

**GENERATION OF ELECTRICITY USING WASTE HEAT RECOVERY
FROM BRAKING SYSTEM**

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering Degree in

Mechanical Engineering.

by

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

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May - 2022



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of Kovarthanan S (Reg. No. 38150053) and Mohamed Hashim A R (Reg. No. 38150066) who carried out the project entitled **"GENERATION OF ELECTRICITY USING WASTE HEAT RECOVERY FROM BRAKING SYSTEM."** under our supervision from September 2021 to April 2022.


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DECLARATION

We, **Kovarthanan S and Mohamed Hashim A R**, hereby declare that the Project Report entitled “**GENERATION OF ELECTRICITY USING WASTE HEAT RECOVERY FROM BRAKING SYSTEM**”, done by me under the guidance of **Dr. S.PRAKASH** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, CHENNAI** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

1.



DATE:

PLACE:

2.



SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my sincere thanks to **Dr. S. Prakash, M.E., Ph.D.**, Dean, School of Mechanical Engineering and **Dr. G. Arun Kumar M.E., Ph.D.**, Head of the Department, Dept. of Mechanical Engineering for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. S.Prakash**, for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I also express my thanks to all Teaching and Non-teaching staff members of the Department of Mechanical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT :

In the modern world, there is high energy drain and the consumption of resources is rapidly increasing, so a special technology is required that recover energy that is generally wasted. In the case of automobiles, one of these useful technologies is the regenerative braking system. Regeneration of electricity while braking is an energy recovery mechanism where the Kinetic Energy released on slowing down a vehicle or an object is converted into a form of energy that can be used immediately or stored for later use. The use of the regenerative braking system in automobiles allow us to restore the Kinetic Energy of the vehicle to a certain extent, which is lost during braking. The converted Kinetic Energy is stored for future use or returned to the vehicle setup system. This energy is often stored in a battery or capacitor bank for later use. Energy can also be stored with the help of a rotating flywheel, which is one of the cheapest and most effective methods of storing and regenerating energy. The present invention provides an energy-storing regenerative braking system by transmitting flywheel force as torque that tends to resist the forward rotation of the wheel when the brakes are applied. A set of brake shoes mounted concentrically with the hub of a ground engaging wheel is actuated under braking to provide frictional engagement between the hub and the clutch mechanism while retarding torque is applied to the wheel. The dedicated brake mechanism is selectively held in position by a driver-controlled clutch mechanism to accumulate energy over various braking events. Vehicles powered by electric motors use the motor as a generator when regenerative braking is used and its output is supplied to an electric charge. The energy transferred to the load provides braking and regenerates power.

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CHAPTER-1

1.1.INTRODUCTION :

Electric automobiles are becoming increasingly popular as people realize that they are environment friendly vehicles that doesn't release any harmful gas that depletes the ozone layer. The car doesn't emit toxic gases that contaminate the environment.

In recent years, the number of electric vehicles on the road has begun to rise in response to market demand. Moreover, the government considers electric vehicle production more seriously. Vehicle technologies such as control technology and integrated technology advanced rapidly over the twentieth century. In any case, mileage restrictions continue to obstruct the development of electric vehicles. Regenerative braking is used to solve this issue.

This strategy can boost an electric vehicle's mileage by 8 to 25%. Most traditional car braking systems use a mechanical friction approach to always transform kinetic energy into thermal energy to provide a stopping effect, this technology has superseded those systems. According to studies, braking consumes 1/3 to 1/2 of the energy required to operate a car in metropolitan environments. Kinetic energy is surplus energy when an electric motor is in braking condition, the energy is dissipated as heat and the overall energy is lost. For hybrid and electric vehicles, this squandered energy can be turned into useful energy.

Regenerative braking has various advantages over regular braking systems, including:

- Increase in fuel economy.
- Extends the battery power by charging the battery, in motion.
- Prevents wear and tear of the mechanical brake.
- Increase in control of braking.

BLOCK DIAGRAM



When the driver presses the brake pedal, the electric motor reverses direction, slowing the vehicle. When the motor is running backwards, it serves as a generator, recharging the batteries, and when it is running forward, it draws energy from the battery. It greatly decreases dependency on fuel by employing regenerative braking, improving fuel efficiency and cutting pollution. These brakes are useful in a variety of driving circumstances, including stop-and-go situations, which are common in cities.

2

a downward motion, pushing the NC switch, which is connected to the motor, to bring the vehicle to a stop. During the motion of rack, the spur gear connected to the DC generator rotates, producing DC electricity from the generator, as indicated by the led. A permanent magnet DC generator is used in this application. This DC voltage is stored in the battery and utilized to power the vehicle's motor.

1.3.TYPES OF REGENERATIVE BRAKING SYSTEM:

Regenerative braking systems use a variety of energy conversion technologies, including springs, flywheels, electromagnetic, and hydraulics. A hybrid electromagnetic-flywheel Regenerative Braking System has also been developed recently. Each form of regenerative braking system employs a distinct method of energy conversion or storage, resulting in differing levels of efficiency and applications. The following are the various types:

- 1.3.1 Electromagnetic

- 1.3.2 Flywheel

- 1.3.3 Electromagnetic flywheel

- 1.3.4 Spring

- 1.3.5 Hydraulic

1.3.1. Electromagnetic

In an electromagnetic system, the vehicle's drive shaft is connected to an electric generator, which employs magnetic fields to slow the vehicle and generate electricity by restricting the drive shaft's rotation. The electricity generated by electric and hybrid vehicles is transmitted to the batteries, which are then recharged. Electricity can be utilized to operate the car's electronics or delivered to a battery for later usage to provide the vehicle a boost of power in gas-powered automobiles. Some of the Prototype racing cars at Le Mans are now using this technology.

1.3.2.Flywheel

The Flywheel Regenerative Braking System captures the vehicle's kinetic energy and uses it to spin a flywheel attached to the drive shaft via a transmission and gear box.

The driving shaft can then receive torque from the rotating flywheel, providing the vehicle a boost in power.

1.3.3.Electromagnetic Flywheel.

The Electro Flywheel Regenerative Braking System is a mix of electromagnetic and flywheel regenerative braking systems. It uses the same basic power generation principles as the electromagnetic system, but instead of batteries, the energy is stored in a flywheel. In this way, the flywheel functions as a mechanical battery, storing and recovering electrical energy. Electric flywheel Regenerative Braking System is the more cost-effective electricity storage solution due to the longer life of flywheel batteries compared to lithium-ion batteries.

1.3.4.Spring.

Human-powered vehicles, such as bicycles and wheelchairs, often use the spring-loaded regenerative braking mechanism. During braking, a coil or spring is wound around a cone to store energy in the form of elastic potential in the spring regenerative braking system. After then, the potential can be used to help the driver while driving uphill or through hard terrain.

1.3.5.Hydraulic.

The Hydraulic Regenerative Braking System reduces vehicle speed by generating electricity that is then utilized to compress a fluid. The working fluid of choice is frequently nitrogen gas. Because the compressed fluid does not dissipate energy over time, hydraulic regenerative braking systems offer the longest energy storage capacity of any device. Compressing gas with a pump, on the other hand, is a laborious procedure that drastically restricts the hydraulic Regenerative Braking System's power.

1.4.Application:

- Mechanism for regaining kinetic energy.
- Electric elevators and crane lifting motors both use regenerative braking techniques.

- Electric and hybrid cars, electric railway vehicles, electric bicycles, and other electric vehicles employ this technology.
- It could be utilized in an industry where a conveyor system transports materials from one workstation to another and stops at a predetermined distance after a set period of time.

1.5.Advantages:

- Improved performance.
- Reduces pollutants caused by supply generation.
- Efficient Fuel Economy–Depending on the machine cycles, vehicle design, automation control plan, and individual component efficiency, fuel consumption is minimized.
- Engines are subjected to less abrasion.
- Reduced Brake Wear– Lowering the cost of new brake linings, installation labour, and machine downtime.
- Engine decoupling minimizes the total number of rotations and hence engine emissions, reducing pollution related to power generation.
- Smaller accessories - lowering the size of the fuel tank and hence the vehicle's weight

1.6.Disadvantages:

- Engines are subjected to less abrasion.In practical, regenerative brakes take longer to slow a car than friction brakes, hence most vehicles that use them also have friction brakes. One of the reasons why regenerative brakes do not save 100% of braking energy is because of this.
- Components, engineering, and installation are all expensive.

- Regenerative brakes, in contrast to dynamic brakes, are required to match the power provided by the input source (both D.C. and A.C. supplies), which can only be accomplished through the advancement of power electronics.
- When the batteries that store the recovered energy are fully charged, regenerative braking safety is reduced. The battery's voltage would grow above a safe level as a result of the excessive charge.
- Added maintenance - Depending on the design's complexity.

◆ 1.7.D.C. GENERATOR:

A DC generator is an electro-mechanical energy conversion device that uses electromagnetic induction to transform mechanical energy into DC electrical power. A DC generator works on the electromagnetic induction principle, which states that when the magnetic flux connecting a conductor changes, an EMF is induced in the conductor. A DC generator has two windings: a field and an armature. The alternating EMF created in the armature winding of a DC generator is converted to direct voltage by a commutator positioned on the generator's shaft. The DC Generator's armature winding is on the rotor, while the field winding is on the stator.

1.7.1.Construction of a DC Generator:

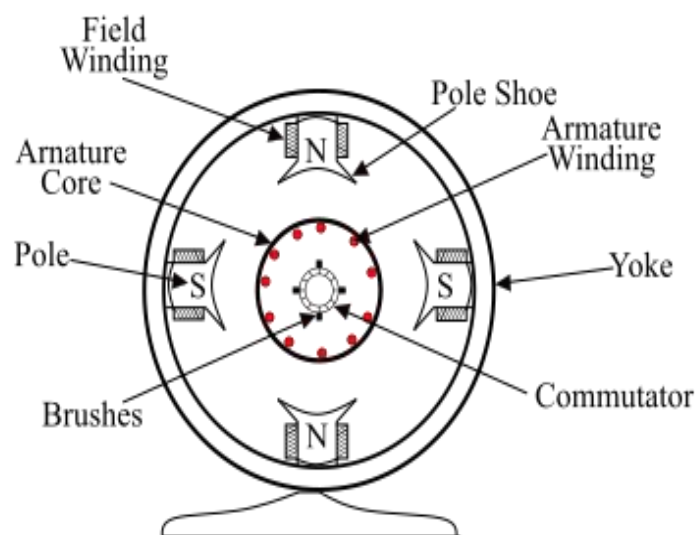


Fig 1.2: DC Generator

A DC generator consists of six main parts, which are as follows

Yoke

The yoke is a hollow cylinder made of cast steel or rolled steel that serves as the outside frame of a DC generator. The yoke is used for two purposes.

- It acts as a protective shell for the machine and supports the field pole core.
- The magnetic flux produced by the field winding has a path through it.

Magnetic Field System

A DC generator's magnetic field system is the machine's stationary component. It is responsible for the generator's principal magnetic flux. It's made up of an even number of pole cores bolted to the yoke and field winding wrapped around pole core. The field system of a DC generator includes prominent poles, which extend inwards and each pole core has a curved surface pole shoe. The pole shoe has two functions.

- The field coils are supported by it.
- By increasing the cross-sectional area of a magnetic circuit, it lowers its reluctance.

To prevent eddy current loss, the pole cores are built of thin sheet steel laminations that are isolated from one another. The field coils are linked in series such that when current passes through coils, alternate north and south poles are produced in the rotational direction.

Field or Exciting Coils

To generate a magnetic field, one or more field coils (windings) are put over each pole core. Enamelled copper wire is used to make a field or exciting coils. The coils are coiled on the former and then positioned around the pole core. The poles are magnetized when direct current flows through the field winding, which provides the flux. All of the poles' field coils are connected in series so that when current passes through them, the adjacent poles achieve opposite polarity.

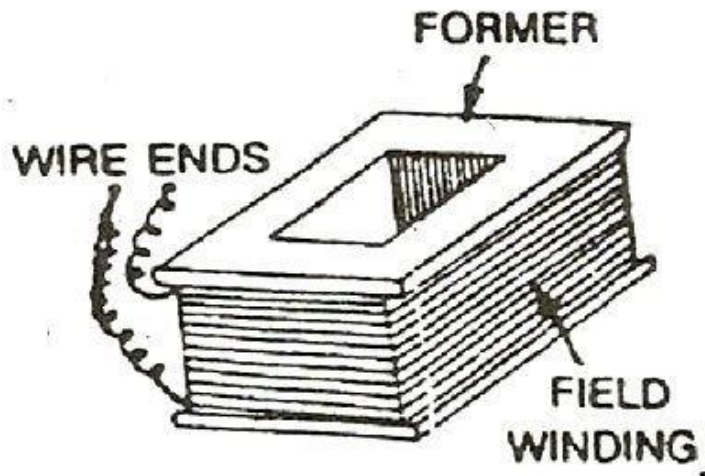


Fig 1.3: Field coils

Pole Core and Pole Shoes

Bolts secure the Pole Core and Pole Shoes to the magnetic frame or yoke. The poles are known as salient poles because they thrust inwards. The surface of each pole core is bent. Pole cores and shoes are typically comprised of thin cast steel or wrought iron laminations that are welded together under hydraulic pressure. To reduce Eddy Current loss, the poles are laminated.

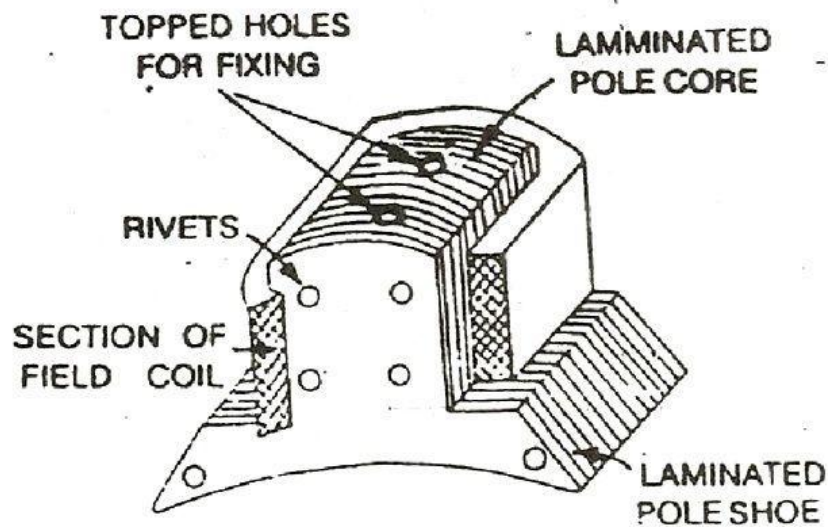


Fig 1.4: Pole shoes and Pole Core

The core of the poles is used for the following purposes:

- Supports the field or exciting coils.
- They more evenly distribute the magnetic flux along the armature's periphery.
- It reduces the resistance of the magnetic path by increasing the cross-sectional area of the magnetic circuit.

Armature Core

The armature core of DC generator is mounted on the shaft and rotates between the field poles. It has slots on its outer surface and the armature conductors are put in these slots.

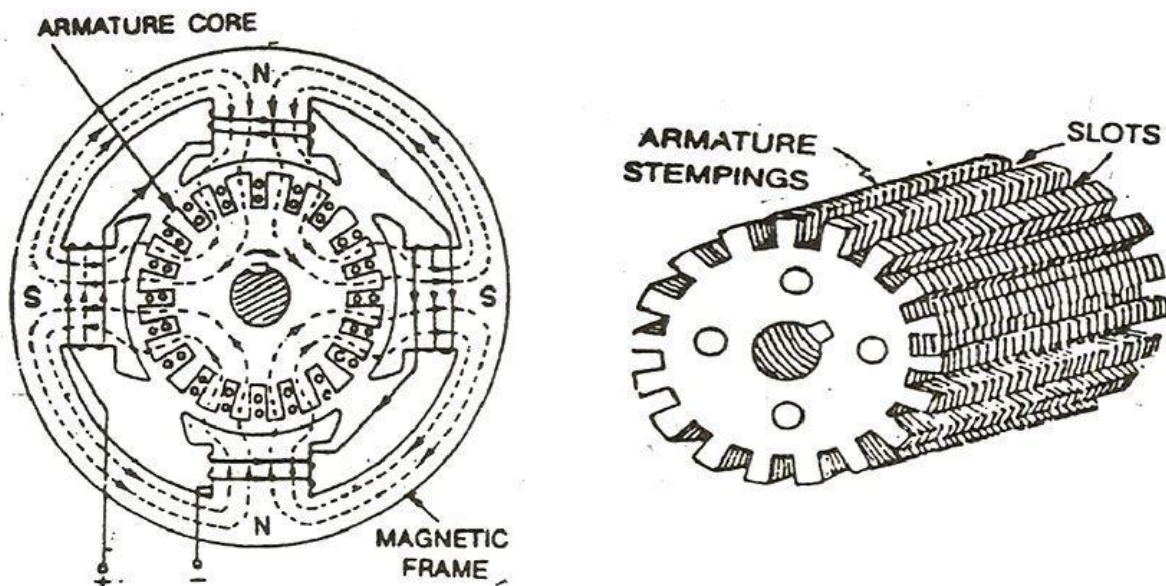


Fig 1.5: Armature core

The armature core is made up of soft iron laminations which are insulated from each other and tightly clamped together. In small machines, the laminations are keyed directly to the shaft, whereas in large machines, they are mounted on a spider. The laminated armature core is used to reduce the eddy current loss.

Armature Winding

The insulated conductors are put into the slots of the armature core. The conductors are suitably connected. This connected arrangement of conductors is known as armature winding. There are two types of armature windings are used – wave winding and lap winding.

Commutator

A mechanical rectifier, known as a commutator, converts the alternating emf generated in the armature winding into direct voltage across the load terminals.

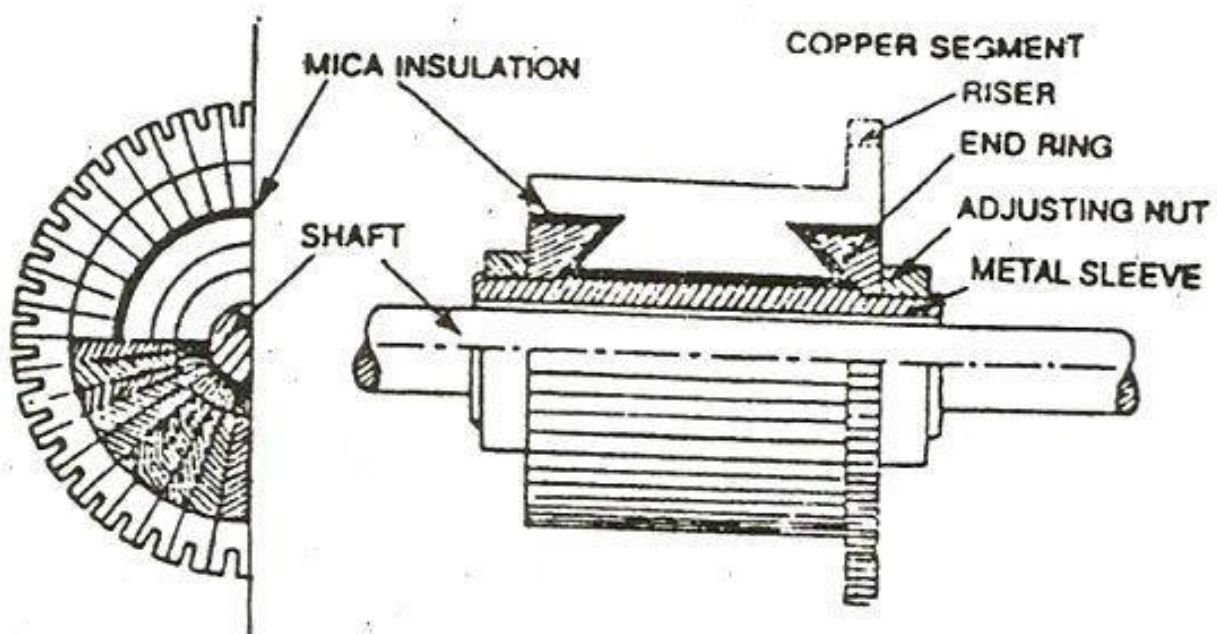


Fig 1.6: Commutator

The commutator is built up of wedge-shaped copper segments separated by mica sheets from each other and from the shaft. Each commutator segment is attached to the armature coil's ends.

Brushes

Brushes are used to gather electricity from the armature winding and are installed on the commutator. Brushes are made of carbon and are held in place by a metal box known as a brush holder. Springs control and maintain the pressure imposed by the brushes on the commutator at a constant value. Through the commutator and carbon brushes, current travels from the armature winding to the external circuit.

1.7.2.Working principle of DC Generator:

Consider a single loop DC generator (as depicted in the illustration), in which a single turn loop 'ABCD' rotates clockwise in a uniform magnetic field at a constant speed. The magnetic flux linking the coil sides 'AB' and 'CD' varies continually as the loop revolves. The induced EMF in one coil side adds to the induced EMF in the other coil side due to the change in flux linkage.

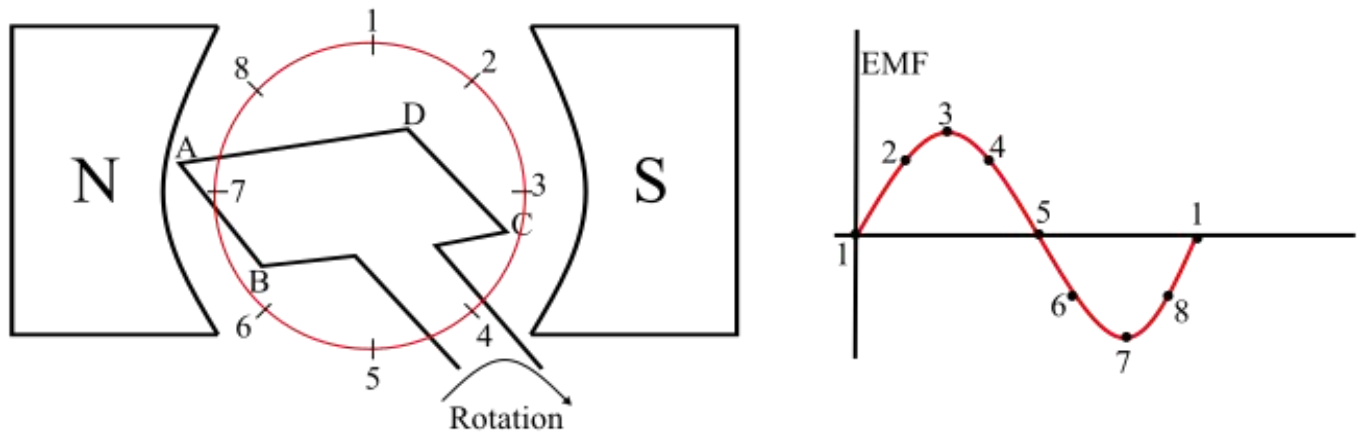


Fig 1.7: Working of DC generator

The EMF generated in a DC generator can be explained in the following way.

- Because the movement of the coil sides is parallel to the magnetic flux while the loop is in position-1, the resultant EMF is zero.
- The coil sides move at an angle to the magnetic flux when the loop is in position-2, resulting in a tiny EMF.

- Because the coil sides are moving at right angles to the magnetic flux while the loop is in position 3, the generated EMF is at its highest.
- When the loop is set to position 4, the coil sides cut the magnetic flux at an angle, resulting in a lower EMF in the coil sides.
- There is no flux linkage with the coil side when the loop is in position-5, and the loop is moving parallel to the magnetic flux. As a result, no EMF is produced in the coil.
- The coil sides move under a pole of opposite polarity at position-6, reversing the polarity of the generated EMF.
- At position-7, the greatest EMF will be generated, whereas at position-1, the EMF will be nil. With each revolution of the coil, the cycle repeats.

The generated EMF in the loop is clearly an alternating one. Because every coil side (say AB) has EMF in one direction when under N-pole influence and in the other way when under S-pole impact. As a result, when a load is connected across the generator's terminals, an alternating current flows through it. This alternating emf created in the loop can now be converted to direct voltage using a commutator. Then there's the DC generator.

1.7.3.Advantages of DC Generator:

The following are some of the benefits of using a DC generator.

- DC generators provide a lot of power.
- These generators have a high terminal load.
- DC generators have a fairly simple design.
- These are used to provide a power output that is uneven.
- With 85-95 percent of efficiency scores, these are extremely consistent.

- They produce reliable result.
- They are both lightweight and compact.

1.7.4. Disadvantages of DC Generator:

The following are some of the drawbacks of a DC generator.

- A transformer cannot be utilized with a DC generator.
- Due to numerous losses such as copper, mechanical, and eddy, the efficiency of this generator is low.
- Over lengthy distances, a voltage loss can develop.
- Because it uses a split ring commutator, the machine design will be more complicated.
- Expensive.
- Maintenance is high.
- While generating electricity, sparks will be formed.
- More energy will be lost during transmission

1.8.ORGANIZATION OF THE THESIS:

This thesis is structured into 5 divisions related to the chapters

- Chapter One provides a detailed introduction about the regenerative Braking .
- Chapter Two discusses the literature review which are done related to Regenerative Braking System.
- Chapter Three describes the Aim and Scope of the project
- Chapter four details the methodology and materials used in the system and also the components in fabrication and usage of equipments in Fabrication.
- Chapter five interprets the results that are obtained while functioning the working model and some discussions related to this thesis

This Braking system we have made could be a useful technology to revive the energy which can reused and enhances the working by recharging the batteries. This technique is beneficial in up the economy of the battery by increasing the potency of the system. Nowadays, Most of the automobile producing corporations use this technique to extend the vehicle's components life and to limit the wastage of energy

CHAPTER-2

LITERATURE REVIEW

The literature review focused primarily on electric cars (EV), hybrid electric vehicles (HEV), and fuel cell-powered hybrid electric vehicles (FCHEV). Using available software, we thoroughly examined books on simulation, critical analysis, and empirical research. Furthermore, an alternate energy-based system has been attempted to some extent. However, there is a greater emphasis on literature connected to fuel savings goals than on environmental savings on global warming and studies conducted to reduce harmful emissions components. This study, which is one of the most significant documents to include here, outlines the infrastructure development requirements and possible advantages as well as the problems and opportunities for the design and implementation of emerging infrastructures connected with plug-in electric vehicles (PEVs). The authors have been able to optimise the benefits of the possibility to reduce fuel use, which is critical for supplying safe, clean electricity, from battery production to communication and control between the car and the grid.

In a study on the "21st century electric vehicle," Eberhard et al. (2005) examined a Tesla Roadster EV with a lithium-ion battery for energy efficiency from well to wheel and emissions from well to wheel. The energy efficiency from the well to the wheel is great, and the Tesla Roadster EV has very low emissions from the well to the wheel when compared to natural gas engines, hydrogen fuel cells, diesel engines, gasoline engines, and hybrid gas/electric vehicles.

Carlson et al. (2008) evaluated differences in fuel efficiency for two kinds of hybrid electric vehicles on previously determined urban driving routes at a range of ambient temperatures (-14 ° C to 31 ° C) for dependence studies. Given the excellent fuel mileage provided by HEVs, performance variations for low and high temperature impacts on HEV operational efficiency have been evaluated for roads in pre-defined cities on the road versus present vehicle technology. The findings revealed that

temperature has a significant impact on battery power control limitations and engine functioning.

A fuel cell hybrid electric vehicle conversion was discussed in detail by Ogburn et al. (2000). The model was constructed with the help of an adviser on a small fuel cell stack, and the model was verified using Virginia Tech - FCHEV in the EPA city and highway driving cycle. When compared to the model v/s test data of total fuel cell system energy production, total energy consumption of the vehicle energy storage system, and total vehicle electric energy usage within 10%, the overall vehicle fuel efficiency accuracy is within 1% during driving cycles and within 6% on the highway.

In Chetan Kumar Maini's article (2005), he defined the possible need for the design and development of an internationally competitive compact electric prototype vehicle for India, concluding that EVs are the best solution for reducing urban pollution and a large social and economic benefit, and that their implementation would result in the use of EVs. The paper also discusses how governments and communities throughout the world are encouraging and advancing electric vehicle (EV) projects.

Burke (2007) explained how batteries and ultracapacitors are used in electric energy storage systems for electric cars and charge-hold hybrid electric vehicles. Lithium-ion batteries and carbon/carbon ultra-capacitors were the focus of the research. The energy density and power density properties of battery and ultra-capacitor technologies are described in this paper. EVs with lithium-ion batteries may be developed to accelerate to 240 km with accelerations equivalent to traditional ICE vehicles, based on simulation results for energy consumption, fuel efficiency, and grid power utilization in federal and highway driving cycles.

According to Ahluwalia et al. (2005), the conventional US driving cycle for fuel consumption operates at 20% of the engine's rated power. He claims that at partial load, the fuel cell is more efficient than at full load. The authors have been evaluating the possibilities of improving FCEV fuel efficiency by using a direct hydrogen compression FC system as an energy conversion device and hybridization of lithium ion battery pack and a sedan car in additional drive hybridization degrees (DOH). The total power rating

of the FC system and the ESS were kept constant during this process. As a result, when the degree of hybridization (DOH) grows, the FC system has been reduced by raising the ESS. Based on mileage per gallon equivalent, the fuel efficiency of hydrogen fuel cell cars was discovered (mpgge).

The impact of design specifications on secondary power sources (with an understanding of motors as secondary power sources) could improve fuel economy, emissions, comfort, driving, and safety (e.g. , rated power, storage capacity, and energy conversion efficiency), including the efficiency of brake energy recovery, according to Hofmman et al (2004). This article outlines issue statements and realised output drive functions (relationships between drive train topology, technology, and control) in order to establish the best hybrid drive train topology and component technologies for certain drive functions. The sensitivity analysis of design input factors is also discussed in the article. They discovered that when the secondary power rating, battery capacity, and energy conversion efficiency rise, so does fuel economy.

Holms et al (2010) explained how an electric car works and compared it to current internal combustion engines and hybrid electric vehicles. The paper detailed the benefits and drawbacks of electric cars, as well as future technical opportunities.

This work presents a model-based integrated power transfer control for emission management and energy management in hybrid electric cars, with the goal of reducing hazardous tailpipe emissions and operational emissions. The cost of the vehicle was judged relevant by Kessels et al. (2010) FISITA SF 2010 A-096. This case study is for a heavy-duty hybrid electric vehicle equipped with SCR-deNOx, and until the system temperature after treatment is low, the suggested control system concentrates on emissions management, and after the system temperature is high enough, energy management will take the position of control. The findings show that the proposed integrated powertrain control results in a trade-off between operating costs and emissions.

In this study, Assanis et al. (2001) described a method for merging vehicle and engine simulations. An engine component adjustment process has been included to ease

engine sizing studies, and the feed-forward model of engine simulation has been altered to allow interaction with vehicle models. A design optimization framework was utilised to discover the ideal overall engine size, battery pack, and motor combination for least fuel consumption within the stated performance parameters. The emission model was completely omitted by the researchers.

Santos et al. (2006) investigated power converters and controls for electric traction and presented the findings in this publication. The focus was on power converter (controller) strategy and setup challenges, as well as power train protection and control. The study vehicle had a motor of 11 KW and 48 V DC. As this motor required a large current of around 200A, stability difficulties in the proposed architecture were vital to consider. The use of DC-DC power converters to accomplish energy saving and low power consumption in forward and backward vehicle operation has been discussed in depth. Under the intuitive association between throttle control and torque, this study explains why the converter's variable output current control is more important than the voltage control. Motors, controllers, and a variety of electrical and mechanical components are all safe and protected with ICE. The current control method, particularly the sliding control mode was discussed.

In this study, Uzunoglu et al. (2007) discussed the design and modelling of fuel cell/ultracapacitor (FC/UC) based hybrid vehicle power systems, as well as the development of power flow control techniques and simulation models. During peak power demand or load shift, FC provided basic power and UC provided additional power. We investigated big, very complicated, and expensive FC technology systems to increase system efficiency for automotive applications using proton exchange membrane fuel cells in order to produce a pretty realistic model to tackle the FC-related issues (PEMFCs). There have been attempts to construct model/executable choices that can deliver power under transient operating conditions such as start-up, sudden load shift, and acceleration.

Chau et al. (2002) analyzed many components of the vehicle to have the best fuel economy, lowest emissions, lowest system cost, and best driving performance. The

author of this research concentrated on drive train power management solutions. The control of power flow for various HEVs is also discussed.

Marinescu et al., FISITA F 2010 A-089, exhibited features of a diesel electric hybrid concept automobile. The diesel powertrain is located on the front side in a traditional position, while the powertrain is mounted on the back side. In the laboratory, prototype vehicles with electric power units and diesel powertrains, a four-wheel drive concept, are yet to be tested.

CHAPTER-3

AIM AND SCOPE OF THE PROJECT:

I. AIM

The aim of this project is to convert the one form of energy into another form during braking and use it to improve the Fuel efficiency of Electric vehicles or to increase the range of Electric Vehicles.

II. SCOPE

Due to a limitation of fuel supplies and a worsening air pollution problem, the automobile industry has a significant task in this century to minimize vehicle fuel consumption and emissions. Conventional ICE vehicles presently contribute 40-50 percent of ozone, 80-90 percent of carbon monoxide, and 50-60 percent of air pollutants prevalent in metropolitan areas, according to numbers supplied by the US Environmental Protection Agency (EPA).

According to a study, braking consumes one-third of one's energy (20 to 25%). The discovery of the Regenerative Braking System is seen as a solution to these four issues, as it recovers wasted energy and converts it to a more useful form. Even though Regenerative Braking System has a valuable and positive effect, it still has issues or problems to be resolved; one of the primary issues is the appropriate battery to utilize in this sort of car.

CHAPTER - 4

METHODOLOGY

4.1.FABRICATION

4.1.1. LIST OF MATEIRALS:

S.NO	Name	Description	Quantity
1.	Square bar	Hollow bar 20 x 20(Mild Steel)	1 no(8 meters)
2.	Solid shaft	12mm dia	1 no
3.	Ball bearing	Internal dia 14mm	4 no
4.	Flat bar	1 x 5 mm (Mild Steel)	1 no(0.5 meters)
5.	Scooter Wheel	400 mm	4 no
6.	Rack and pinion	Straight teethed(Mild Steel)	1 no
7.	Motor	12V,30RPM	1 no
8.	Chain sprocket	Inner dia 14 mm	1 no
9.	Chain	Drive chain	1 no
10.	Battery	Lead-acid	1 no
11.	Electric wires	Copper wire	1 no(5 meters)
12.	Switch	ON/OFF Switch	1 no

13.	DC generator	12V	1 no
14.	Nut and Bolt	MS	6 no
15.	LED	2V	1 no
16.	Push button	Normally closed switch	1 no
17.	Bridge rectifier	1.2A	1 no
18.	Capacitor	1.5 μ F	1 no

Table 4.1. List of materials

4.1.1.1. Square bar:

These are used to make a frame. The mild steel solid bar is welded into a square frame.



Fig 4.1: Square bar

4.1.1.2. Solid Shaft:

The wheels are supported by a solid shaft made of mild steel. On the shaft, the wheel is installed. With the use of a chain and sprocket, the shaft is connected to the electric motor. When the motor starts, motion is transferred from the motor to the sprocket via chain, then to the shaft, which rotates the wheel.



Fig 4.2: Solid Shaft

4.1.1.3. Plummer block:

A plumber block is a device that contains an anti-friction bearing and allows any solid shaft to rotate while keeping the outer ring stationary. The solid shaft is inserted into the bearing, which is used to rotate the shaft.



Fig 4.3: Plummer block

4.1.1.4. Flat bar:

It is used for supporting materials. It is used to support motor and other parts to the frame.



Fig 4.4: Flat bar

4.1.1.5. Wheel:

Scooter wheel is used as the wheel of the vehicle. The rear wheels are rotated using chain sprocket and motor connected by the chain.



Fig 4.5: Wheel

4.1.1.6. Rack and pinion:

Rack teeth are cut horizontally about the required length. This is made up of Cast iron. The gear wheel which is provided to get mesh with rack, converts the linear motion into rotary motion. They are made up of Cast iron. Rack is connected with the brake pedal. When the pedal is pressed, linear motion is created in rack and converted to rotary motion by pinion. Pinion is connected with the generator.



Fig 4.6: Rack and Pinion

4.1.1.7. Motor:

The motor is a 12V D.C. with maximum speed of 30RPM. The motor transmits the power using the chain and sprocket to the wheel.

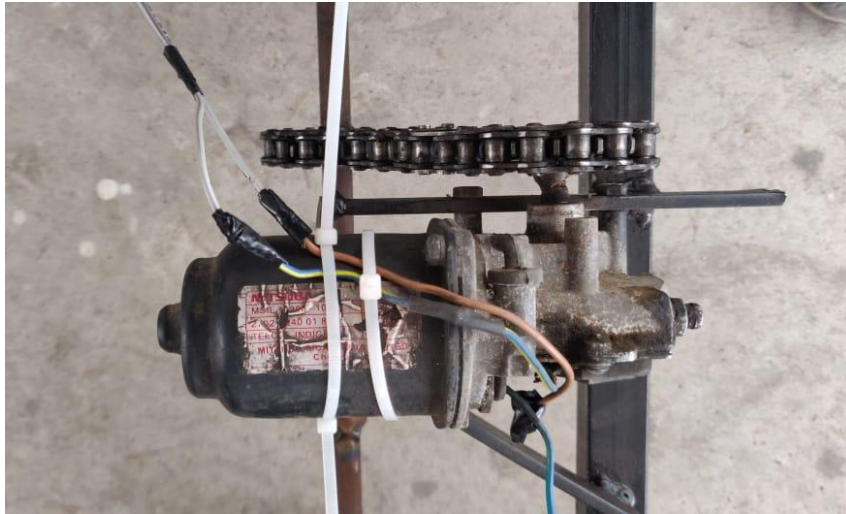


Fig 4.7: Motor

4.1.1.8. Chain sprocket:

It is used to transfer the rotary motion of the motor to the shaft. Sprocket is connected to the motor using chain.



Fig 4.8: Chain Sprocket

4.1.1.9. Chain:

The chain drive transmits mechanical power from one place to another. This roller chain connects motor and sprocket which is fixed with shaft.



Fig 4.9: Chain

4.1.1.10. Battery:

Lead acid battery is used in this project. Battery gives power to the motor to rotate the wheels. The electric power generated using regenerative braking is stored in the battery.



Fig 4.10: Lead acid Battery

4.1.1.11. Normally closed push button:

Normally closed push button is a switch in which the circuit is closed until the button is pressed. This button is pressed at the time of pressing the pedal , which cuts off the power to motor from the battery.



Fig 4.11: Normally closed push button

4.1.1.12. Switch:

This switch is used to turn on the motor of the vehicle.



Fig 4.12: Switch

4.1.1.13. LED:

These are used to display the power generated by the regenerative brakes.



Fig 4.13: LED bulb

4.1.1.14. Electrical wires:

The inner wire is insulated and made of copper. They are used to transmit power from the motor to the LEDs.

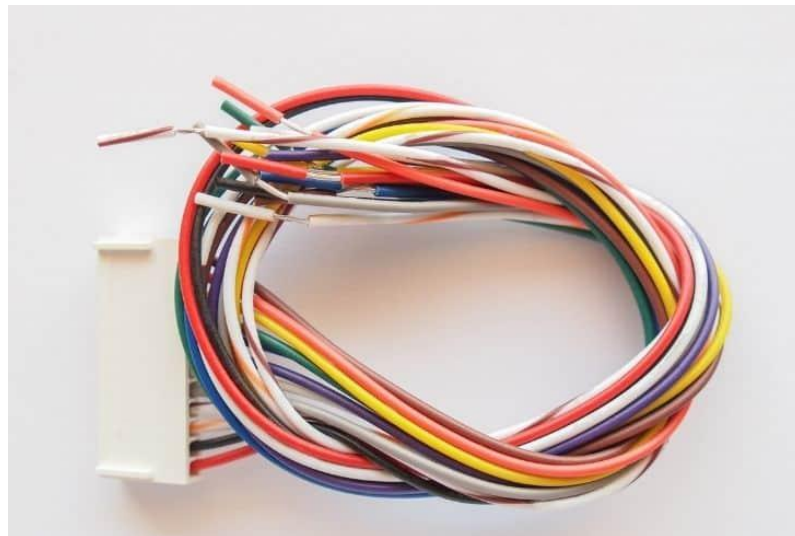


Fig 4.14: Electrical wires

4.1.1.15. Bridge rectifier:

Bridge rectifier is connected to the DC generator, here it acts as a linear regulator where the power is transmitted in one way only and there is some voltage drop. Also the bridge rectifier blocks the DC current when it returns back from the battery.



Fig 4.15: Bridge Rectifier

4.1.1.16. Capacitor:

A capacitor is included in the rectifier circuit to act as a filter to reduce ripple voltage. The DC current passes through the bridge rectifier and it passes the capacitor where the capacitor is placed next to the rectifier.



Fig 4.16: Capacitor

4.1.1.17. DC Generator:

A DC generator is an electromechanical energy conversion device that uses electromagnetic induction to transform mechanical energy into DC electrical power.



Fig 4 .17: DC Generator

4.1.1.18. Bolts and Nuts:

Nuts and bolts are used to hold two pieces together in a way that is removable, unlike a weld. For example, joining two different steel sections, assembly of motor and other vehicle parts, pipe joint with bolted flange, fabricated joints of steel.



Fig 4.18: Bolts and Nuts

4.1.2. Equipments used in fabrication:

4.1.2.1. Drilling:

Drilling is a metal removal technique that involves cutting or enlarging a circular cross-section hole in solid materials with a drill bit. The drill bit is a multi-point rotary cutting tool. The bit is pushed against the work piece and spun at speeds ranging from hundreds to thousands per minute. As a result, the cutting edge is forced against the work piece, cutting off chips from the hole being drilled.



Fig 4.19: Drilling machine

4.1.2.2. Metal cutting:

Metal cutting is a method of removing unwanted metal from a work piece in the form of chips.

Using a hacksaw blade, we were able to get the work piece to the desired dimensions.



Fig 4.20: Hacksaw blade

4.1.2.3. Arc welding:

Arc welding is the process of joining two pieces of metal together using an electric arc and an electrode that is guided along with the connection between the pieces. The electrode can be a simple rod that conducts electricity between the tip and the work or a rod or wire that melts and feeds filler metal to the joint.

The basic arc welding circuit consists of an alternating current (AC) or direct current (DC) power supply linked to the work piece via a "work" cable and an electrode via a "hot" cable. An arc is formed across the space between the metal and the hot cable electrode when the electrode is placed close to the work item. To complete the circuit, an ionized gas column forms.

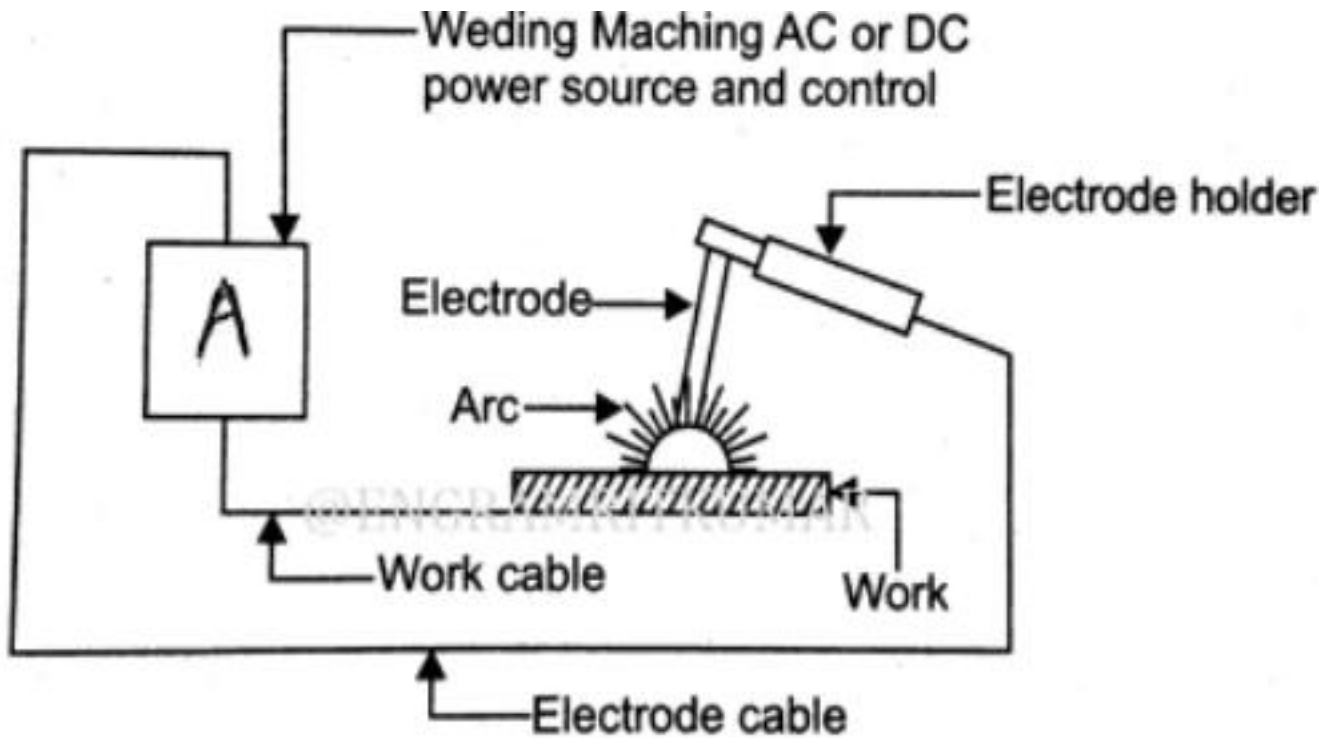


Fig.4.21: Arc Welding Circuit Diagram

The arc generates a temperature of around 3600°C at the tip, melting a portion of the metal being welded and a portion of the electrode. As the electrode is moved along the joint, a puddle of molten metal forms behind it, which cools and hardens.

Electrodes are divided into two types.

- ❖ Consumable electrode tips melt, releasing molten metal droplets into the weld pool.
- ❖ Electrodes that are not consumable do not melt. Instead, a separate rod or wire is used to melt filler metal into the junction.

When metals react with oxygen and nitrogen in the air to generate oxides and nitrides at high temperatures, the weld's strength is weakened. With a shield of gas, vapour, or slag, most arc welding methods reduce contact between the molten metal and the air. Granular flux, for example, includes deoxidizers that form a shield around the molten pool, enhancing weld quality.

4.2. PROCEDURE:

- ◆ The square bar is first cut at a 45-degree angle and then welded together to make a frame.
- ◆ A rectangle-like structure is formed by welding square bar at each corner.
- ◆ The frame is painted with black paint to prevent from dust.
- ◆ The flat plate is welded to the rectangular frame and the plummer block is fitted over the flat plate.
- ◆ The wheel sprocket is mounted on a solid shaft that is placed into the Plummer block.
- ◆ The motor is welded to the frame.
- ◆ Battery is attached to the frame.
- ◆ The power from the battery is passed to the motor through copper wires.
- ◆ The motor's power is transferred to the wheel via a chain that connects the sprocket and the motor.
- ◆ The brake pedal is attached to the frame.
- ◆ Near the rear wheel, the brake wheel is fitted which is connected to the brake pedal via a flat bar.
- ◆ Rack is fixed to the frame under the brake pedal and pinion is fixed to mesh with rack.
- ◆ Generator is fixed to the frame using flat bar. Generator and pinion are connected.
- ◆ The LED light is connected with the generator.
- ◆ Capacitor and bridge rectifier are connected in a breadboard.

- ◆ The output of the generator is connected to the breadboard circuit which is connected to the battery.

4.2.1. Precautions used during Fabrication:

- ◆ Apron is worn throughout the the process of fabrication.
- ◆ A face shield and welding gloves are worn during the welding operation.
- ◆ Proper coolant is given during the drilling procedure.
- ◆ Gloves are worn during the grinding operation to protect hands.
- ◆ The materials were handled with extreme caution during the process of fabrication

4.3. FINAL FABRICATION:



Fig 4.22: Final fabrication

CHAPTER-5

5.1. RESULT:

The model is operated after satisfactory testing. The results obtained are noted and tabulated below.

Result Table:

S.NO	REVOLUTIONS PER SECOND OF THE GENERATOR	VOLTAGE OUTPUT
1.	60 RPM	3.83V
2.	120 RPM	4.56V
3.	180 RPM	5.47V

Table 5.1 Result

From the result table, it can be seen that the efficiency of regenerative braking systems employing DC generator improves as the angular velocity of the motor increases. Therefore, regenerative braking systems are more efficient as angular velocities and recoverable energy increase with increased generator speed. Faster the generator spins, higher the output. Lower speed losses are greater because generators are less efficient at lower speeds but losses at higher speeds are mostly mechanical losses such as friction and air drag..

5.2. DISCUSSION:

With the increasing growth of the markets for hybrid, electric, and extremely efficient, low-emission conventionally driven vehicles, the pace of development of regenerative braking systems appears to be picking up. The high cost (especially of battery packs) and restricted range of battery-electric vehicles (BEVs) are now the two most significant market hurdles. Future difficulties for system developers will include cost reduction, increased vehicle range, and compliance with higher safety and pollution norms. Advanced technologies that not only stop the vehicle but also recover lost braking energy will require braking management.

In summary, current "first-generation" regenerative braking technologies do not impact braking safety, according to the analysis. The tests on one such system, which was installed in a hybrid vehicle, revealed no safety concerns. The power capacity of the battery or other energy storage device/system, that is, its ability to swiftly convert the kinetic energy of the vehicle into its stored form, may be the key determinant of how powerful the regenerative braking system is.

According to basic mechanical engineering theory, for current systems that can only operate at very low power levels (say, 30KW), the regenerative braking component is likely to be quite small, especially at high speeds. For medium-high deceleration stops from such speeds, such systems require a significant additional source of braking torque, i.e. a conventional friction braking system.

CHAPTER-6

6.1. CONCLUSION

The goal of the regenerative braking system used in vehicles is to save a portion of the energy wasted during braking. This braking system cannot be employed as a vehicle's primary braking system since it cannot bring the vehicle to a complete stop. Friction brakes turn the energy into heat, which is then released into the environment. The regenerative braking system is intended to generate energy to charge the vehicle's battery. This energy is used to move the generator's rotor, which converts mechanical energy from the wheels into an usable charge in the battery. Spur gear converts linear motion into rotatory motion. This rotational energy is used to revolve the generator's rotor, which converts the mechanical energy of the wheels into a useful charge in the battery.

Results demonstrate that as the spur wheel's speed (rpm) increases, the voltage generated increases as well.

As a result, if this system is installed in actual vehicles, the regenerative braking system may recover a minimum of 7% battery energy. Using regenerative braking, the distance travelled between two consecutive charging requirements can be enhanced by 6 to 11%.

6.2. RECOMMENDATIONS:

Since this project is entirely based on an experimental test rig, there may be some issues if this system is used in existing operational automobiles, causing discomfort for drivers. Because regenerative braking does not offer braking at high speeds, this system should be used in combination with other methods of braking systems, such as anti-lock brakes (ABS).

Implementing this technology in a currently operational vehicle will increase the vehicle's mass and take up additional space. As a result, this aspect should be studied prior to vehicle design so that it may be overcome.

Regenerative braking in a car necessitates some adjustments in driving style, which are dependent on the system's technological setup. This takes some getting used to, but studies show that drivers respond positively and attempt to maximise the amount of energy they can reclaim, so increasing their range.

Furthermore, eco-driving is intimately tied to the use of regenerative braking. If a big number of drivers adopt eco-driving tactics, this might have a significant impact on traffic flow.

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