Design and Fabrication of Regenerative Braking System

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Milan Lamichhane
Malla Reddy College of Engineering & Technology

Navin Bhetal

Surendra Yonjan
Malla Reddy College of Engineering & Technology

Malla Reddy College of Engineering and Technology

UGC Autonomous, NBA Accredited, Approved by AICTE, Affiliated to JNTUH

Department of Mechanical Engineering

Design and Fabrication of Regenerative Braking System

Name of the student(s)	Hall Ticket Number(s)
Milan Lamichhane	(16N31A03G8)
Surendra Yonjan	(16N31A03H0)
Navin Bhetal	(16N31A03H4)

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Design and Fabrication of Regenerative Braking System

A Major Project report submitted in partial fulfillment of the

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of

Bachelor of Technology

in

Mechanical Engineering

by

Milan Lamichhane	**(16N31A03G8)**
Surendra Yonjan	**(16N31A03H0)**
Navin Bhetal	**(16N31A03H4)**

Under the guidance of
Mr. O.Y Venkata Subba Reddy
Assistant Professor

Department of Mechanical Engineering

Malla Reddy College of Engineering and Technology

UGC Autonomous, NBA Accredited, Approved by AICTE, Affiliated to JNTUH

Secunderabad – 500100, Telangana, India.

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MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

Autonomous Institution - UGC Govt. of India

(Affiliated to JNTU, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade)

Secunderabad – 500100, Telangana State, India

Department of Mechanical Engineering

CERTIFICATE

This is to certify that the Major Project work entitled "**Design and Fabrication of Regenerative Braking System**" is carried out by **Milan Lamichhane (16N31A03G8), Surendra Yonjan (16N31A03H0), Navin Bhetal (16N31A03H4)** in partial fulfillment for the award of degree of **Bachelor of Technology** in **Mechanical Engineering**, Jawaharlal Nehru Technological University, Hyderabad during the academic year 2019-2020.

Mr. O.Y Venkata Subba Reddy — Prof. Dr A. N. R. Reddy

Internal Guide — HOD

External Examiner

DECLARATION

We hereby declare that the project titled "**Design and Fabrication of Regenerative Braking System"** submitted to Malla Reddy College of Engineering and Technology (UGC-Autonomous), affiliated to Jawaharlal Nehru Technological University Hyderabad (JNTUH) for the award of the degree of Bachelor of Technology in Mechanical Engineering is a result of original research carried-out in this thesis. We understand that our report may be made electronically available to the public. It is further declared that the project report or any part thereof has not been previously submitted to any University or Institute for the award of degree or diploma.

Name of Student(s)	:	Milan Lamichhane, Surendra Yonjan & Navin Bhetal.
Hall Ticket Number(s)	:	16N31A03G8, 16N31A03H0 & 16N31A03H4.
Degree	:	Bachelor of Technology in Mechanical Engineering
Department	:	Mechanical Engineering
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(Milan Lamichhane) (Surendra Yonjan) (Navin Bhetal)

Date:

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Milan Lamichhane : 16N31A03G8

Surendra Yonjan : 16N31A03H0

Navin Bhetal : 16N31A03H4

Abstract

As in today’s world, where there are energy crises and therefore the resources are depleting at a better rate, there's a requirement of specific technology that recovers the energy, which gets usually wasted. So, just in case of automobiles one among these useful technologies is that the regenerative braking system. Regenerative braking is an energy recovery mechanism that slows a vehicle or object by converting its Kinetic Energy (K.E) into a form which will be either used immediately or stored until needed. Using regenerative braking system in automobiles enables us to recover the K.E. of the vehicle to some extent that's lost during the braking process.The converted K.E. is stored for future use or is fed back to the facility system of the vehicle. This energy is often stored during a battery or bank of capacitors for later use. Energy also can be stored with the assistance of a rotating flywheel which is one among the foremost inexpensive and effective method of storing and regenerating power. The present invention provides energy-storing regenerative braking system by transmitting the flywheel force as a torque tending to oppose the forward rotation of a wheel on applying the brakes.

A brake-pad assembly, mounted concentrically with the hub of a ground-engaging wheel, is actuated upon braking to supply frictional engagement between the hub and clutch mechanism, while applying a decelerating torque to the wheel. The special braking mechanism is selectively held in position by a rider-controlled clutch mechanism, to accumulate energy over several braking events. Vehicles driven by electric motors use the motor as a generator when using regenerative braking and its output is supplied to an electrical load. The transfer of energy to the load provides the braking effect and regenerates power.

Keywords: Regenerative Braking, Generator, Brake pad, Energy Recovery, Flywheel.

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CHAPTER 1

1.1 Introduction

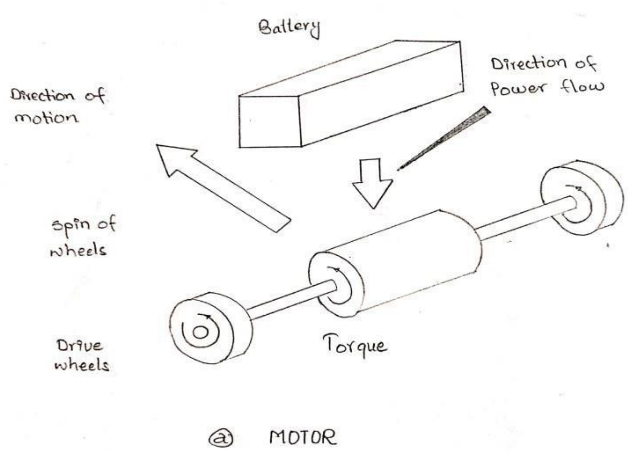
In recent years, there is the lack of reliable alternative energy sources, increasing efficiency and reducing exhaust gas emissions has become the focus of the modern automotive research. Commercial vehicles such as refuse trucks and delivery vehicles lose a tremendous amount of kinetic energy during frequent braking and constant drive at low speeds on designated city routes, which results in higher fuel consumption and Green House Emission Gas (GHG) emission than other on-road vehicles. Numerous attempts have been made to improve type of vehicles. The technological combination of Exhaust Gas Recirculation (EGR) and Diesel Particulate Filter (DPF) after treatment is one of the effective ways to solve the vehicle emission, especially for NOx and soot. However, this method is not able to reduce the GHG emission since the low temperature combustion of this technology results in increasing the fuel penalty. Sacrificing engine efficiency in exchange for reduced pollutants cannot fundamentally solve the energy crisis. In order to achieve overall GHG reduction targets, a strong reduction is needed particularly for commercial vehicles.

Regenerative energy technology is one of the key features of electrified vehicles. It allows the vehicle to capture a tremendous amount of the kinetic energy lost during braking or decelerating for reuse. That is saying, energy recovery technology can significantly bring down the energy consumption of electrified vehicle, particularly in urban operated route. Generally, there are two regenerative energy approaches which have been applied to commercial vehicles: Regenerative Braking System and Boost Recuperation System. The former is usually applied in series hybrid architecture; the latter in the parallel architecture. The regenerative braking system is equipped in the driven axle to recuperate the braking energy loss. The boost recuperation system is parallelly coupled with the mechanical propulsion system to recuperate kinetic energy during the deceleration process. Both technologies allow commercial vehicles to have a significant improvement of reducing fuel consumption as well as emissions. However, few researchers have addressed the regenerative energy rate of hybrid commercial vehicles. The more energy the regenerative braking recuperates; the less fuel is consumed. Typical hybrid commercial vehicles are generally designed as rear drive and the regenerative braking system is equipped in rear driven axle(es) to recuperate the braking energy loss. Due to the change of the center gravity in the vehicle under different load conditions, braking energy loss may vary in both front and rear axles.

Current braking research indicates that around 50-80% of braking energy loss of commercial vehicles occurs in the front axle and the braking energy loss varies slightly under different load states. Therefore, the majority of the regenerative energy potential is not taped.

1.2 Working Principle

Regenerative braking is a braking method that utilizes the mechanical energy from the motor by converting kinetic energy into electrical energy and fed back into the battery source. Theoretically, the regenerative braking system can convert a good fraction of its kinetic energy to charge up the battery, using the same principle as an alternator.



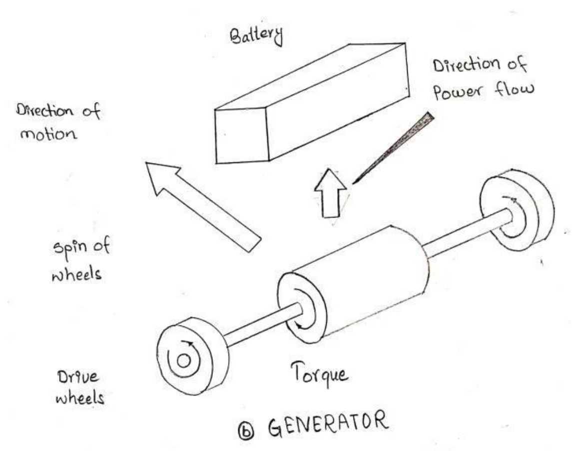


Fig 1.2.1: Normal forward driving condition   Fig 1.2.2: Regenerative action during braking

In regenerative braking mode, it uses the motor to slow down the car when the driver applies force to the brake pedal then the electric motor works in reverse direction thus slowing the car. While running backwards, the motor acts as the generator and recharge the batteries as shown in figure (1.2.2). Meanwhile in figure (1.2.1) shows the car in normal running condition whereas the motor turning forward and taken energy from the battery. By using regenerative braking, it vastly reduces the reliance on fuel, boosting fuel economy and lowering emissions. These types of brakes work effectively in driving environment such as stop-and-go driving situations especially in urban city.

1.3 Types of Regenerative Braking System

There are multiple methods of energy conversion in Regenerative Braking System including spring, flywheel, electromagnetic and hydraulic. More recently, an electromagnetic-flywheel hybrid Regenerative Braking System has emerged as well. Each type of Regenerative Braking System utilizes a different energy conversion or storage method, giving varying efficiency and applications for each type. The Types are as follows:

- 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 Electromagnetic system, the drive shaft of the vehicles is connected to an electric generator, which uses magnetic fields to restrict the rotation of the drive shaft, slowing the vehicle and generating electricity. In the case of electric and hybrid vehicles, the electricity generated is sent to the batteries, giving them a recharge. In gas powered vehicles, the electricity can be used to power the cars electronics or sent to a battery where it can later use to give the vehicle an extra boost of power. This technique is currently used in some Le Mans Prototype racing cars.

1.3.2 Flywheel

In Flywheel Regenerative Braking System, the system collects the kinetic energy of the vehicle to spin a flywheel that is connected to the drive shaft through a transmission and gear box. The spinning flywheel can then provide torque to the drive shaft, giving the vehicle a power boost.

1.3.3 Electromagnetic flywheel

Electro flywheel regenerative brake is a hybrid model of electromagnetic and flywheel Regenerative Braking System. It shares the basic power generation methods with the electromagnetic system; however, the energy is stored in a flywheel rather than in batteries. In this sense, the flywheel serves as a mechanical battery, where electrical energy can be stored and recovered. Due to the long life of flywheel batteries compared to lithium-ion batteries, electric flywheel Regenerative Braking System is the more cost-effective electricity storage method.

1.3.4 Spring

The spring-loaded regenerative braking system is typically used on human powered vehicles, such as bicycles or wheelchairs. In spring Regenerative Braking System, a coil or spring is winded around a cone during braking to store energy in the form of elastic potential. The potential can then be returned to assist the driver while going uphill or over rough terrain.

1.3.5 Hydraulic

The Hydraulic Regenerative Braking System slows the vehicle by generating electricity which is then used to compress a fluid. Nitrogen gas is often chosen as the working fluid. Hydraulic Regenerative Braking Systems have the longest energy storage capability of any system, as compressed fluid does not dissipate energy over time. However, compressing gas with a pump is a slow process and severely limits the power of the hydraulic Regenerative Braking System.

1.4 Problem statement

At this century, automotive industry has posted a great challenge in order to reduce the vehicle fuel consumption and emission, these is due to the shortage of fuel resources and worsen air pollution problem. According to figures released by the US Environmental Protection Agency (EPA), conventional ICE vehicles currently contribute 40-50% of ozone, 80-90% of carbon monoxide, and 50-60% of air toxins found in urban areas.

A study shows that, one third (20 to 25%) energy is consumed during brake. The invention of Regenerative Braking System is viewed as a solution to these 4 problems, as it recovered wasted energy and restored to another form of useful energy. Although the valuable and positive effect brought by Regenerative Braking System is realized, it still has its issue or problem to be solved; one of the major problems is observed as the suitable battery to be used in this type of vehicle.

1.5 Applications

- Kinetic energy recovery mechanism.
- Regenerative braking systems are used in electric elevators and crane lifting motors.
- Also used in electric and hybrid cars, electric railway vehicles, electric bicycles, etc.
- Could be used in an industry that uses a conveyor system to move material from one workstation to another and halts at a certain distance after a prescribed interval.

1.6 Advantages

- Better Performance.
- Cuts down on pollution related to supply generation.
- Efficient Fuel Economy–The fuel consumption is reduced, dependent on the machine cycles, vehicle design, automation control plan, and the individual component’s efficiency.
- Reduced wear and tear of Engines.
- Reduced Brake Wear– Cutting down the replacement brake linings cost, the cost of labor for installation, and machine downtime.
- Reduced emissions–Cuts down on pollution related to power generation, engine decoupling reduces the total number of revolutions and thus engine emissions.
- Smaller accessories – reducing fuel tank size and thus the weight of the vehicle.

1.7 Disadvantages

In practice, the regenerative brakes take the time to slowdown a vehicle, hence most of the vehicles that use them, also have friction brakes working alongside. This is one reason why regenerative brakes don't save 100 percent of braking energy.

- High cost of components, engineering, and installation.
- As compared to dynamic brakes, regenerative brakes are needed to match the power produced by the input supply (D.C. and A.C. supplies), and it is achieved only with the help of development of power electronics.
- A Regenerative braking safety is limited when the batteries storing the recovered energy are 100 % charged. The excessive charge would cause the voltage of the battery to rise above a safe level.
- Added maintenance – Dependent on the complexity of the design.

1.8 Future Scope

Future developments, however, such as ultra-capacitors, flywheels and hydraulic systems could have much higher power capacities, which could open up the possibility to rely more heavily on the regenerative braking system, even for high speed, high stops and the opportunity to downsize or even eliminate the friction-braking system.

1.9 Organization of the thesis

This thesis is structured in five correlated chapters in following order.

Chapter 1 provides brief introduction on Regenerative Braking System.

Chapter 2 discusses the literature review on Regenerative Braking System.

Chapter 3 describes methodology and materials used in regenerative braking system.

Chapter 4 interprets the obtained results.

Chapter 5 concludes the research and presents summary of research findings.

Regenerative Braking system is a useful technology to restore the kinetic energy which will fade away in heat produced during friction. This system is useful in improving the fuel economy of the vehicle and also in increasing the efficiency of the system. Nowadays, Most of the car manufacturing companies use this system to increase the vehicle’s parts life and to limit the emissions.

CHAPTER 2

LITERATURE REVIEW

2.1 History

Use in motor sport

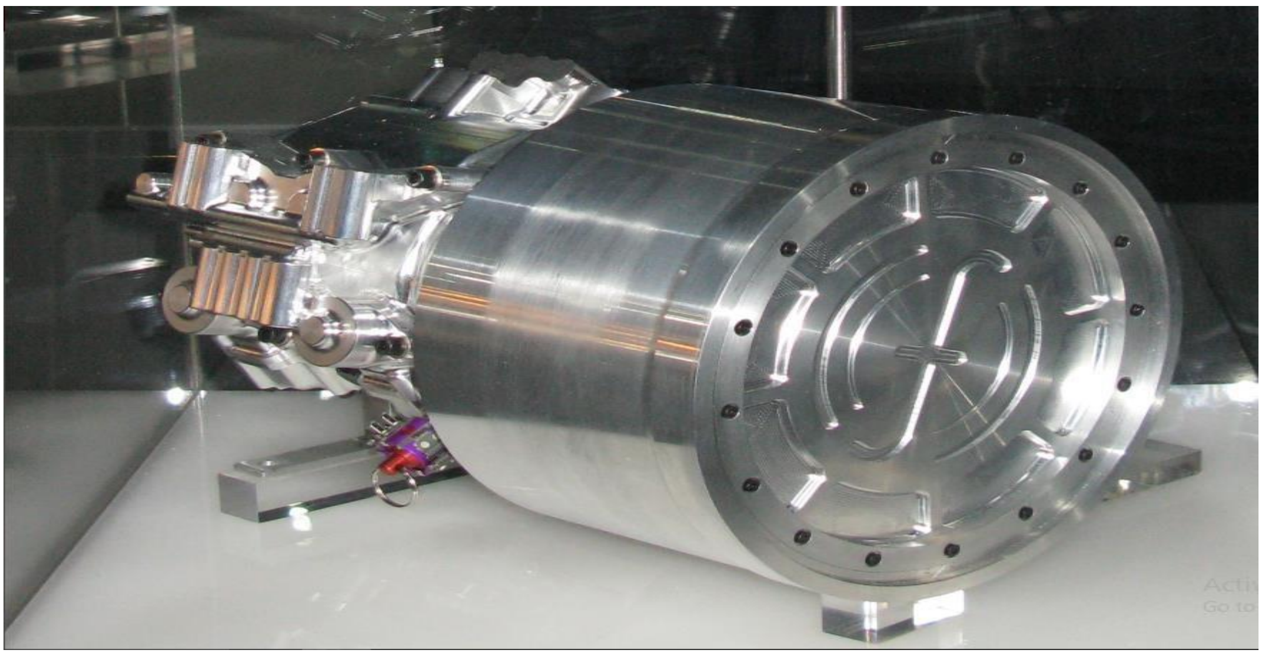


Fig 2.1: A Flybrid Systems kinetic energy recovery system [1]

The first of these systems to be revealed was the Flybrid. This system weighs 24 kg and has an energy capacity of 400 kJ after allowing for internal losses. A maximum power boost of 60 kW (81.6 PS, 80.4 HP) for 6.67 seconds is available. The 240 mm diameter flywheel weighs 5.0 kg and revolves at up to 64,500 rpm. Maximum torque is 18 Nm (13.3 ft lbs). The system occupies a volume of 13 liter.

Formula One

Fig 2.2: A KERS flywheel [2]

Formula One have stated that they support responsible solutions to the world's environmental challenges, and the FIA allowed the use of 81 hp (60 kW; 82 PS) KERS in the regulations for the 2009 Formula One season. Teams began testing systems in 2008: energy can either be stored as mechanical energy (as in a flywheel) or as electrical energy (as in a battery or super capacitor).

Two minor incidents were reported during testing of KERS systems in 2008. The first occurred when the Red Bull Racing team tested their KERS battery for the first time in July: it malfunctioned and caused a fire scare that led to the team's factory being evacuated [3]. The second was less than a week later when a BMW Sauber mechanic was given an electric shock when he touched Christian Klien's KERS-equipped car during a test at the Jerez circuit [4]. With the introduction of KERS in the 2009 season, four teams used it at some point in the season:

Ferrari, Renault, BMW, and McLaren. During the season, Renault and BMW stopped using the system. Vodafone McLaren Mercedes became the first team to win a F1 GP using a KERS equipped car when Lewis Hamilton won the Hungarian Grand Prix on 26 July 2009. Their second KERS equipped car finished fifth. At the following race, Lewis Hamilton became the first driver to take pole position with a KERS car, his teammate, Heikki Kovalainen qualifying second. This was also the first instance of an all KERS front row. On 30 August 2009, Kimi Räikkönen won the Belgian Grand Prix with his KERS equipped Ferrari. It was the first time that KERS contributed directly to a race victory, with second placed Giancarlo Fisichella claiming "Actually, I was quicker than Kimi. He only took me because of KERS at the beginning" [5].

Auto part makers

Bosch Motorsport Service is developing a KERS for use in motor racing. These electricity storage systems for hybrid and engine functions include a lithium-ion battery with scalable capacity or a flywheel, a four to eight-kilogram electric motor (with a maximum power level of 60 kW or 80 hp), as well as the KERS controller for power and battery management. Bosch also offers a range of electric hybrid systems for commercial and light-duty applications [6].

Carmakers

Automakers including Honda have been testing KERS systems. At the 2008 1,000 km of Silverstone, Peugeot Sport unveiled the Peugeot 908 HY, a hybrid electric variant of the diesel 908, with KERS. Peugeot planned to campaign the car in the 2009 Le Mans Series season, although it was not capable of scoring championship points [7]. Peugeot plans also a compressed air regenerative braking power train called Hybrid Air [8]. Vodafone McLaren Mercedes began testing of their KERS in September 2008 at the Jerez test track in preparation for the 2009 F1 season; although at that time it was not yet known if they would be operating an electrical or mechanical system [9]. In November 2008 it was announced that Free scale Semiconductor would collaborate with McLaren Electronic Systems to further develop its KERS for McLaren's Formula One car from 2010 onwards. Both parties believed this collaboration would improve McLaren's KERS system and help the system filter down to road car technology [10].

Toyota has used a super capacitor for regeneration on Supra HV-R hybrid race car that won the 24 Hours of Tokachi race in July 2007 [11]. BMW has used regenerative braking on their E90 3 Series as well as in current models like F255 Series under the Efficient Dynamics moniker. Volkswagen have regenerative braking technologies under the Blue Motion brand in such models as the MK7 Golf and MK7 Golf Estate/Wagon models, other VW group brands like SEAT, Skoda and Audi.

Motorcycles

KTM racing boss Harald Bartol has revealed that the factory raced with a secret kinetic energy recovery system (KERS) fitted to Tommy Koyama's motorcycle during the 2008 season-ending 125cc Valencian Grand Prix. This was against the rules, so they were banned from doing it afterwards.

Races

Automobile Club de l'Ouest, the organizer behind the annual 24 Hours of Le Mans event and the Le Mans Series is currently "studying specific rules for LMP1 that will be equipped with kinetic energy recovery system." Peugeot was the first manufacturer to unveil a fully functioning LMP1 car in the form of the 908 HY at the 2008 Auto sport 1000 km race at Silverstone [12].

2.2 Use in civilian transport

Bicycles

Regenerative braking is also possible on a non-electric bicycle. The EPA, working with students from the University of Michigan, developed the Hydraulic Regenerative Brake Launch Assist (RBLA) [13]. It is available on electric bicycles with direct-drive hub motors.

Cars

Many electric vehicles employ regenerative braking since the first used in the US by the AMC Amitron concept car [14]. Regenerative braking systems are not able to fully emulate traditional brake function for drivers, but there are continuing advancements [15]. The calibrations used to determine when energy will be regenerated and when friction braking is used to slow down the vehicle affects the way the driver feels the braking action [16].

Examples of cars include:

- Audi e-tron
- Ford Fusion Hybrid
- Hyundai Kona Electric
- Nissan Leaf
- Tesla Model 3
- Toyota Prius

2.3 Literature Review

Sayed Nashit, Sufiyan Adhikari, Shaikh Farhan, Srivastava Avinash and Amruta Gambhire, ‘Design, Fabrication and Testing of Regenerative Braking Test Rig for BLDC Motor’, 2016, 1881-84.

In this paper [17] a test bench for testing of regenerative braking capability of a Brushless DC Motor is design and then fabricated. The project creates awareness to engineers towards energy efficiency and energy conservation. It concludes that the regenerative braking systems are more efficient at higher speed and it cannot be used as the only brakes in a vehicle. The definite use of this technology described as in the project in the future automobiles can help us to a certain level to sustainable and bright future of energy efficient world as a part of power that is lost can be regained by using the regenerative braking system.

Khushboo Rahim, and Mohd. Tanveer, ‘Regenerative Braking System: Review Paper’, *International Journal on Recent and Innovation Trends in Computing and Communication, 5.5* (2018), 736-39.

In this paper [18] the advantages of regenerative braking system over conventional braking system has been mentioned. Regenerative braking systems can work at the high temperature ranges and are highly efficient when compared to the conventional brakes. They are more effective at higher momentum. The more frequently a vehicle stops, the more it can benefit from this braking system. Large and heavy vehicles that movies at high speeds builds up lots of kinetic energy, so they conserve energy more efficiently. It has broad scope for further advancements and the energy conservation.

Tushar L. Patil, Rohit S. Yadav, Abhishek D. are, Mahesh Saggam, Ankul Pratap, ‘Performance Improvement of Regenerative braking system’, *International Journal of Scientific & Engineering Research Volume 9, Issue 5,* (2018). 2229-5518

In this paper [19] the techniques to increase the efficiency of the regenerative braking system is mentioned. The technique mentioned was to reduce the weight of the automobile which increase performance, using super capacitor also improves the conversion rate of energy in regenerative braking system, making the automobile compact also tends to increase the efficiency of the system.

C. Jagadeesh Vikram, D. Mohan Kumar, Dr. P. Naveen Chandra, ‘Fabrication of Regenerative Braking System’, *International Journal of Pure and Applied Mathematics Volume 119,* (2018). 9973-9982.

In this paper [20] the Fabrication process on the Regenerative Braking System had been implemented as per the prescribed measures has been taken and the future enhancements should be processed on basis of the need of the study. The Implementation of the regenerative braking system be quite essential in automotive transportation with maximized performance in braking.

A. Eswaran, S Ajith, V Karthikeyan, P Kavin, S Loganandh, ‘Design and Fabrication of Regenerative Braking System’, *International Journal of Advance Research and Innovative Ideas in Education-Vol-4 Issue-3 (*2018). 2395-4396,

In this paper [21] the regenerative braking system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. Also, it can be operated at high temperature range and are efficient as compared to conventional braking system. Regenerative braking systems require further research to develop a better system that captures more energy and stops faster. All vehicles in motion can benefit from these systems by recapturing energy that would have been lost during braking process. The use of more efficient systems could lead to huge savings in the economy of any country.

Ketan Warake, Dr. S. R. Bhahulikar, Dr. N. V. Satpute, ‘Design & Development of Regenerative Braking System at Rear Axle’, International *Journal of Advanced Mechanical Engineering. Volume 8, Number 2 (2018), 2250-3234*

In this paper [22] the regenerative braking system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. The regenerative braking system is designed to partially recover the battery charge wasted in braking of the vehicle. The energy is converted into heat by friction brake which is dissipated to the environment. This Energy is utilized to rotate the rotor of generator converting mechanical energy of wheels into useful charge of battery. The regenerative braking system cannot be used as main braking system of vehicle as it cannot bring the vehicle to rest. Experimentation shows that minimum 11% battery energy can be recovered using the regenerative braking system which would otherwise be wasted to heat in friction brakes. Hence the distance travelled between two successive charging requirements can be increase to 10 to 15 % using this regenerative braking, when installed in actual vehicles.

Siddharth K Sheladia, Karan K Patel, V raj D Savalia, Rutvik G Savaliya, ‘A Review on Regenerative Braking Methodology in Electric Vehicle’, *International Journal of Creative Research Thoughts, Volume 6, Issue 1* (2018*). 2320-2882.*

In this paper [23] it is mentioned that Regenerative braking can save up to 5% to 8% of waste energy. The systems have been enhanced with advanced power electronic components such as ultra-capacitors, DC-DC converters (Buck-Boost) and flywheels. Ultra-capacitors, which help improve the transient state of the car during startup, provide a smoother charging characteristic of the battery and improve the overall performance of the electric vehicle system. Buck-boost converters help maintain power management in regenerative braking systems, such as boosting acceleration. Finally, flywheels are used to improve the power recovery process through automotive wheels.

We have learnt the recommendation and conclusion from the previous researcher and then we have utilized in our experiment. We have also changed the components and methods as the researcher suggested to make the experiment more practical and efficient.

Objectives

- To control the speed of the vehicle as well as to stop it quickly and efficiently without sticking.
- To reduce the reaction time of braking by using regenerative braking and generating power by converting kinetic energy into electrical energy.

CHAPTER 3

METHODOLOGY

3.1 DESIGN

3.1.1 Design consideration

Regenerative braking system may not suffice the basic requirement of braking system alone. This is because of limitation of energy dissipation at very high power. The storage and generation systems may not be capable to operate at those levels due to design limitations. Due to critical level of safety involved with the system, reliability becomes debatable and it necessitates a frictional braking system to co-exist with electrical regenerative braking system. [24] This forms a hybrid braking system [25], which means:

1. Just like hybrid propulsion systems, there can be many design configurations and control strategies.
2. Design and control of system should be such that they ensure vehicle's desired braking performance while at the same time capturing as much energy as possible.

During developing strategies, a careful consideration of braking behavior and its characteristics with respect to speed, braking power, deceleration rate etc. must be made.

3.1.2 Design procedure:

The design is done by using Creo software.

- ❖ Open the Creo software version 6.0.
- ❖ Go to the file select new, click on part-design, remove using default templates, then click ok.

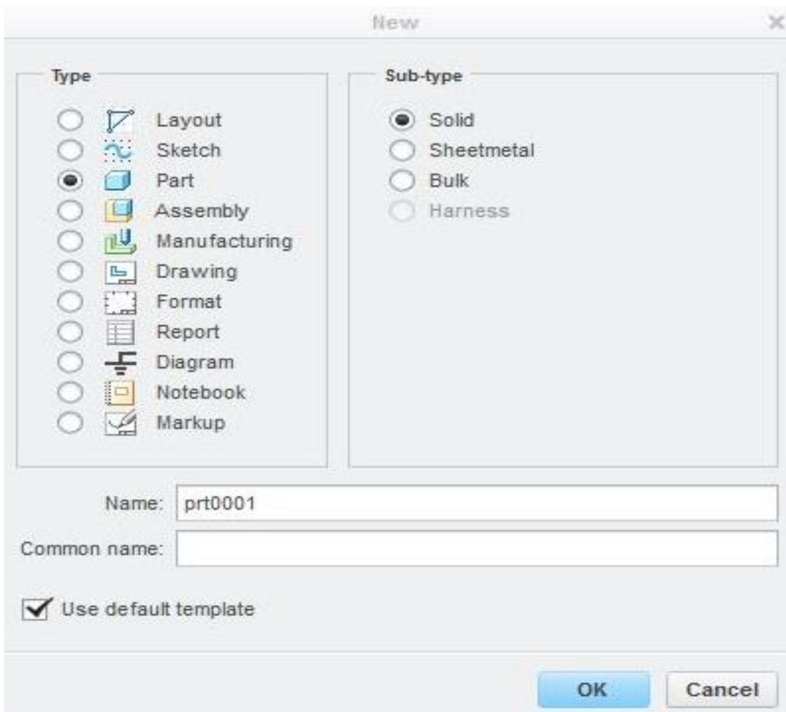


Fig. 3.1: Initialization of project.

- ❖ Go to the sketch, select the plane and click on the sketch view. Select the required commands.
- ❖ Go to the extrude command, select the object, give the required thickness, then click ok.

3.1.3 Design of Frame:

- ❖ Go to the sketch, select the front plane, sketch view.
- ❖ Select Rectangle command and draw the rectangle of 1000mm and breadth 800mm, click ok.
- ❖ Go to extrude command, select the object, give the thickness of plates 15mm, and click OK.
- ❖ Go to Framework and then make the joint as per the required.

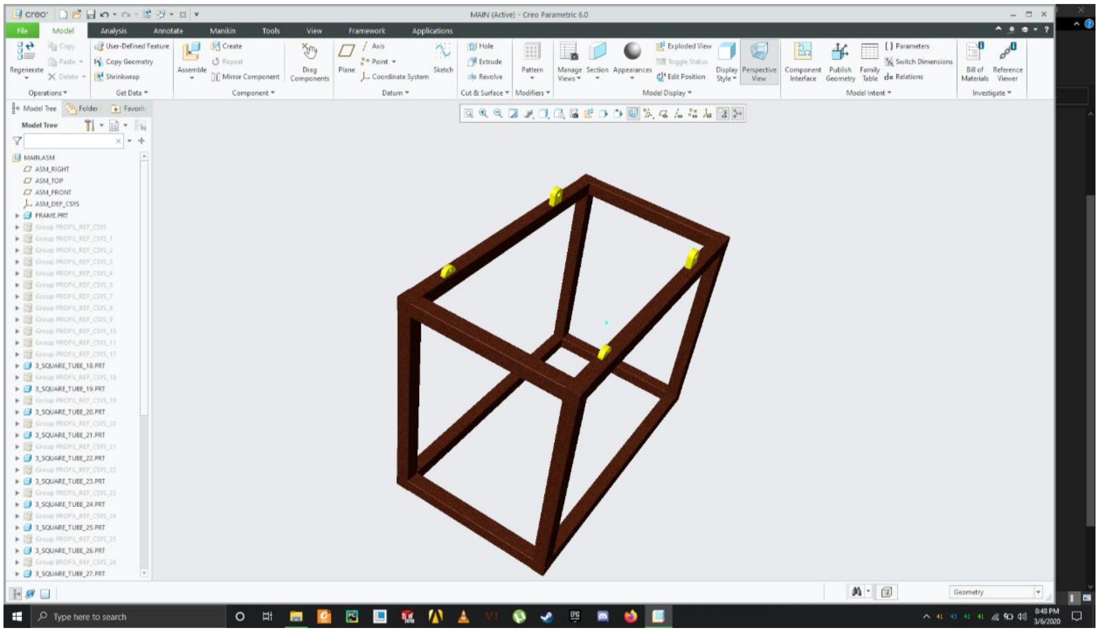


Fig. 3.2: Design of Frame.

3.1.4 Design of Pulley:

- ❖ Go to the sketch, select the front plane, draw an axis line, select line command and draw the 2D profile of pulley at one side of the plane with required dimensions, then click ok.
- ❖ Go to the revolve command, select the object then click ok.

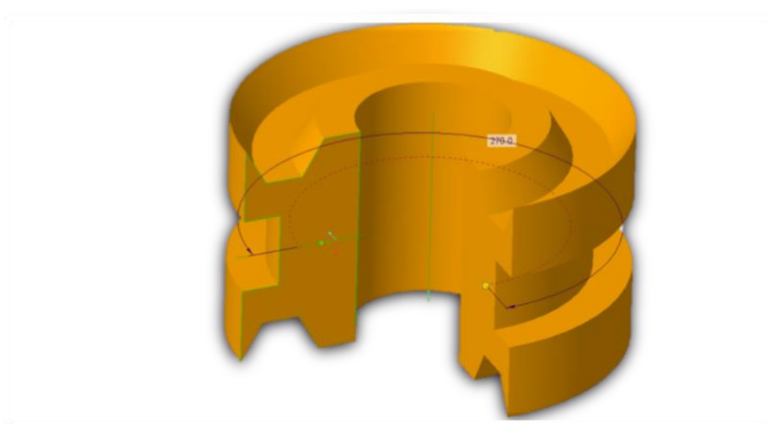


Fig. 3.3: Design of pulley.

3.1.5 Motor:

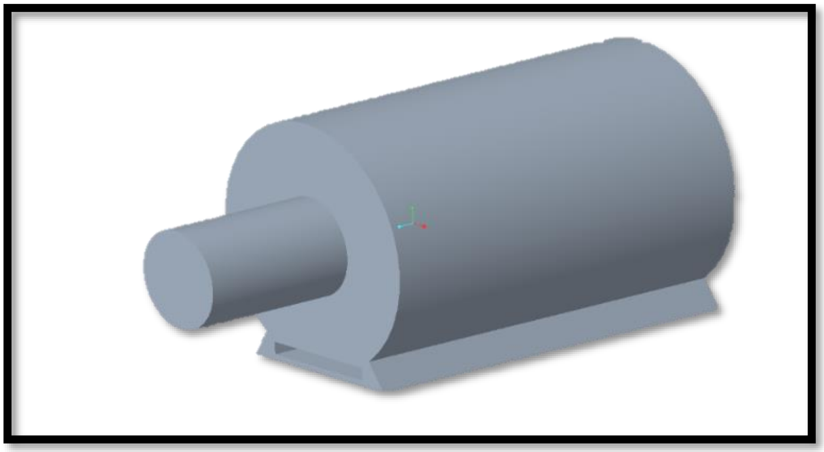


Fig. 3.4: Design of motor.

3.1.6 Bearing

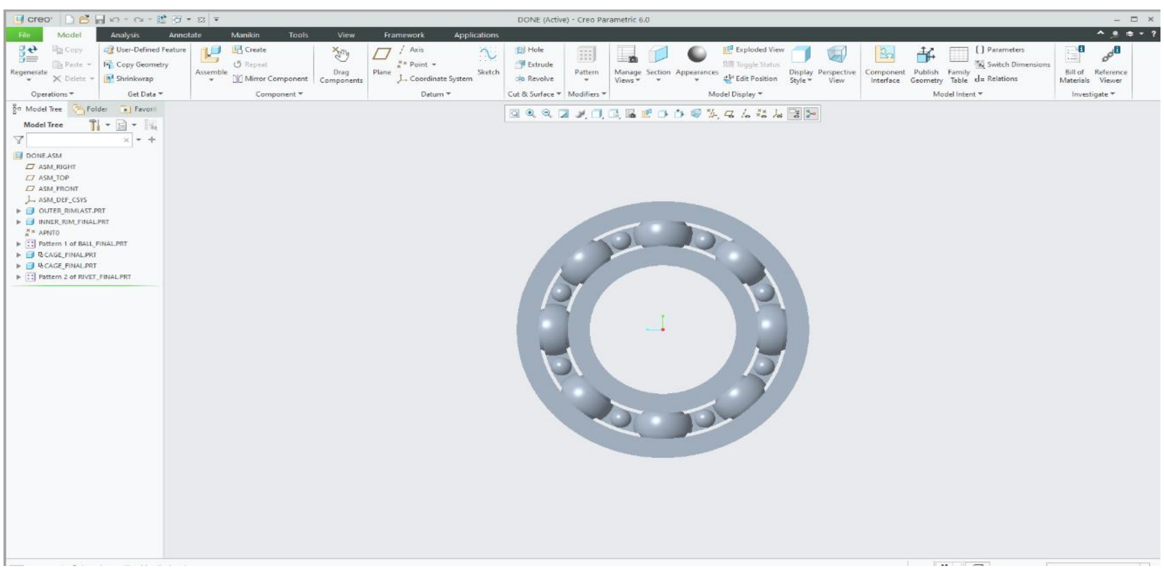


Fig. 3.5: Design of Bearing.

3.1.7 Assembly of parts:

❖ Go to the file, select new, select Assembly-part, remove use default templates, select mmns-ass-design then click ok.

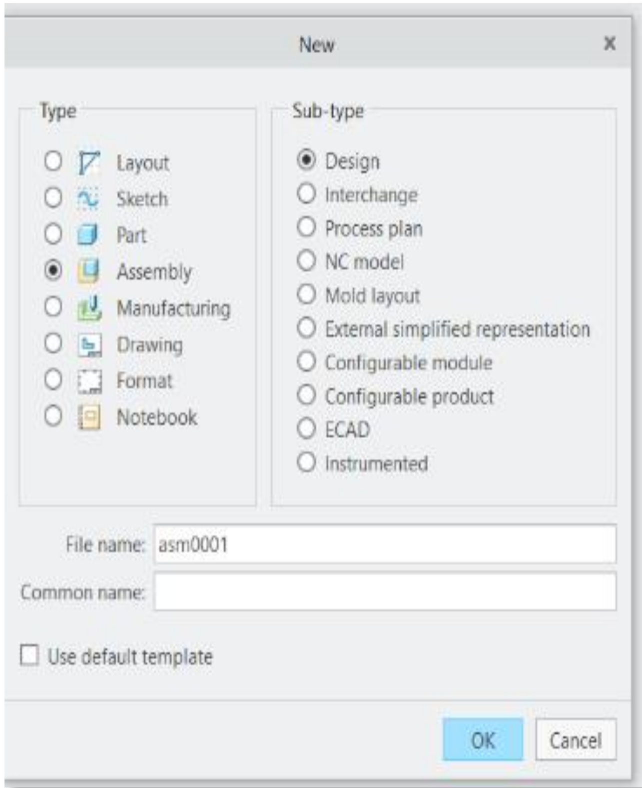


Fig. 3.6: Assembly Dialog box.

❖ Select the plane, click on assembly, and select the designed part from the files-open, click ok.

❖ Select another object, go to assembly, select another part drawing, give the required assembly reference and click on ok.

❖ The assembly reference can be

i. Coincident

ii. Normal

iii. Tangent

iv. Distance

v. Automatic

vi. Angle Offset

vii. Default

viii. Parallel

ix. Co-Planar

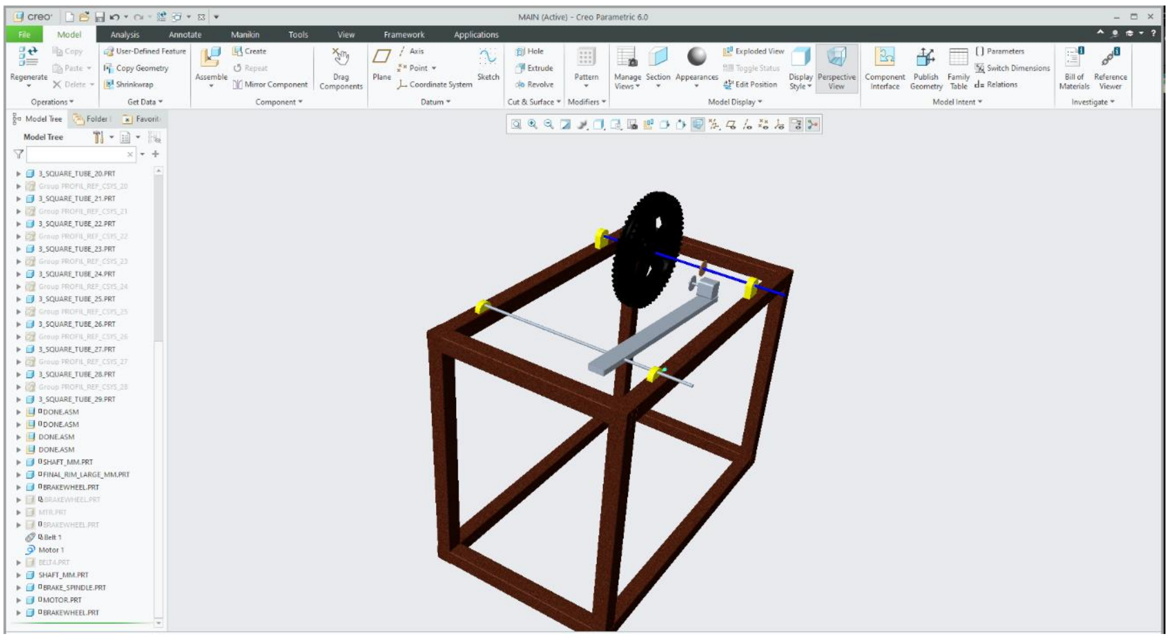


Fig. 3.7: Assembly of the Component.

3.1.8 Belt drive

- ❖ Go to the applications, select the mechanism, select belt command, click on the surface of the pulley and press ctrl and then select surface of another pulley, belt will appear, then click on OK.
- ❖ Go to connection click on belts then right click on the belt, select the make part option, give the file name as belt drive click ok, then click on empty click OK.
- ❖ Right click on the belt drive, and then activate the belt part, exit from the mechanism.
- ❖ Go to the model, select the sweep command, go to references click on details, press ctrl and select the belt part then click OK.
- ❖ Go to sketch, sketch view, click on references, select the reference point then close.
- ❖ Select the line command draw the profile of the belt then click OK.
- ❖ Go to the assembly part and make it activate.

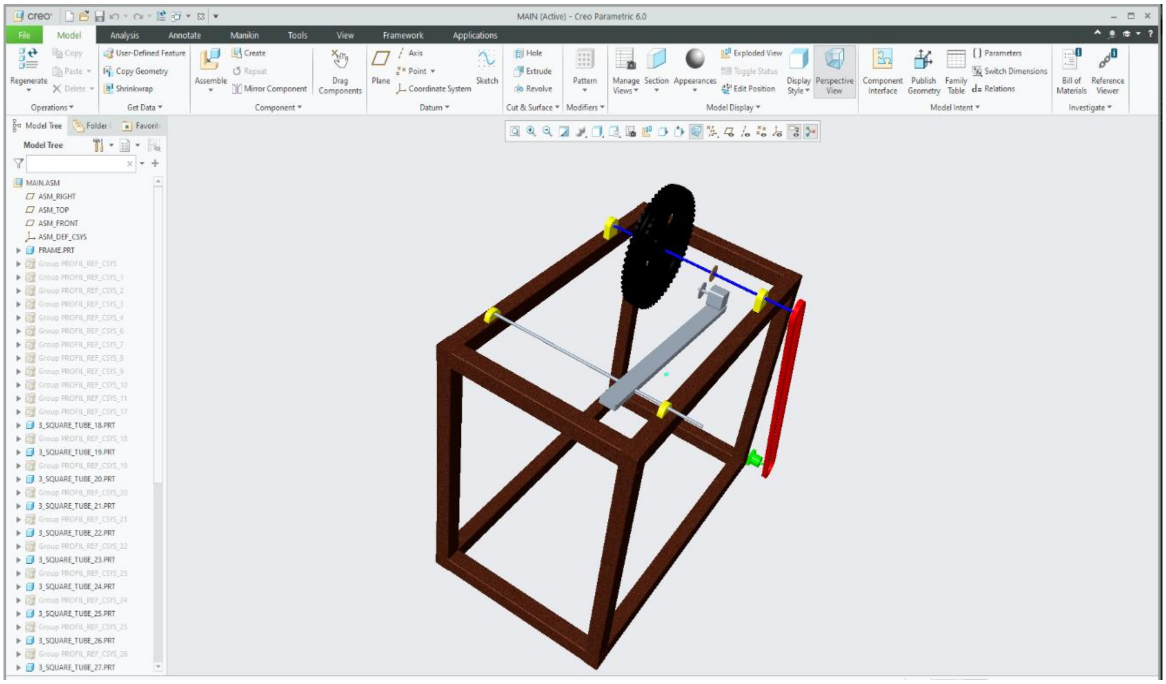


Fig. 3.8: Final assembly with belt drive Mechanism.

3.2 FABRICATION

3.2.1 List of Materials used in Fabrication

Sr. No	Name of Parts Used	Description	Quantity
1	Square bar	40*40 Hollow Bar (M.S)	8m
2	Journal Bearing	Internal Dia.12mm	2 piece
3	Brake Wheel	Outer Dia.8cm	1 piece
4	Solid Shaft	Outer Dia.12mm	1.5m
5	Bicycle Wheel	Inner Dia. 12 mm	1 piece
6	Brake Spindle	40*40 Hollow Bar (M.S)	0.6m
7	Sewing Machine Motor	9500 rpm	1 piece
8	Pulley	Internal Dia.12mm	2 piece
9	Pulley Rope	V-belt	0.5m
10	LEDs	12v	6 piece
11	Electric Wires	Copper wire	6m
12	D.C Motor	Brushed D.C 12v	1piece

Table 3.1: List of Materials

3.2.1.1 Square Bar

These were used in order to build a frame. The Solid bar was of mild steel and was welded into a square frame.

Fig 3.9: Square Bar.

3.2..2 Solid Shaft

Solid shaft used was also of mild steel and were used in order to make the base for the wheel and the brake spindle. The wheel was fitted on the shaft. One of the shafts was connected to the electric motor with the help of pulley and pulley rope. Once the motor starts the motion is transferred from the motor to the pulley and from the pulley to the shaft which rotates the wheel.

Fig 3.10: Solid Shaft.

Name of materials	**Young's Modulus(Gpa)**	**Density(Kg/m^3)**	**Poisions Ratio**
Mild Steel	210	7800	0.3

Table 3.2: Properties of Mild Steel

3.2..3 Plummer block

Plummer block is a device with an anti-friction bearing in it, which helps any solid shaft to have rotational movement while holding the outer ring in stationary position. The Plummer block used in the project is of inner diameter 12 mm. The solid shaft is inserted in the bearing which is used for rotational movement in the shaft.

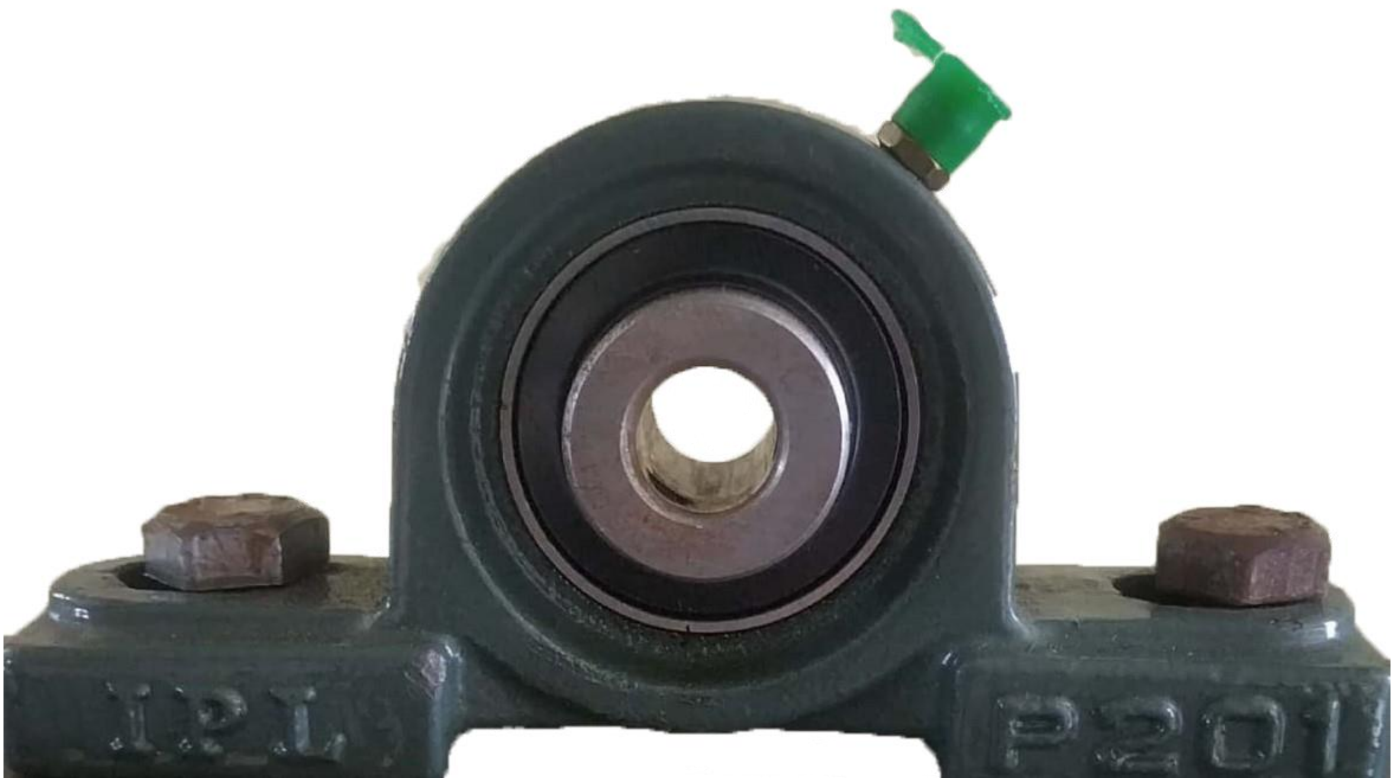


Fig 3.11: Plummer block

3.2..4 Bicycle Wheel

The Bicycle wheel used here is a representation of the wheel of automobile or vehicle. It is used in order to show how the movements takes place and brakes are applies to a normal vehicle. The Bicycle wheel is rotated using the pulley and motor connected with the belt.

Fig 3.12: Bicycle Wheel.

3.2..5 Brake Wheel

The brake wheel is used to stop the movement of the shaft. The brake wheel is connected on the shaft and has internal dia. of 12mm.The Brake wheel is made of Polyvinyl Chloride (PVC).

Fig 3.13: Brake Wheel.

3.2..6 Brake Spindle

The brake spindle contains a small gear mounted in the tip of the motor. The gear on the brake spindle meshes with another gear on the brake wheel gear and then slows down the movement of the shaft.

Fig 3.14: Brake Spindle.

3.2..7 Sewing Machine Motor

The Sewing Machine Motor is of 220V A.C having the max. speed of 9500 rpm. The tip of the motor has small pulley where the belt is connected. The motor has an acceleration system which is used to increase and decrease the speed as per requirements.

Fig 3.15: Sewing Machine Motor

3.2..8 Pulley

The pulley is used in order to transfer the rotatory motion of the motor to the shaft. The pulley used has an internal diameter of 12 mm. Pulleys are connected through the belt.

Fig 3.16: Pulley

3.2..9 Pulley Rope

The pulley rope is used in order to transfer the power from the motor to the shaft.

Fig 3.17: Pulley Rope

3.2.1.10 LEDs

These are used in order to show the power generated from the regenerative brakes.

Fig 3.18: LED

3.2..10 Electric Wires

The inner wire is made of with copper and it is insulated. They are used in order to transfer the power from the motor to the LEDs.

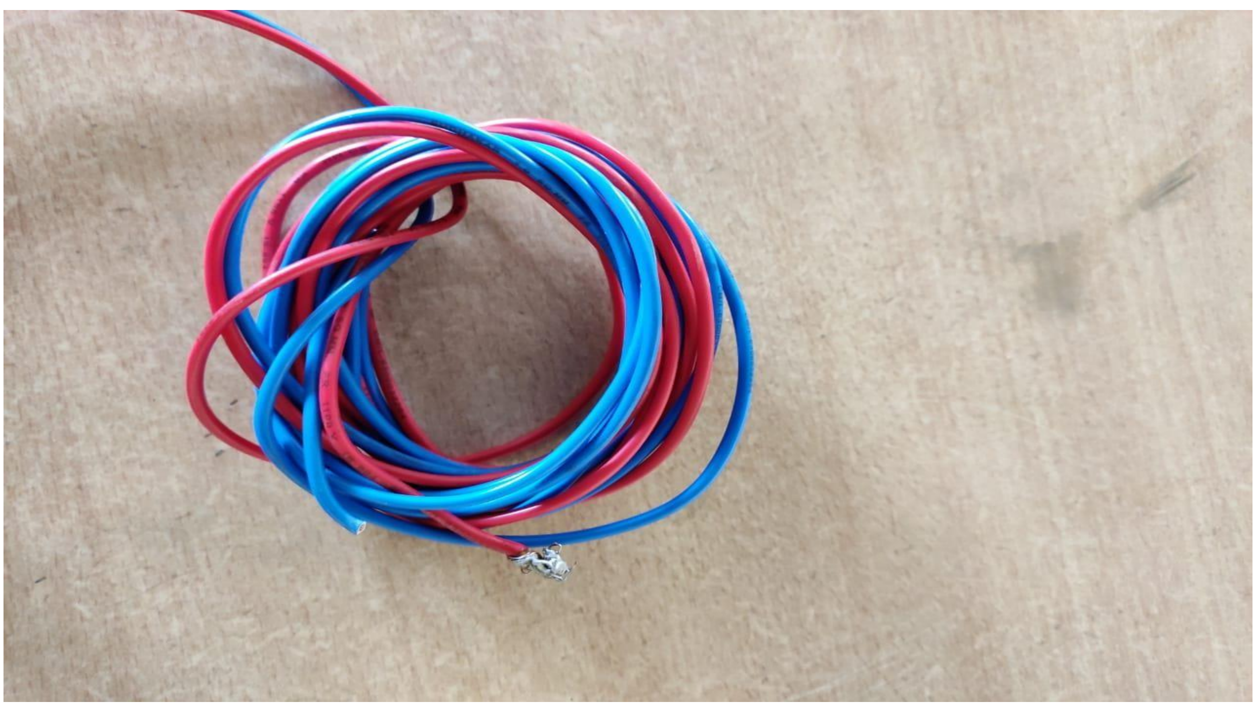


Fig 3.19: Wire

3.2..11 Brushed D.C Motor

This motor is used as Dynamo. The motor tip is connected to the gear and when the gear meshes with the brake wheel gear, the motor spindle rotates. The rotating spindle has kinetic energy and due electro-magnetic force the kinetic energy is converted into electrical energy. The motor has the capacity of 12v.

Fig 3.20: Brushed D.C Motor

3.3 Equipments used in Fabrication:

❖ Drilling

Drilling is a metal removal process that uses a drill bit to cut or enlarge a hole of circular cross-section in solid materials. The drill bit is a rotary cutting tool, often multipoint. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work piece, cutting off chips from what will become the hole being drilled.

Fig 3.21: Drilling Machine

❖ **Metal-Cutting**

Metal cutting is a process by which the excess metal is removed by the workpiece in the form of chips. There process we used in order to get the workpiece of the required dimension was by using a hacksaw blade.

Fig 3.22: Hacksaw.

The square bar was cut in angle at 45° to join the bar and create a frame which is later welded together to form the base of the model.

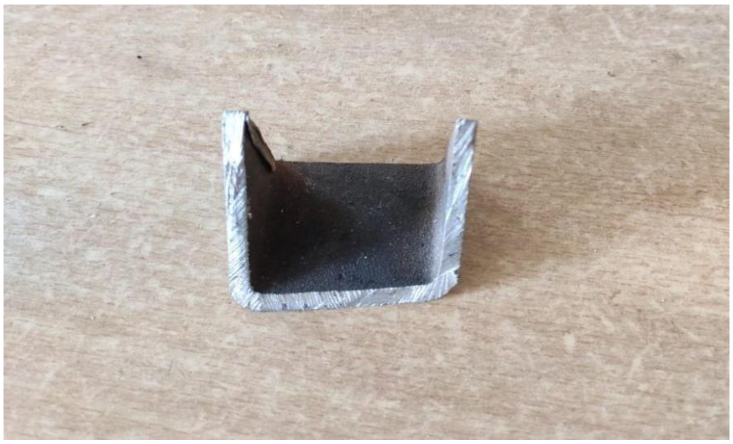


Fig 3.23: Angle chip from the square bar.

❖ Arc-Welding

Arc welding is the fusion of two pieces of metal by an electric arc between the pieces being joined to the work pieces by an electrode that is guided along the joint between the pieces. The electrode is either a rod that simply carries current between the tip and the work, or a rod or wire that melts and supplies filler metal to the joint.

The basic arc welding circuit is an alternating current (AC) or direct current (DC) power source connected by a "work" cable to the work piece and by a "hot" cable to an electrode. When the electrode is positioned close to the work piece, an arc is created across the gap between the metal and the hot cable electrode. An ionized column of gas develops to complete the circuit.

Basic Welding Circuit

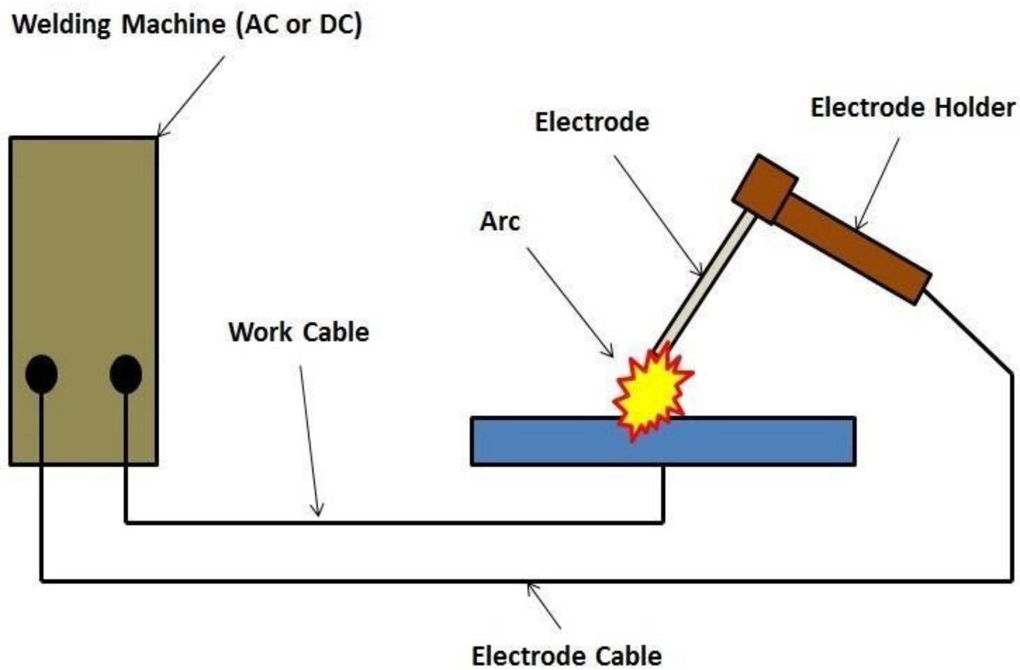


Fig 3.24: Basic Welding Circuit [23]

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 types of electrodes.

- ❖ Consumable electrode tips melt, and molten metal droplets detach and mix into the weld pool.
- ❖ Non-consumable electrodes do not melt. Instead, filler metal is melted into the joint from a separate rod or wire.

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

- ❖ First the square bar is cut into an angle of 45 degree and then welded together in order to form a square frame.
- ❖ The square bar is welded at each corner to form a table like structure.
- ❖ The flat mild steel plate is drilled and welded in the square bar to hold the solid shaft for brake spindle.
- ❖ The Plummer block is fitted over the flat plate welded on the square frame.
- ❖ Solid shaft is inserted in the Plummer block upon which the bicycle wheel and brake wheel and pulley are fitted.
- ❖ On the Frame the motor is welded.
- ❖ The power of the motor is transmitted to the Bicycle wheel by the joining the pulley and motor with a belt.
- ❖ The brake wheel is fixed at the tip of the Geared D.C motor which is fixed upon the brake spindle.

- The L.E.Ds is fixed on the square frame.
- The output of the Geared D.C motor is connected to L.E.Ds through copper wire.
- The small wheels are placed on the legs to give movements to the Assembly.
- The Entire Assembly is coloured with Red and black Paint to protect form Rust.

Precautions used during Fabrication

- The Apron is worn at every process during Fabrication.
- Face shield and welding gloves are used during the welding process.
- Proper coolant is supplied during the Drilling process.
- Gloves are used to project hands during the Grinding process.
- The materials were handled very carefully during the Fabrication.

Final Fabrication

Fig. 3.25: Final Fabrication

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

After the successful testing, the model is operated and the results obtained in various loading condition are noted and tabulated below.

4.2 Result table

S.N	RPM before brake pedal pressed	RPM after brake pedal pressed	Voltage output
1	500	480	9.34
2	900	870	10.88
3	1300	1260	11.81
4	1700	1650	12.91
5	2100	2040	13.49
6	2300	2270	13.89
7	2500	2460	14.49

It can be seen from the result tables that the efficiency of the regenerative braking systems using D.C Motors increases as the angular velocity of the motor increases and hence the regenerative braking systems are more efficient as higher angular velocities and the recoverable energy increases with increase in the motor speed. The losses are higher at lower speed because the motors are inefficient at lower speeds, whereas the losses at higher speeds are mainly mechanical losses like friction losses and air drag.

4.3 Discussion

With the markets for hybrid, electric and highly efficient, low emission conventionally- powered vehicles set to grow rapidly, the pace of development of regenerative braking systems looks similarly set to increase. The two key barriers to the market for battery- electric vehicles (BEVs) are currently their high cost (particularly of the battery packs) and limited range. For system developers, future challenges will include reducing costs, increasing vehicle range and meeting stricter safety and emissions standards. The braking regulation will need to be applied to advanced systems that not only stop the vehicle but recover lost braking energy.

In summary, the analysis suggests that current, “first-generation” regenerative braking systems do not compromise braking safety. The tests carried out on one such system, fitted to a hybrid vehicle, did not raise any safety issues. The primary determinant of how powerful the regenerative braking system might be the power capacity of the battery or other energy storage device/system, that is its ability to quickly convert the kinetic energy of the vehicle into its stored form.

Basic mechanical engineering theory suggests for current systems, which can only operate at quite low power levels (< 30KW, say), the regenerative braking component is likely to be quite small, particularly at high speeds. Such systems thus need a substantial additional source of braking torque for medium-high deceleration stops from such speeds, i.e. a conventional friction-braking system.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The regenerative braking system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. The regenerative braking system is designed to partially recover the battery charge wasted in braking of the vehicle. The energy is converted into heat by friction brakes which are dissipated to the environment. This Energy is utilized to rotate the rotor of generator converting mechanical energy of wheels into useful charge of battery. The regenerative braking system cannot be used as main braking system of vehicle as it cannot bring the vehicle to rest.

Experimentally it is found that, on increasing the speed of the wheel (rpm) the voltage generated will also be increasing and vice-versa. As others researchers had used stepper or servo motors as regenerative motor, so in this project, it is replaced with D.C motor. motor with gear. It has been found that the voltage generated by the D.C motor with gear is higher than that of voltage produced by those two motors.

Hence, if this system is installed in the actual vehicles minimum 11% battery energy can be recovered using the regenerative braking system which would otherwise be wasted to heat in friction brakes. So the distance travelled between two successive charging requirements can be increase to 10 to 15 % using this regenerative braking.

5.2 Recommendations

As this project is completely based on the experimental test rig and if this system is applied in the current working vehicles there are may be some problems which may cause uncomfortable for drivers. As regenerative braking system don't provide braking at high speed so this system should be implemented with other forms of Braking system like Anti-Lock Braking System (ABS).

Implementing this system in the current working vehicle will increase the mass of the vehicle and occupies additional space. So this factor should be considered before design of the vehicle so that this factor could be overcome.

Integrating regenerative braking into a vehicle requires some changes in the driving style which depends on the technical configuration of the system. This takes some time getting used to, but studies have shown that drivers respond positively and try to maximize the energy they can recapture and hereby extend their range.

Additionally, the usage of regenerative braking is closely linked to eco-driving. If eco-driving strategies are applied by a large number of drivers, this could have considerable effects on traffic flow.

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