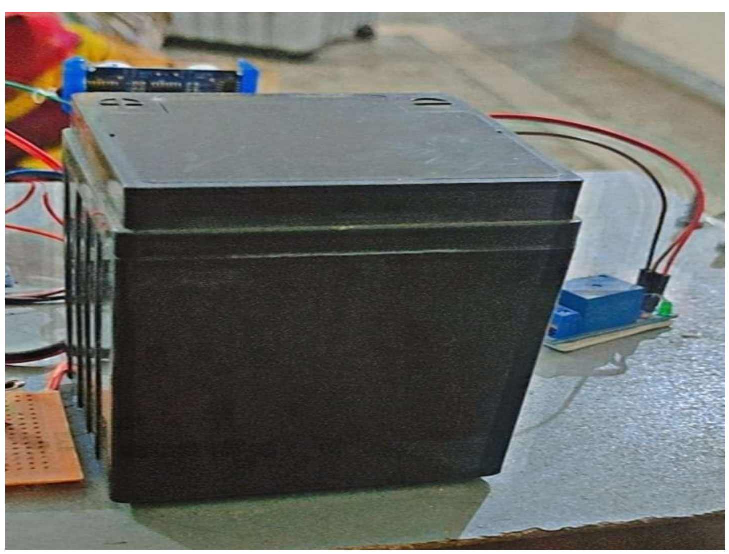

Fig. 3.5: Battery

3.1.2.7 Relay Module

The relay module plays a crucial role in the automatic braking system, acting as a device that enables the switching of high-voltage or high-current circuits using a low-voltage signal. Specifically, the relay module is employed to control the power flow to the motor and activate the brakes when the ultrasonic sensor detects an obstacle in the vehicle's path.

Upon receiving a signal from the Arduino Uno, the relay module functions as an intermediary to activate the braking system. It effectively controls the circuit that supplies power to the motor, enabling the initiation of the braking mechanism. This activation signal is triggered by the ultrasonic sensor's detection of an obstacle, ensuring that the vehicle responds promptly to potentially hazardous situations.

The utilization of the relay module in the automatic braking system enhances safety and precision by facilitating the reliable and controlled actuation of the brakes. By effectively switching high-voltage or high-current circuits based on the low-voltage signal from the Arduino Uno, the relay module ensures the timely and accurate engagement of the braking system when needed.

Fig 3.6: Relay Module

3.1.2.8 Motor Driver

The motor driver is a critical circuit within the system, responsible for controlling the speed and direction of the motor. It acts as an intermediary between the Arduino Uno and the motor, receiving signals from the microcontroller and regulating the power supplied to the motor accordingly.

By receiving instructions from the Arduino Uno, the motor driver adjusts the voltage, current, and other parameters to control the motor's speed and direction of rotation. This precise control allows for efficient and reliable operation of the motor within the system.

The motor driver's role is vital as it enables the system to achieve the desired performance characteristics, ensuring optimal motor functionality and responsiveness. Without the motor driver, the motor may not receive the appropriate power supply or lack the necessary control signals to operate effectively.

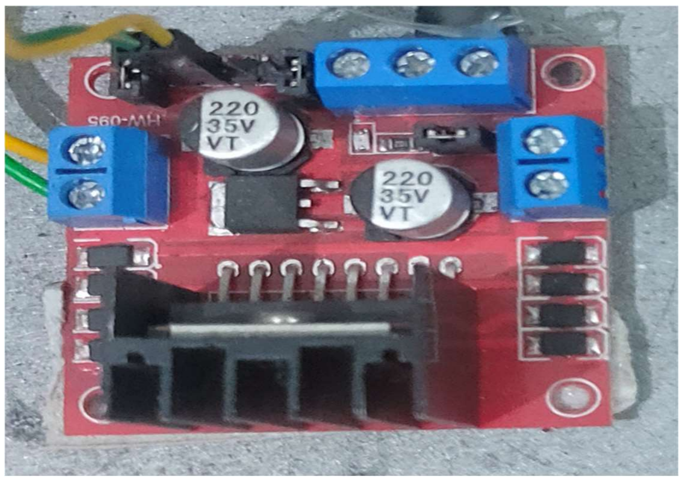

Fig. 3.7: Motor Driver

3.1.2.9 Speed Controller

In the fabrication of a regenerative and automatic braking system using ultrasonic sensors, a speed regulator, or speed controller, is a critical component that is responsible for controlling and adjusting the speed of the motors used in the system. The speed regulator acts as an intermediary between the control system and the motors, receiving signals and instructions from the control system and adjusting the power supply to the motors accordingly.

One important aspect of the speed regulator is its ability to facilitate manual adjustment of motor speed. Incorporating a manual control mechanism, such as a knob or dial, allows for convenient and precise manual adjustment of the motor speed by hand rotation. This feature provides flexibility and control over the motor speed, enabling fine-tuning based on specific requirements or preferences.

The manual control mechanism is connected to the speed regulator circuitry, which adjusts the power supplied to the motors based on the rotation input. By rotating the control knob or dial, the user can increase or decrease the voltage or current supplied to the motors, directly influencing their rotational speed.

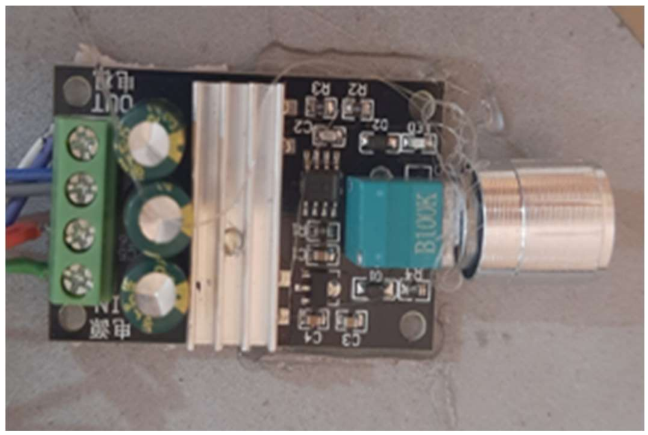

Fig 3.8: Speed Controller or Regulator

3.1.2.10 LEDs

Light Emitting Diodes (LEDs) are miniature electronic components that emit light when an electrical current passes through them. In the realm of regenerative and automatic braking systems, LEDs find utility as indicators to visually communicate the system's current status.

One potential application is the use of LEDs to indicate the activation of the regenerative braking system. When the system engages, an LED can be illuminated, providing a clear visual signal to the driver that regenerative braking is in operation.

Furthermore, LEDs can be employed to signify the detection of obstacles by the ultrasonic sensor. For instance, when the sensor detects an obstacle in the vehicle's path, an LED can be triggered to illuminate, alerting the driver to the potential hazard.

The incorporation of LEDs as indicators within the regenerative and automatic braking system enhances user awareness and provides real-time feedback on the system's functionality. By leveraging the unique lighting capabilities of LEDs, the system can effectively communicate critical information to the driver, fostering safer and more informed driving experiences.

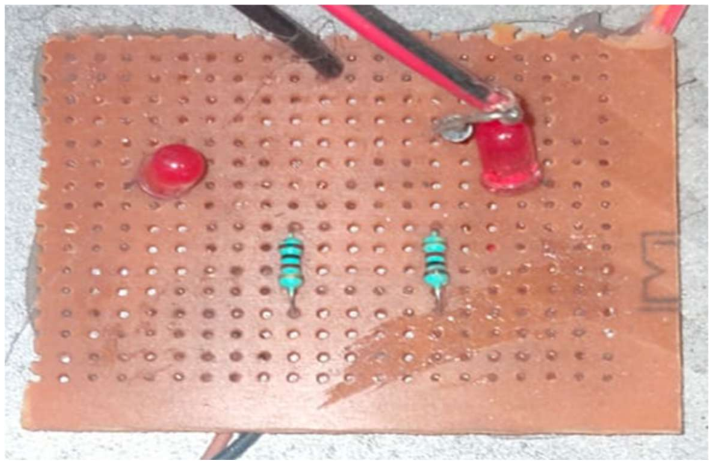

Fig. 3.9: LEDs

3.1.2.11 Electric Wires

Electric wires play a fundamental role in electrical systems as they serve to establish connections between various components. In the context of a regenerative and automatic braking system, electric wires are essential for linking key components such as the battery, Arduino Uno, motor driver, ultrasonic sensor, and relay module.

These wires facilitate the flow of electrical current between the different elements, enabling effective communication and power distribution within the system. It is crucial to utilize high-quality wires in order to ensure the reliable and safe operation of the system. High-quality wires possess good conductivity, durability, and insulation properties, minimizing the risk of electrical faults, overheating, or short circuits.

By employing appropriate wires in the regenerative and automatic braking system, the integrity and efficiency of electrical connections are maintained, ensuring the smooth functioning of the system as a whole. Reliable wire connections contribute to the system's overall reliability, enhancing safety and minimizing the likelihood of performance issues or component failures.

Fig. 3.10: Electric Wires

3.1.2.12 Brake Wheel

The brake wheel is a critical component within the vehicle's wheel assembly responsible for reducing or halting the vehicle's motion. In the context of a regenerative and automatic braking system, the brake wheel can synergistically collaborate with the regenerative braking system to achieve enhanced deceleration and energy recovery.

Fig. 3.11: Brake Wheel

When the driver initiates braking, the regenerative braking system engages to convert the vehicle's kinetic energy into electrical energy. Simultaneously, the brake wheel is activated to apply mechanical friction to the wheels, further slowing down the vehicle. This combined action of regenerative braking and traditional braking using the brake wheel allows for efficient deceleration while recovering energy.

3.1.2.13 Wheel

Wheels, being circular components that rotate on an axle, hold paramount importance in a vehicle's operation. In the context of a regenerative and automatic braking system, wheels serve as vital components as they facilitate the movement of the vehicle and collaborate with the braking system to decelerate it.

The primary function of the wheels is to provide traction and support the weight of the vehicle. They enable the transfer of power from the motor to the ground, propelling the vehicle forward. Moreover, the wheels can also play a role in the braking process. When the braking system is activated, the brake pads or other braking mechanisms apply pressure to the wheels, creating friction that hinders their rotation. This friction ultimately assists in slowing down or halting the vehicle.

Fig. 3.12: Traction Wheel

3.2 Equipment used in Fabrication

❖ **Drilling**

Drilling is an essential metal removal process employed to create or enlarge holes of circular cross-section in solid materials. It involves the utilization of a drill bit, which is a rotary cutting tool typically equipped with multiple cutting edges. During drilling, the drill bit is pressed against the workpiece and rotated at high speeds, ranging from hundreds to thousands of revolutions per minute.

The rotational motion of the drill bit exerts pressure against the workpiece, resulting in the removal of material in the form of chips. As the cutting edges of the drill bit engage with the workpiece, they penetrate and cut through the material, progressively forming the desired hole. The chips generated during the drilling process are expelled from the hole, allowing the drill bit to continue its penetration.

Drilling finds widespread applications across various industries, including manufacturing, construction, woodworking, and metalworking. It enables the creation of precise holes with controlled dimensions, facilitating the assembly of components or the insertion of fasteners.

By harnessing the principles of cutting and rotational motion, drilling provides a versatile and efficient method for hole production, contributing to the fabrication and assembly of numerous structures and products.

- **Metal Cutting**

Metal cutting is a fundamental process employed to remove excess metal from a workpiece, resulting in the formation of chips. In the context of obtaining a workpiece with the desired dimensions, one method used is utilizing a hacksaw blade.

A hacksaw blade is a hand tool consisting of a narrow, toothed blade made of hardened steel. The blade is mounted in a frame or handle, allowing it to be manually guided across the workpiece. By applying force and sawing back and forth, the hacksaw blade cuts through the metal, gradually removing material and forming the desired shape.

The teeth on the hacksaw blade have a specific pitch and configuration, allowing them to effectively engage with the metal and facilitate the cutting process. As the blade moves across the workpiece, the teeth bite into the metal, producing chips that are expelled from the cut area.

The use of a hacksaw blade provides a relatively simple and cost-effective method for cutting metal. It is commonly employed in situations where precision cutting is not required, or when the workpiece is not suitable for other cutting processes such as milling or turning.

❖ **Arc-Welding**

Arc welding is a welding process that involves the fusion of two metal pieces by creating an electric arc between them using an electrode. The electrode is guided along the joint between the workpieces, and it serves the purpose of carrying current or melting to provide filler metal to the joint.

The welding circuit typically consists of a power source, which can be either alternating current (AC) or direct current (DC), connected to the workpiece through a 'work' cable and to the electrode through a 'hot' cable. The power source supplies the necessary electrical energy for the welding process.

When the electrode is brought close to the workpiece, an electric arc is formed across the gap between the metal and the electrode. The intense heat generated by the arc melts the base metals, creating a molten pool. Simultaneously, the electrode itself may also melt to supply additional filler metal to the joint if needed.

The arc welding process relies on the formation of an ionized column of gas, often referred to as a plasma, to establish and maintain the electrical circuit between the workpiece and the electrode. This plasma column is created by the ionization of gases present in the surrounding environment.

Basic Welding Circuit

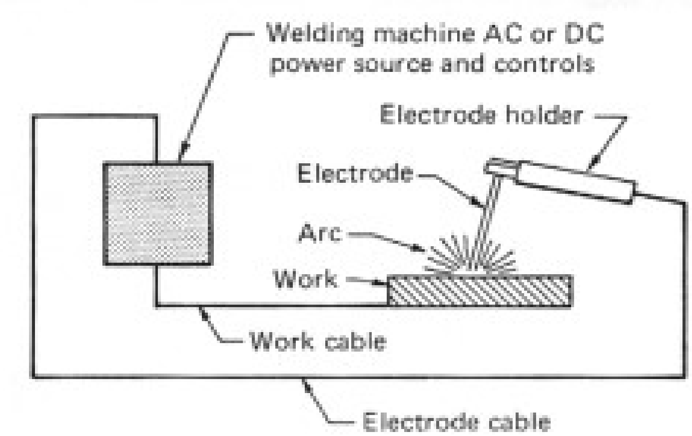

Fig 3.13: Basic Arc-Welding Circuit

The arc produces a temperature of about 3600°C at the tip and melts part of the metal being welded and part of the electrode. This produces a pool of molten metal that cools and solidifies behind the electrode as it is moved along the joint. There are two main types of electrodes used in arc welding:

- **Consumable electrodes**: These electrodes are designed to melt during the welding process. As they melt, molten metal droplets detach from the electrode and mix into the weld pool, contributing to the formation of the joint. Consumable electrodes often contain specific alloying elements that provide desirable properties to the weld, such as increased strength or corrosion resistance.
- **Non-consumable electrodes**: Unlike consumable electrodes, non-consumable electrodes do not melt during welding. Instead, they serve as a conductor of the electric current and may also be used to provide filler metal to the joint. In this case, a separate rod or wire containing the filler metal is used, and it is melted into the joint while the non-consumable electrode maintains the electrical arc.

The strength of the weld is reduced when metals at high temperatures react with oxygen and nitrogen in the air to form oxides and nitrides. Most arc welding processes minimize contact between the molten metal and the air with a shield of gas, vapor or slag. Granular flux, for example, adds deoxidizers that create a shield to protect the molten pool, thus improving the weld.

PROCEDURE

1. Begin by cutting the square bar into appropriate lengths and shapes according to the desired dimensions of the frame.
2. Weld the cut pieces of the square bar together to form a sturdy and square frame structure.
3. Use a drill to create holes in the square bar at designated locations for fastening the sheet and the L-shaped clamp.
4. Fit the sheet securely into the square bar frame to serve as a platform for assembling and organizing the various components.

5. Attach the 4 L-shaped clamps to the square frame, ensuring they are properly aligned and tightened. These clamps will hold the D.C. motors in place.
6. Install the wheels onto the D.C. motors, ensuring they are securely attached. The wheels will provide traction and support the weight of the vehicle.
7. Secure the 3 L-shaped clamp onto the frame to hold the motor responsible for generating energy during the braking process. Ensure proper alignment and tight fastening.
8. Attach the brake wheel to the motor, ensuring it is properly aligned and securely fastened. This will facilitate deceleration and collaborate with the regenerative braking system for energy recovery.
9. Apply a coat of silver paint to the entire assembly to provide protection against rust and enhance aesthetics.
10. Fit the battery, Arduino Uno, motor driver, relay module, drag-board, and ultrasonic sensor onto the sheet, ensuring they are properly positioned and secured.
11. Install the LEDs onto the sheet, ensuring they are properly aligned and securely fastened.
12. Connect all the components using copper wires to establish proper electrical connections between the battery, Arduino Uno, motor driver, relay module, drag-board, ultrasonic sensor, and LEDs.
13. Connect the output of the geared D.C. motor to the LEDs using copper wires to establish the desired electrical connection.
14. Program the Arduino Uno to automatically operate the braking system, ensuring it applies brakes and stops the movement of the prototype as required.
15. Test the system to ensure proper functioning and make any necessary adjustments or refinements as needed.

Practices Ensured for Safe Fabrication

- **Personal Protective Equipment (PPE)**: The use of appropriate PPE is essential to ensure the safety of the individuals involved in the fabrication process. This includes wearing an apron to protect clothing, using a face shield to protect the face and eyes during welding, and wearing welding gloves to protect the hands from heat and potential hazards.

- **Cooling and Lubrication**: Proper coolant is supplied during the drilling process to prevent overheating of the drill bit and workpiece. This helps in maintaining the integrity of the materials and prolonging the life of the drilling equipment.
- **Hand Protection**: Gloves are worn during the grinding process to protect the hands from potential injuries caused by the abrasive nature of the grinding wheel. This helps in reducing the risk of cuts, abrasions, and burns.
- **Careful Handling of Materials**: Handling the materials with care is important to prevent accidents, injuries, or damage to the components. Proper lifting techniques and suitable equipment should be used when moving heavy or bulky materials to avoid strain or dropping them.
- **Safety Awareness**: It is crucial to maintain a high level of safety awareness throughout the fabrication process. This includes being aware of potential hazards, following safety guidelines, and adhering to standard operating procedures. Regular safety briefings and training can help ensure that all individuals involved are well-informed about safety protocols.

Final Fabricated Model

The final fabricated model of our research has shown below-

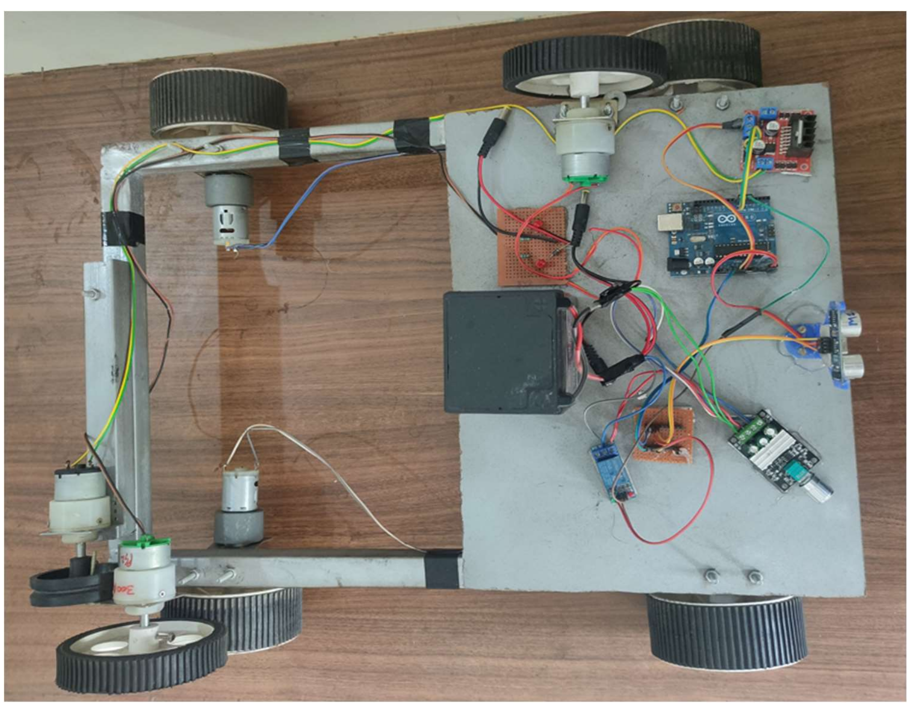

Fig. 3.14: Top view of Fabricated Model

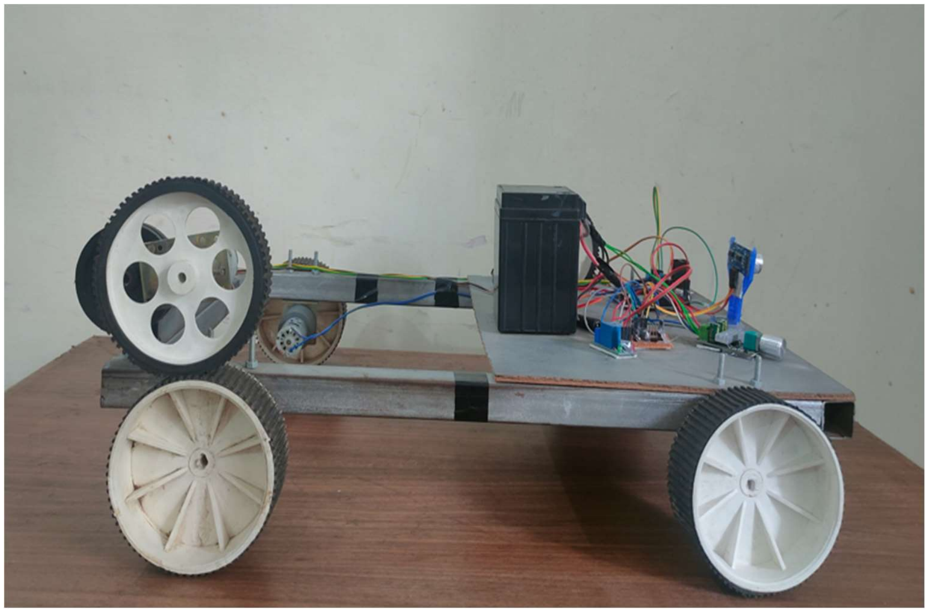

Fig. 3.15: Side view of Fabricated Model

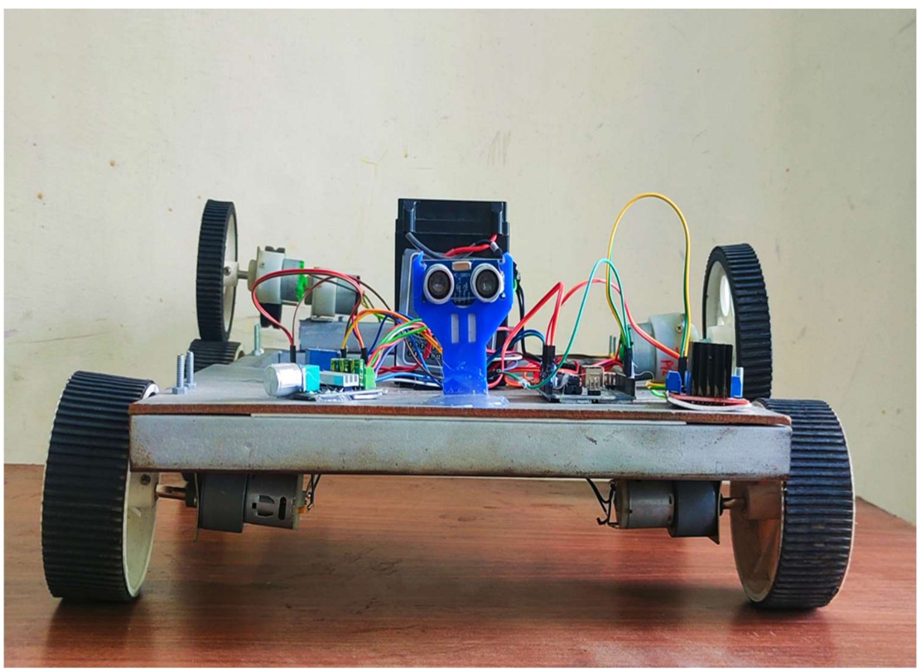

Fig. 3.16: Front view of Fabricated Model

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

The functioning of the regenerative and automatic braking system using an ultrasonic sensor involves the activation of the Arduino board when the power supply is turned on. Initially, the relay switch is in the OFF state, and the motor connected to the battery remains in the stationary position. As the motor is activated by the Arduino board, the vehicle starts moving forward. The ultrasonic sensor installed in the vehicle detects obstacles in its path from a distance of 200 cm. When an obstacle is detected between 150 and 60 cm, the sensor sends a signal to the motor driver, which slows down the vehicle. As the obstacle comes closer to the vehicle and is 60 cm away from it, the ultrasonic sensor sends a signal to the relay switch, which cuts off the power supply to the motor, and the vehicle comes to a complete stop.

Following successful testing, the model was operated under various loading conditions, and the resulting data was recorded and tabulated for analysis.

Table 4.1: Result Table

Sr. No.	RPM before brake pedal pressed	RPM after brake pedal pressed	Voltage output
1	50	40	1.78
2	100	93	1.96
3	125	114	2.22
4	150	136	2.48
5	200	176	2.86
6	250	231	3.29

The efficiency of the regenerative braking system using D.C. motors was found to increase as the angular velocity of the motor increased, as indicated by the results presented in the tables. This increase in efficiency can be attributed to the fact that higher motor speeds result in a greater amount of recoverable energy. Conversely, the system was less efficient at lower speeds, likely due to the inherent inefficiency of D.C. motors at low speeds. At higher speeds, the losses were primarily due to mechanical factors such as friction and air resistance, rather than electrical losses. These findings underscore the importance of careful consideration of motor speed in designing and optimizing regenerative braking systems. By focusing on achieving higher motor speeds, it may be possible to significantly improve the efficiency and effectiveness of these systems in recovering energy and reducing waste.

4.2 Discussion

When discussing the fabrication of a regenerative and automatic braking system using ultrasonic sensors, it is important to consider the advantages and challenges associated with this technology.

One of the advantages of using ultrasonic sensors in a regenerative braking system is that they can detect the distance between the vehicle and the obstacle in front of it, enabling the system to adjust the amount of regenerative braking force applied to the wheels. This can result in a smoother and more efficient braking experience, reducing the wear and tear on the vehicle's braking system and increasing its overall lifespan.

However, there are also some challenges associated with the fabrication of a regenerative and automatic braking system using ultrasonic sensors. One challenge is the complexity and cost of the system, which can be higher than traditional braking systems due to the addition of sensors, controllers, and other electronic components. This can make the system more difficult and expensive to manufacture and maintain.

Another challenge is the limited performance of the system in certain driving conditions, such as low light or adverse weather conditions, which can affect the accuracy of the ultrasonic sensors. In addition, the limited battery capacity of electric vehicles can also limit the range of application of the system.

Driver acceptance and behavior is also an important factor to consider when discussing the fabrication of a regenerative and automatic braking system using ultrasonic sensors. Drivers may need to adapt their driving behavior to maximize the benefits of the system, such as maintaining a safe distance from the vehicle in front of them to allow the system to detect and adjust the braking force accordingly.

Therefore, the fabrication of a regenerative and automatic braking system using ultrasonic sensors presents both advantages and challenges. While the technology offers the potential to improve the efficiency and performance of vehicles, careful consideration must be given to the complexity, cost, and limitations of the system, as well as the need for driver education and behavior modification.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, regenerative and automatic braking systems using ultrasonic sensors have the potential to significantly improve the efficiency and safety of the vehicle's braking system. The regenerative braking system can recover kinetic energy that is normally lost during braking and store it in the battery for later use, which can improve the overall energy efficiency of the vehicle and reduce fuel consumption or extend the range of electric vehicles. The automatic braking system can detect obstacles in front of the vehicle and apply the brakes automatically to avoid a collision, which can help prevent accidents and improve the safety of the vehicle.

Furthermore, these systems can provide a more comfortable and convenient driving experience for the driver, reducing the need for sudden and harsh braking maneuvers. The integration of these systems with other advanced safety features can provide a more comprehensive safety system for the vehicle.

However, it is important to note that these systems have some limitations, such as the need for proper maintenance and the dependence on the quality of the ultrasonic sensor. Further research and development can help optimize these systems for different driving conditions and enhance their overall performance, making them an important part of the future of automotive safety and sustainability. Overall, regenerative and automatic braking systems using ultrasonic sensors have the potential to provide significant benefits to the environment and drivers alike, contributing to a more sustainable and efficient transportation system.

5.2 Recommendations

Integration with existing braking systems: The regenerative and automatic braking system should be designed to integrate with existing braking systems, such as ABS, to ensure that the system is reliable and effective at all speeds.

Consideration of weight and space: Implementing the regenerative and automatic braking system may increase the weight and occupy additional space in the vehicle. These factors should be considered during the design phase of the vehicle.

Driver education and training: Integrating regenerative braking into a vehicle requires a change in driving style, which may take time for drivers to adjust to. Driver education and training programs should be developed to help drivers understand how to maximize energy recapture and extend the vehicle's range.

Eco-driving strategies: The usage of regenerative braking is closely linked to eco-driving strategies. Therefore, promoting eco-driving strategies among drivers could have considerable effects on traffic flow and promote wider adoption of the technology.

Compliance with safety regulations: The system should be designed and fabricated in compliance with relevant safety regulations to ensure that it is safe for use by drivers and passengers.

Overall, the recommendations focus on ensuring the integration and adoption of the regenerative and automatic braking system using ultrasonic sensors in a way that is safe, effective, and beneficial for both drivers and the environment.

REFERENCES

1. Bhandari.P., Deshbhratar R., Dubey S., & Kandu S. (2017). Regenerative braking systems (RBS). *International Journal of Scientific & Engineering Research*.
2. Deotale M. S., More R., & Shivankar H. (2016). Review on Intelligent Braking System. *International Journal on Recent and Innovation Trends in Computing and Communication.*
3. Hemanth C. S., Sai, K. K., Sairam G. V., & Suresh B. (2013). Intelligent mechatronic braking system. *International Journal of Emerging Technology and Advanced Engineering*.
4. Adware, R. H., & Malode, S. K. (2016). Regenerative braking system in electric vehicles. *International Research Journal of Engineering and Technology (IRJET)*.
5. Deb, S., Gupta, P., & Kumar, A. (2014). Regenerative Braking Systems (RBS) (Future of Braking Systems). *International Journal of Mechanical and Production Engineering*.
6. Khan, M. A., Kumar, B. K., Rajyalakshmi, M., Sai, B. S., & Vaibhav, A. K. (2018). Design and Fabrication of Intelligent Mechatronic Braking System. *International Journal of Science Technology & Engineering*.
7. Darshan, U. R., Laxmikant, S. P., Omkar, S. M., Waingankar S., & Wargaonkar, A. J. (2020). Regenerative Braking System of BLDC Motor With Automatic Braking And Brake Fail Detection For Electric Vehicle. *International Journal of Creative Research Thought (IJCRT)*.
8. Giridharan, A., Handi, V., & Jeyanthi, S. (2018). Development of automated braking system for collision avoidance of vehicles. *International Journal of Vehicle Structures & Systems*.
9. Ajith, S., Eswaran, A., Kavin, P., Karthikeyan, V., & Loganandh, S. (2018). Design and Fabrication of Regenerative Braking System. *International Journal of Advance Research and Innovative Ideas in Education*.
10. Bhahulikar, S. R., Satpute, N. V., & Warake, K. (2018). Design & Development of Regenerative Braking System at Rear Axle. *International Journal of Advanced Mechanical Engineering*.
11. Patel, K. K., Savalia, V. D., Savaliya, R. G., & Sheladia, S. K. (2018). A Review on Regenerative Braking Methodology in Electric Vehicle. *International Journal of Creative Research Thoughts*.

12. Chandra, P. N., Kumar, D. M., & Vikram, C.J. (2018). Fabrication of Regenerative Braking System. *International Journal of Pure and Applied Mathematics.*
13. Mandhare, A., Saggam, M., Singh, A. P., Patil, T., & Yadav, R. (2018). Performance Improvement of Regenerative braking system. *International Journal of Scientific & Engineering Research*.
14. Rahim, K., & Tanveer. M. (2018). Regenerative Braking System: Review Paper. *International Journal on Recent and Innovation Trends in Computing and Communication*.
15. Adhikari, S., Avinash, S., Farhan, S., Gambhire, A., & Nashit, S. (2016). Design, fabrication and testing of regenerative braking test rig for BLDC motor. *Int. Res. J. Eng. Technol*.
16. Jagadeep, B., Kumar, B. R., Manikanta, K. M. S. V., Pavanth, G., & Ram, J. (2017). Automatic braking system using ultrasonic sensor. *International Journal of Innovative Science and Research Technology*.
17. Chaithra, M., Hemalatha, B. K., Megha, S., Pooja, P., & Rakshitha, R. T. (2016). Automatic Braking System for Automobiles Using IR Sensor. *International Journal of Advanced Research in Electrical*.
18. Salami, M. J. E., & Sidek, S. N. (2018). Hardware Implementation of Intelligent Braking System. *First International Conference on Mechatronics- ICOM '01*.
19. Atyalkar, M. A., Desai, V. S., Gavali, G. S., Gujar, A. J., Khot, P. R., & Sonawane, S. V. (2021). Design and Development of Regenerative Braking System. *International Journal of Scientific Research & Engineering Trends.*
20. Kumari, M., Kumar, S., Kumar, A., & Kumari, N. (2020). Intelligent Braking System Using Ultrasonic Sensor. *International Journal of Science and Research (IJSR).*
21. Arman, N. R. V. S., Balaji, B., & Bharath Kumar, T. (2017). Design and analysis of regenerative braking system and automatic braking using ultrasonic sensor. *International Journal for Science and Advance Research in Technology.*
22. Bhetal, N., Lamichhane, M., & Yonjan, S. (2021). Design and fabrication of regenerative braking system. *International Journal of Engineering Research*.
23. Parmar, A. (2022). Automatic braking system. *International Journal of Progressive Research in Science and Engineering.*
24. Navagana, J. S., Navudu, N., Palli, S., Polaki, J., & Ramapatruni, A. (2021). Automatic Breaking System Using Ultrasonic Sensor. *IRE Journals*.
25. Bhanewad, K., Khandekar, S. B., Pandhurnekar, R., & Parshiwanikar, T. C. (2021). Design and development of regenerative braking system. *Journal of Xi'an University of Architecture & Technology*.

26. Karanam, Y. K., Kohir, P., Kola, A. K., Movva, S. R. K., & Vasamsetti, S. (2021). Design of Low-Speed Intelligent BrakeAssist System in Vehicle. *International Journal for Modern Trends in Science and Technology.*