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Determination of Maximum Efficiency of a Fabricated Regenerative Breaking System

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ABSTRACT
The increasing emphasis on sustainable transportation and energy efficiency has led to the advancement of regenerative braking technologies. This study presents the design and fabrication of a regenerative braking system (RBS) aimed at enhancing energy recovery in small-scale electric and hybrid vehicles. The proposed system integrates a mechanical braking setup with an electromechanical energy conversion unit, wherein kinetic energy typically dissipated as heat is captured and converted into electrical energy via a DC motor operating in generator mode.A comprehensive design methodology was employed, encompassing system modelling, component selection, and energy storage optimization. The fabricated prototype utilizes a flywheel-assisted DC generator and a battery bank for energy storage, regulated through a control circuit ensuring efficient energy capture and redistribution. Experimental validation demonstrates a significant improvement in energy efficiency and braking performance, with measurable reductions in energy loss and mechanical wear.The results indicate that regenerative braking not only improves overall vehicle performance but also contributes to long-term sustainability goals by reducing reliance on external charging and minimizing environmental impact. This research provides a foundational framework for scalable RBS implementations in future mobility solutions.

***Keywords*: Regenerative braking, energy recovery, electromechanical system, DC generator, energy efficiency, sustainable transportation, braking system design**

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 auto motive 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 a key feature in the advancement of electrified vehicles. It enables the vehicle to capture a significant portion of the kinetic energy that would otherwise be lost during braking or deceleration, allowing it to be reused for propulsion or auxiliary functions. This energy recovery mechanism can substantially reduce the overall energy consumption of electric and hybrid vehicles, especially in urban driving conditions, where frequent braking and acceleration are common.In commercial vehicle applications, two primary regenerative energy systems have been widely implemented: the Regenerative Braking System (RBS) and the Boost Recuperation System (BRS). Both systems aim to enhance energy efficiency, but they differ in their operational principles and integration strategies. While RBS focuses on energy capture during braking events, BRS typically operates during deceleration and utilizes advanced control logic to optimize energy recuperation across various driving scenarios.

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.

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1. Regenerative braking has the potential to improve the fuel economy of vehicles
2. It reduces emission of the vehicles
3. It improves fuel consumption by 33%

When a conventional vehicle applies its brakes, kinetic energy is converted to heat as friction between the brake pads and wheels. This heat is carries away in the airstream and the energy is effectively wasted the total amount of energy lost in this way depends on how often, how hard and for how long the brakes are applied. Regenerative braking refers to a process in which a portion of the kinetic energy of the vehicle is stored by a short-term storage system. Energy normally dissipated in the brakes is directed by a power transmission system to the energy store during deceleration. That energy is held until required again by the vehicle, whereby it is converted back into kinetic energy and used to accelerate the vehicle. The magnitude of the portion available for energy storage varies according to the type of storage, drive train efficiency, and drive cycle and inertia weight. A lorry on the way could travel 100 miles between stops. This represents little saving even if the efficiency of the system is 100%. City centre driving involves many more braking events representing a much higher energy loss with greater potential savings. With buses, taxis, delivery vans and so on there is even more potential for economy. Since regenerative braking results in an increase in energy output for a given energy input to a vehicle, the efficiency is improved the amount of work done by the engine of the vehicle is reduced, in turn reducing the amount of prime energy required to propel the vehicle. In order for a regenerative braking system to be cost effective the prime energy saved over a specified lifetime must offset the initial cost, size and weight penalties of the system. The energy storage unit must be compact, durable and capable of handling high power levels efficiently, and any auxiliary energy transfer or energy conversion equipment must be efficient, compact and of reasonable cost.

1.1 History of Regenerative Braking

The idea of a brake that could take the kinetic energy it absorbs and turns it into potential energy for later use has been around since the late 1800s. Some of the early attempts of this technology were to install spring type RBS on front-wheel-drive bicycles or horse-drawn cabs.

The Baku-Tbilisi-Batumi railway started applying RBS in the early 1930s. This is one example of the early use of this technology in the railway system. In the 1950s, Swiss company Oerlikon developed the gyro bus, which utilized flywheel as its energy storage method. The effects of gyroscopic motion on the bus soon resulted in it being discontinued. In 1967, the American Motor Car Company (AMC) created an electrical energy regeneration brake for their concept electric car, the AMC Amitron. Toyota was the first car manufacturer to commercialize RBS technology in its Prius series hybrid cars. Since then, RBSs has evolved to be used in almost all-electric and hybrid cars, as well as some gas-powered vehicles.

1.2 Principle of Regenerative Braking System

Law of conversation of energy states that the total energy of an isolated system cannot change it is said to be conserved over time. Energy neither be created nor be destroyed but it can be change from one form to another form. The most common form of regenerative brake involves using an electric motor as an electric generator. The generated electricity is fed back into the supply system, whereas in battery electric and hybrid electric vehicles, the energy is stored chemically in a battery.

1.3 Working Principle of Regenerative Braking System

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.

In regenerative braking mode, the car's engine slows down on an incline. When force is applied to the brake pedal, the vehicle slows down and the motor runs in the opposite direction. When operating in the opposite direction, the engine acts as a generator and Converts Torque energy into electrical energy. In this way, fuel consumption and emissions are reduced. In high-speed vehicles, the braking force is lower, and therefore does not adversely affect the traffic flow. This system uses the motor to drive an electric vehicle as well as to perform the braking function. The motor in this system has a dual function as a motor and generator. In one direction, it works like a motor whereas, in another direction, it works like a generator. Once the brake is applied then the motor runs in the opposite direction like a generator mode thus, wheels get slow down. So, the wheels generate the kinetic energy and the generator changes the energy from kinetic to electrical while rotating. After that, it transmits the generated electricity back to charge the batteries. This braking system uses multiple electronic circuits to select among the forward or reverse the direction of the revolution of the electric motor. In some situations, designers utilize capacitors to store the energy for afterward use. In an electric vehicle, a fully charged battery is very helpful because it expands its range of driving and also aids to recover the mileage. Regenerative braking is an energy recovery mechanism that slows down a moving vehicle or object by converting its kinetic energy or potential energy into a form that can be either used immediately or stored until needed.

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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. In regenerative braking mode, it uses the motor to slow down the car. When the driver applies force to the brake pedal, the electric motor works in reverse direction thus, slowing it

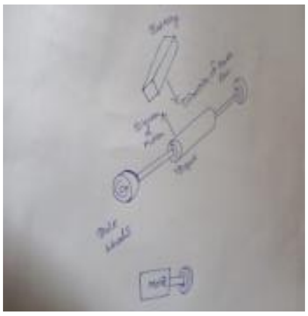


Fig 1.3.1 Normal forward driving

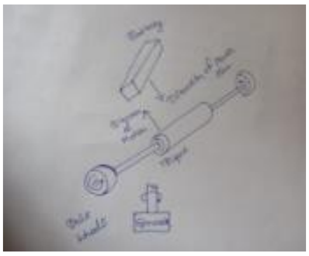


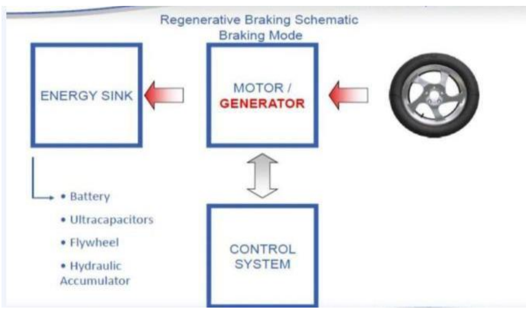
Fig 1.3.2 Regenerative action during braking

The figure (1.3.1) shows the car in normal running condition where the motor is producing torque by taking energy from the battery. While running backwards, the motor acts as a generator and recharges the batteries as shown in figure (1.3.2). By using regenerative braking, it vastly reduces the reliance on fuel, boosting fuel economy and lowering emissions.

1.4 Regenerative Braking Schematic Braking Mode

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 (1.4) Meanwhile in figure (1.4) shows the car in normal running condition whereas the motor turning forward and taken energy from the battery. By using regenerative braking, it vastly red 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. The regenerative braking system delivers a number of significant advantages over a car that only has friction brakes. In low-speed, stop- and-go traffic where little deceleration is required; the regenerative braking system can provide the majority of the total braking force.

This vastly improves fuel economy with a vehicle, and further enhances the attractiveness of vehicles using regenerative braking for city driving. At higher speeds, too, regenerative braking has been shown to contribute to improved fuel economy – by as much as 20%.



1.5 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:

1.5.1 Electromagnetic
1.5.2 Flywheel
1.5.3 Electromagnetic flywheel
1.5.4 Spring
1.5.5 Hydraulic
1.5.1 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

1.5.2 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

1.5.3 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.

1.5.4 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.

1.5.5 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 6 compressed fluids 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.

1.6 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.

1.7 Advantages of Regenerative Braking
1. Better Performance.
2. Cuts down on pollution related to supply generation.
3. Efficient Fuel Economy–The fuel consumption is reduced, dependent on the machine cycles, vehicle design, automation control plan, and the individual component's efficiency.
4. Reduced wear and tear of Engines.
5. Reduced Brake Wear– Cutting down the replacement brake linings cost, the cost of labor for installation, and machine downtime.
6. Reduced emissions–Cuts down on pollution related to power generation, engine decoupling reduces the total number of revolutions and thus engine emissions.
7. Smaller accessories – reducing fuel tank size and thus the weight.
8. Energy conservation.
9. This braking system will increase the vehicle's fuel economy.
10It permits for conventional brakes based on friction.
11. It extends the battery charge

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1.8 Disadvantages of Regenerative Braking

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.

1. High cost of components, engineering, and installation.
2. 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.
3. 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.
4. Added maintenance – Dependent on the complexity of the design.
5. Extra apparatus is necessary to manage the regeneration
6. Maintenance cost is high for protecting the apparatus as well as machines.

1.9 Applications of Regenerative Braking

1. Kinetic energy recovery mechanism.
2. Regenerative braking systems are used in electric elevators and crane lifting motors.
3. Also used in electric and hybrid cars, electric railway vehicles, electric bicycles, etc.

2 MATERIALS AND METHODS

Sl.No	Name of parts used	Description	Quantity
1	Plywood	55*40*10	1
2	Journal bearing	InternalDia10mm	1
3	Solid shaft	Diameter9mm	1
4	Wheel	15cm	1
5	Chain drive	25links	1
6	Braking system	Diameter4cm	1
7	Electric transformer	30volts	1
8	Electric wire	Copperwire2mm	2
9	LED Bulb	3volts	1
10	Dynamometer	Dc12volts	1
11	Brake pedal	Length10cm	1
12	Gears	6teeths	2
13	Regulator	5 speed	1
14	Portable drilling machine	To produce Holes	1
15	Electric saw cutter	For cutting	1

Table 2.1.1 list of components

2.1.1 Plywood

Plywood is a versatile engineered wood product made from thin layers of wood veneer, called plies or veneers, glued together. These layers are stacked perpendicular to one another, which enhances the strength and stability of the final product.

In the table 2.1.1. This was used in order to build as a base. And all the components are mounted or placed on ply wood.

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Fig 2.1.1: plywood

1. Composition: Plywood is typically made from hardwoods, softwoods, or a combination of both. Each layer of wood veneer is known as a ply. The number of plies used can vary, with more plies generally indicating a stronger and thicker plywood sheet.
2. Manufacturing Process: The manufacturing process involves peeling or slicing thin layers of wood from logs. These veneers are then dried, graded, and layered with their grains running perpendicular to one another. The layers are glued together using adhesives under high pressure and heat, resulting in a strong composite material.
3. Environmental Considerations: The sustainability of plywood production depends on the sourcing of the wood and the adhesive used in its manufacture. Many plywood manufacturers adhere to certification standards such as the Forest Stewardship Council (FSC) certification, which promotes responsible forest management practices.

2.1.2 JOURNAL BEARING

The purpose of a bearing is to support a load, typically applied to a shaft, whilst allowing relative motion between two elements of a machine. The portion of the shaft which is in actual contact with the bearing is known as journal. For every machine and engine, It is necessary to have a provision for the support of rotating shaft. Such support is called as bearing. In other words, shaft must be supported through bearing.

In the Fig 5.1.2. The bearing used in this project has an outer diameter of 10mm.

Fig 2.1.2: Journal Bearing

Basic Principle: A journal bearing, also known as a sleeve bearing, operates on the principle of hydrodynamic lubrication. When a rotating shaft is inserted into the bearing, a thin film of lubricant, usually oil, forms between the shaft and the bearing surface. This film of lubricant supports the shaft's weight and reduces friction and wear.

Components: A journal bearing typically consists of two main components: the stationary bearing housing and the rotating shaft. The bearing housing contains a cylindrical bore, known as the journal, which accommodates the shaft. The interface between the shaft and the bearing forms the lubricating film.

2.1.3 SOLID SHAFT

A solid shaft is a cylindrical rod or bar that has a constant diameter along its entire length. It is typically made of metal, such as steel or stainless steel, although other materials like aluminium or titanium may be used for specific applications.

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

Fig 2.1.3 solid shaft

Solid shafts are primarily used to transmit torque and rotation from one mechanical component to another. They can transfer power between various machine elements, such as gears, pulleys, sprockets, and couplings. Solid shafts are often employed in applications where high strength and rigidity are required.

Design Considerations:
Diameter: The diameter of a solid shaft is determined based on factors such as the amount of torque to be transmitted, the speed of rotation, and the desired level of stiffness and deflection.
Material Selection: Solid shafts are typically made from materials with high strength and good fatigue resistance to withstand the loads and stresses encountered during operation. Common materials include carbon steel, stainless steel, and alloy steel.
Surface Finish: The surface finish of a solid shaft is important for reducing friction and wear, as well as improving corrosion resistance. It may be polished, ground, or coated with materials like chrome or nickel.
2.1.4 Braking system:
Braking system is a crucial part of any vehicle, as it allows the driver to control the speed and bring the vehicle to a stop safely. There are several types of braking systems, each with its own components and functionality.

Fig 2.1.4 Braking system

2.1.5 DYNAMOMETER:
Device that converts mechanical energy into electrical energy. It's a type of generator that uses magnetic fields to generate electricity.
In the Fig 2.1.5. A dynamometer, often abbreviated as dyno, is a device used to measure and evaluate the force, torque, power, or speed characteristics of a machine or engine. Here's some information about dynamometers:

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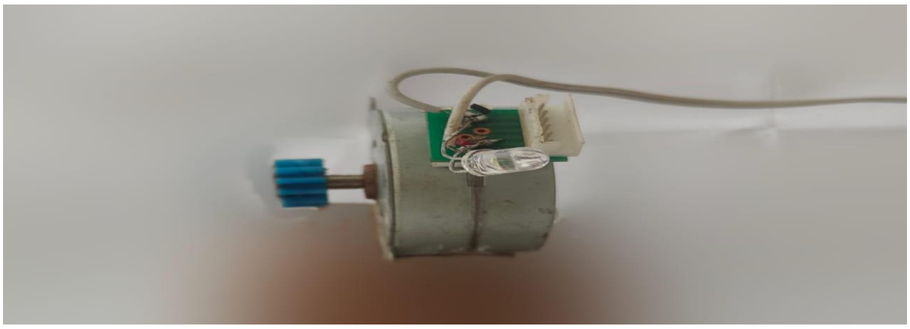

Fig 2.1.5 Dynamometer

2.1.6 WHEEL:

In the Fig 2.1.6. The Bicycle wheel used here is a representation of the wheel of automobile or vehicle. It is used in order to show how the movement takes place and brakes are applies to a normal vehicle. The Bicycle wheel is rotated using the pulley and motor connected with chain.

Fig 2.1.6 wheel

2.1.7 CHAIN DRIVE:

A chain drive is a mechanism used to transmit power and motion between two or more rotating shafts via a looped chain. Here's some information about chain drives.

Fig 2.1.7 chain drive

Chain drives transmit power from one shaft to another by transferring torque through the meshing of the chain and sprockets. They are commonly used in applications where a high torque transmission is required, such as in industrial machinery, bicycles, motorcycles, and agricultural equipment.

By using sprockets of different sizes, chain drives can be used to achieve speed reduction or increase between the input and output shafts. This makes them versatile for a wide range of applications with varying speed requirements.

2.1.8 ELECTRIC TRANSFORMER:

In the simplest of terms, a transformer is an electrical device that takes a given input voltage and changes it to a different output voltage. This change can either be an increase or a decrease in voltage.

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The basic principle behind working of a transformer is the phenomenon of mutual induction between two windings linked by common magnetic flux. The figure at right shows the simplest form of a transformer. Basically, a transformer consists of two inductive coils; primary winding and secondary winding.
In the Fig 2.1.8. DC output of 12 volts and 3 amps, you'd need a power adapter or power supply that can provide at least 12 volts DC and 3 amps of current. These are commonly used to power various electronic devices.

Fig 2.1.8 Electric Transformer

2.1.9 LED BULB:
In the Fig 2.1.9. LED bulb is used as a indicator in regenerative braking system, white colour LED bulb requires 3 volts for lightening. LED indication bulbs consume significantly less power compared to traditional bulbs, making them energy-efficient and cost-effective.

Fig 2.1.9 LED Bulb

- LED bulbs have a much longer lifespan compared to incandescent or fluorescent bulbs, often lasting tens of thousands of hours. This reduces the need for frequent replacement and maintenance.
- Instant On/Off LEDs illuminate instantly when powered on and do not require warm-up time, providing immediate indication.
- Wide Operating Voltage Range of LED indication bulbs can operate over a wide range of voltages, making them suitable for various applications.
- Compact Size of LED bulbs are available in small sizes, allowing for compact and space-saving designs.
- High Visibility of LEDs offer bright and uniform illumination, making them highly visible even in bright ambient light conditions.

2.1.10 ELECTRIC WIRES:
In the Fig 2.1.10. Electrical wire is used for power distribution to transmit electricity from a transformer or other source to an outlet, appliance, device, cable, switch, distribution board, socket, and light fitting. They conduct electricity and provide a low-resistance path for electricity to flow through.

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Fig 2.1.10. Electric wires

- Electric wires are conductive materials used to transmit electrical power or Signals from one point to another in electrical circuits. Here's some information about electric wires.
- The core of the wires typically made of a conductive material such as copper, aluminium, or a combination of both (aluminium alloy). Copper is the most common conductor material due to its high conductivity and corrosion resistance.
- The conductor is usually surrounded by an insulating material to prevent electrical leakage and provide protection against contact with other conductors or external elements. Insulation materials can include PVC (Polyvinyl Chloride), XLPE (Cross-Linked Polyethylene), rubber, Teflon (Poly tetra fluoro ethylene), and others.

2.1.11 REGULATOR:

- A voltage regulator is a circuit that creates and maintains a fixed output voltage, irrespective of changes to the input voltage or load conditions. Voltage regulators (VRs) keep the voltages from a power supply within a range that is compatible with the other electrical components.
- There are two main types of voltage regulators: linear and switching. Both types regulate a system’s voltage, but linear regulators operate with low efficiency and switching regulators operate with high efficiency. In high-efficiency switching regulators, most of the input power is transferred to the output without dissipation.
- In the Fig 2.1.11. A regulator, in the context of electronics and engineering, refers to a device or system that controls or regulates a parameter to maintain it at a specific value.

Fig 2.1.11. Regulator

- A voltage regulator maintains a stable output voltage regardless of changes in input voltage or load conditions. It ensures that electronic devices receive a constant and reliable supply voltage, preventing damage and ensuring proper operation.
- A current regulatory control the flow of electric current in a circuit, ensuring that it remains constant despite changes in voltage or load conditions. Current regulators are commonly used in LED drivers, battery charging circuits, and motor control applications.
- A pressure regulator maintains a constant output pressure in a fluid system by adjusting the flow of fluid to compensate for changes in input pressure or demand. Pressure regulators are used in various applications such as gas distribution, hydraulic systems, and pneumatic systems.
- A temperature regulator maintains a desired temperature by controlling the heating or cooling process in a system. Thermostats, for example, are temperature regulators commonly used in HVAC systems, refrigerators, ovens, and water heaters.

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2.1.12 Portable Drilling Machine:

- In the Fig 2.1.12. 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. The forces the cutting edge against the work piece, cutting off chips from what will become the hole being drilled.
- Portable drilling machines are used in construction projects for drilling holes in concrete, masonry, and other building materials for installing anchors, fasteners, and fixtures.

Fig 2.1.12. Portable Drilling Machine

Portable drilling machines, also known as handheld drills or hand drills, are versatile power tools used for drilling holes in various materials. Here's some information about portable drilling machines.

2.1.13. Electric Saw Cutter

Electric saw cutters, also known as electric saws or power saws, are versatile power tools used for cutting various materials such as wood, metal, plastic, and masonry. Here's some information about electric saw cutters.

In the Fig 2.1.13. The cutter is used to remove a material of wood. They are handheld or mounted on a table or track for more precise cuts. Circular saws are commonly used in construction,

3. FINAL FABRICATION AND CALCULATIONS

3.1 FINAL FABRICATION: Firstly, we collected all the parts according to our design and located the equipment position in plywood. All parts are fitted in the plywood by the nut and bolts, connected all the equipment as per our configuration. Make a circuit by connecting all parts with an electric wire. After connecting, give the power supply to the circuit and check the all equipment's are working/not. After conforming, test the equipment as per our design and fabrication.

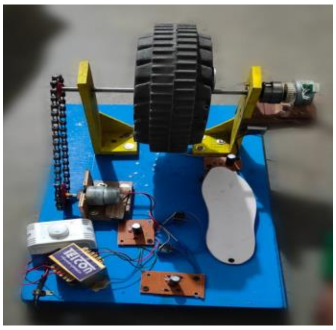

Fig 3. Final design and fabrication of regenerative braking system

3.2 Result &Discussion:

3.2.1 Chain drive Efficiency

EFFICIENC$(\eta) = \frac{OUTPUT\ POWER}{INPUT\ POWER}$

1. At First Stage (η_1) = 72/84 =85%
2. At Second Stage (η_2) =171/193 =88%
3. At Third Stage (η_3) = 226/260 =86%
4. At Fourth Stage (η_4) =250/280 =89%
5. At Fifth Stage (η_5) = 264/308=85%
6. Average $(\eta_{avg}) = (85 + 88 + 86 + 89 + 85)/5 = 87\%$

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3.2.2 MOTOR SPECIFICATIONS

Current (I) =5 amp
Voltage (V) =16 V
Torque (T) =8.2 kg*cm
=8.2*9.81*1/100
T = 0.80442 Nm

Efficiency of the Motor (H) = Mechanical Output Power / Electrical Input Power

Efficiency of the Motor $(\eta_{motor}) = \frac{P_M}{P_E} = \frac{T\times\omega}{V\times I} = 82\%$

3.2.3 ANGULAR VELOCITY OF THE MOTOR AT DIFFERENT STAGES

1. ω_1=0.82×5.68/0.80442 =5.79 rad/sec
2. ω_2=0.82×15.09/0.80442= 15.38 rad/sec
3. ω_3=0.82×25.00/0.80442= 25.49 rad/sec
4. ω_4=0.82×32.41/0.80442 = 33.03 rad/sec
5. ω_5=0.82×43.66/0.80442 = 44.51 rad/sec

3.2.4 EFFICIENCY OF THE MOTOR AT DIFFERENT STAGES

1. At First Stage (η_1) = 0.80442×5.79/5.68 = 81.54%
2. At Second Stage (η_2) =0.80442×15.38/15.09= 81.98%
3. At third stage (η_3) = 0.80442×25.49/25.00= 81.99%
4. At fourth stage (η_4) = 0.80442×33.03/32.41=81.99%
5. At fifth stage (η_5) = 0.80442×44.51/43.66= 81.98%

3.2.5 Motor Efficiency

S.NO	CURRENT (I)in Amps	VOLTAGE (V)in volts	POWER (P)in watts	RPM	PM	PE	EFFICIENCY (η)
1	0.8	7.10	5.68	72	4.632	5.68	81.54%
2	1.354	11.15	15.09	171	12.304	15.09	81.53%
3	1.832	13.65	25.00	226	20.392	25.00	81.56%
4	2.190	14.80	32.41	250	26.43	32.41	81.54%
5	2.892	15.10	43.66	264	35.60	43.66	81.53%

Table 3.1: Motor Efficiency

Total power consumed (P total) =121.858 watts

Total Power for Two Led Bulbs = 2(0.5×2) = 2 watts

3.2.6 Developed energy

S.NO	RPM	CURRENT	VOLTAGE	POWER
1	52	0.51	2.07	1.055
2	126	0.51	4.3	2.193
3	284	0.51	5.4	2.754
4	320	0.51	6.2	3.162
5	335	0.51	7.04	3.5904

Table 3.2: Developed Energy

Total Power Developed = 12.7551 Watts
One Led Bulb = 0.51×2 = 1.02 Watts
Developed Energy = 12.755 Watts
Power of LED Bulb = 1.02 Watts
Total Generated Energy = 13.775 Watts
Total Power Supply (P) = I×V = 3×16 = 48 Watts
P= 3×57.286= 171.858 Watts

Efficiency of the System:

η_{SYSTEM} = 121.858+13.775/171.858+2 = 0.7265
η_{SYSTEM}= 72.65%

Efficiency of the Regenerative System:

Regenerative system ($\eta_{REGENERATIVE\ SYSTEM}$) = 13.775/52 = 26.49%
Therefore, the Final Efficiency of Total System: 72.65%
Final Efficiency of the Regenerative Braking System: 26.49%

4. CONCLUSION AND FUTURE SCOPE

4.1 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.

4.2 Future Scope:

Supplied power of system should be less when we use generated energy as input of the system.

Regular lubrication will give more efficient work.

By reducing the shocks in the system, we can improve the efficiency.

By placing the controlled gear drive we can achieve the maximum efficiency.

By installing it in hybrid electric vehicles we can improve the vehicle efficiency.

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