FABRICATION OF REGENERATIVE BRAKING SYSTEM

A Project report submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

Submitted by

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CERTIFICATE

This is to certify that the Project Report entitled **"FABRICATION OF REGENERATER BREAKING SYSTEM"** being submitted by VANDRANGI SAI SWAROOP (317126520119), PERLA LAXMI VARA PRASAD (318126520L16), MOHAMMED ASLAM (317126520098), PANGI PAVAN KUMAR (318126520L22), in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING, ANITS**. It is the work of bona-fide, carried out under the guidance and supervision of **MR.B.G.CHANDRA SEKHAR**, Assistant Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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ABSTRACT

Regenerative braking system is the system in which the kinetic energy of the vehicle is stored temporarily; during deceleration and is reused as kinetic energy. Regenerative braking is a step to reduce the use of fossil fuels.

While braking, a large amount of energy is lost in the form of heat. A regenerative braking system aims to utilize this energy instead of getting it wasted.

In this mechanism, the electric traction motor uses the vehicle's momentum to recover energy lost while braking. This contrasts with the conventional braking system, where the excess kinetic energy gets converted to unwanted heat and is wasted due to friction in the brakes, or with dynamic brakes. In most of the regenerative braking systems the energy is recovered by using electric motors as generators.

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CHAPTER - I

INTRODUCTION

1.1 INTRODUCTION

Brakes are employed to stop or retard the motion of any moving body. In an automobile, brakes are equally important as the engine.

In **a conventional braking system,** the motion is retarded or stopped by absorbing kinetic energy by friction; by making the contact of the moving body with a frictional rubber pad (called brake liner) which causes the absorption of kinetic energy. This energy dissipates as heat into surroundings. Each time brakes are applied, the momentum gets absorbed to re-accelerate, the vehicle has to start from scratch, redeveloping it using power from the engine. Thus, it will ultimately result in the wastage of energy.

A regenerative brake is an energy recovery mechanism that slows a vehicle by converting its kinetic energy into another form, which is used immediately or stored until needed. Thus, the generated energy during the braking is sent back into the supply system (in the case of electric trains), whereas, in battery electric and hybrid electric vehicles, the energy is stored in a battery or bank of capacitors for later use. Energy can also be stored by compressing air or in a rotating flywheel.

There are many existing applications of regenerative braking

1. Many metro trains across the globe, are equipped with regenerative braking which returns about 25% of the electrical energy to the power source.

1. The Škoda transportation is producing electric trams equipped with regenerative braking system; which are widely being used across Europe.

2. Some of vehicles using regenerative brake:-
    a) The electric car manufacturing giant, TESLA, equipped most of its models with regenerative braking system.
    b) Audi E-TRON, BMW I8
    c) MG ZS EV and HYUNDAI KONA
    d) Toyota Prius
    e) Ford FUSION

The concept of this regenerative brake is better understood from a bicycle fitted with a Dynamo. If a bicycle is fitted with a dynamo (a small electricity generator) for powering the lights, it's harder to peddle when it is engaged than disengaged. That's because some of the energy is being "used" by the dynamo which gets converted into electrical energy used for lighting. If a bicycle, going with a particular velocity, stops peddling followed by turning on the dynamo, it'll stop the vehicle quicker than it would normally (without using brakes). Now imagine a bicycle with a bigger and powerful dynamo equipped with a battery. It will bring the bike to a halt relatively quickly by converting the kinetic energy into electricity which can be stored in a battery. This is the basic idea behind regenerative brakes.

Fig, 1.1: a bicycle with a dynamo

1.2 HISTORY

Early examples of this system were the front-wheel drive conversions of horse-drawn cabs by Louis Antoine Krieger in Paris in the 1890s. The Krieger electric landaulet had a drive motor in each front wheel with a second set of parallel windings (bifilar coil) for regenerative braking.

In 1908 the first car equipped with regenerative braking was patented by C.J. Paulson.

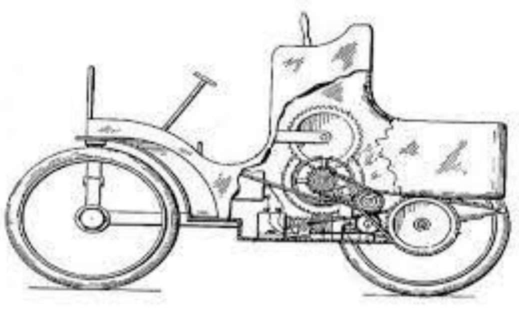


Fig 1.2: the first car patented for regenerative braking

In England, "automatic regenerative control" was introduced to tramway operators by John S. Raworth's Traction Patents 1903–1908, offering them economic and operational benefits as explained in some detail by his son Alfred Raworth. These included tramway systems at Devonport (1903), Rawtenstall, Birmingham, Crystal Palace-Croydon (1906), and many others. Slowing the speed of the cars or keeping it in control on descending gradients, the motors worked as generators and stopped the vehicles. The tram cars also had wheel brakes and track slipper brakes which could stop the tram should the electric braking systems fail. In several cases the tram car motors were shunt wound instead of series wound, and the systems on the

Crystal Palace line utilized series-parallel controllers. Following a serious accident at Rawtenstall, an embargo was placed on this form of traction in 1911; the regenerative braking system was reintroduced twenty years later.

Fig 1.3: an article in England about RBS in trains

In Scandinavia the Kiruna to Narvik electrified railway carries iron ore on the steeply-graded route from the mines in Kiruna, in the north of Sweden, down to the port of Narvik in Norway to this day. The rail cars are full of thousands of tons of iron ore on the way down to Narvik, and these trains generate large amounts of electricity by regenerative braking, with a maximum recuperative braking force of 750 kN. From Riksgränsen on the national border to the Port of Narvik, the trains use only a fifth of the power they regenerate. The regenerated energy is sufficient to power the empty trains back up to the national border. Any excess energy from the railway is pumped into the power grid to supply homes and businesses in the region, and the railway is a net generator of electricity.

Fig 1.4: the Kiruna - Narvik train equipped with RBS

Electric cars used regenerative braking since the earliest experiments, but this was often a complex affair where the driver had to flip switches between various operational modes in order to use it. The Baker Electric Runabout and the Owen Magnetic were early examples, which used many switches and modes controlled by an expensive "black box" or "drum switch" as part of their electrical system.

Improvements in electronics allowed this process to be fully automated, starting with 1967's AMC Amitron experimental electric car. Designed by Gulton Industries, the motor controller automatically began battery charging when the brake pedal was applied. Many modern hybrid and electric vehicles use this technique to extend the range of the battery pack, especially those using an AC drive train (earlier designs used DC power).

Fig 1.5: AMC Amitron car with RBS

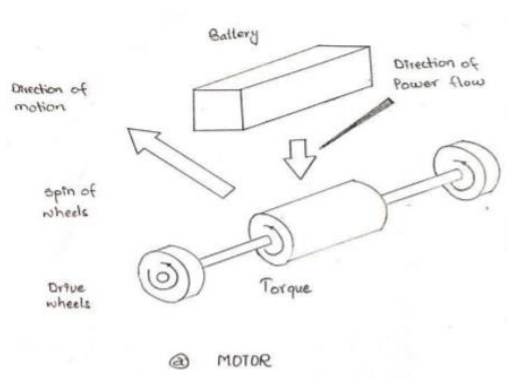
There are many existing applications of RBS in railways all over the world. In India, one of the oldest metro, the Delhi metro, is equipped with regenerative braking.

The Delhi Metro reduced the amount of carbon dioxide (CO_2) released into the atmosphere by around 90,000 tons by regenerating 112,500 megawatt hours of electricity through the use of regenerative braking systems between 2004 and 2007. It was expected that the Delhi Metro would reduce its emissions by over a million tons of CO_2 per year once its phase II was complete, through the use of regenerative braking.

Fig 1.6: Delhi metro equipped with RBS

1.3 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. 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.



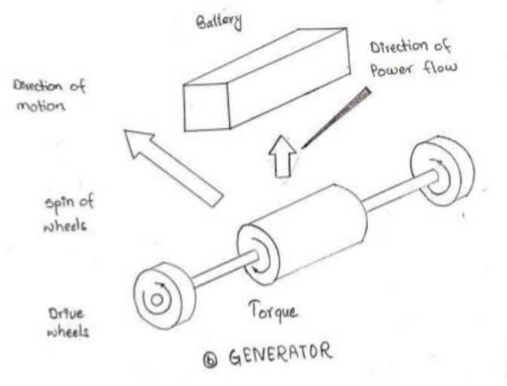


Fig 1.7: Normal forward driving

Fig 1.8: Regenerative action during braking

The figure (1.7) 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 (1.8). 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.

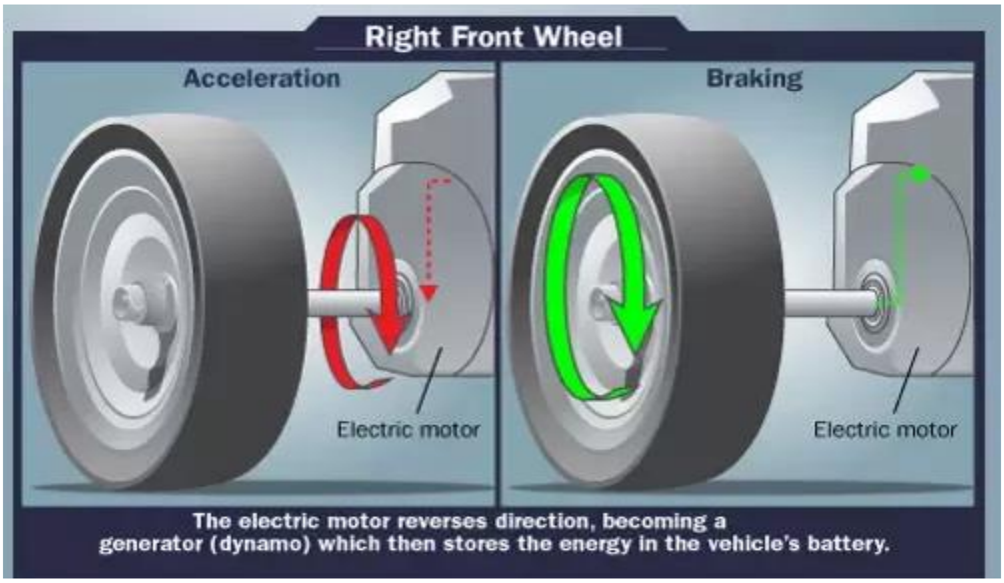


Fig 1.9: a simple representation of regenerative braking system

1.4 APPLICATIONS

Hybrid and Electric Cars:

Modern hybrid and electric cars both utilize an electric engine to power the car which makes applying regenerative braking very simple and efficient.

Fig 1.10: AUDI E- TRON

Fig 1.11: HYUNDAI KONA

Railways:

As regenerative brakes conserve a lot of energy, they are applicable in railways locomotives. Jaipur metro system uses the regenerative braking system and saves up to 35% of electric energy.

fig 1.12: DELHI METRO

fig 1.13: LONDON METRO

fig 1.14: SKODA TRAMS

Industrial applications:

Can be used in industries that use conveyor system to move material from one workstation to another and halt at a certain distance after a prescribed interval.

Fig 1.15: Regenerative braking integrated MACK trucks and E-CATERPILLAR

Other applications:

Regenerative braking systems are used in electric elevators, crane lifting motors and kinetic energy recovery mechanisms.

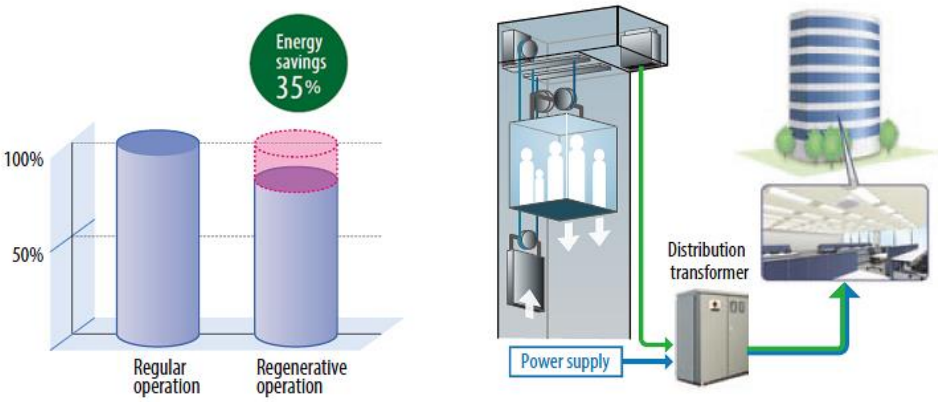


Fig 1.16: Regenerative braking integrated Mitsubishi elevators

Fig 1.17: Regenerative braking system integrated in DANIELI cranes

1.5 ADVANTAGES OF REGENERATIVE BRAKING

Energy conservation:

The flywheel absorbs energy when braking via a clutch system slowing the car down and speeding up the wheel. To accelerate, another clutch system connects the flywheel to the drive train, speeding up the car and slowing down the flywheel. Energy is therefore conserved rather than wasted as heat and light which is what normally happens in the contemporary shoe/disc system.

Fuel economy:

The amount of fuel consumed can be dramatically reduced with this type of braking system. The energy efficiency of a conventional car is only about 20%, with the remaining 80% of its energy being converted to heat through friction. The miraculous thing about regenerative braking is that it may be able to capture as much as half of that wasted energy and put it back to work. This could reduce fuel consumption by 10 to 25%.

Recharging the battery:

Once the energy is captured by the regenerative brakes, the energy is used to recharge the batteries of the vehicle. Because this energy would normally be lost, it allows each vehicle to experience a prolonged charge while driving.

Wear Reduction:

In regenerative braking, when the motor is not receiving power from the battery pack, it resists the turning of the wheels, capturing some of the energy of motion as if it were a generator and returning that energy to the battery pack. Because an electric drive train is part of this system, the greater efficiency given to the braking allows for a reduced level of wear on the brakes of the vehicle. With standard friction brakes, there is no way to accomplish this benefit.

Reduced Brake costs:

Cutting down the replacement brake linings cost, the cost of labour for installation, and machine downtime.

CHAPTER - II

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 (1) 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.

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 (2) 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 (3) 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 (4) 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 (5) 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 (6) it is mentioned that Regenerative braking can save up to 25% to 28% 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 start up, 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.

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 (7) 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.

Yimin Gao and Mehrdad Ehsani. SAE Transactions. Vol. 110, Section 7: JOURNAL OF PASSENGER CARS: ELECTRONIC AND ELECTRICAL SYSTEMS (2001), pp. 576-582 (7 pages). Published By: SAE International.

In paper (8) proposed electronic braking system for EV and HEV integrates the regenerative braking, automatically controlled mechanical braking together. This braking system can recover most of braking energy. Therefore, the energy efficiency of the vehicle can be significantly improved. Meanwhile, the braking system can realize wheel antilock function by controlling the electric motor and/or the electrically powered braking actuators.

CHAPTER - III

ELEMENTS OF THE SYSTEM

3.1 ELEMENTS OF THE SYSTEM

There are four elements required which are necessary for the working of regenerative braking system, these are

- Energy Storage Unit (ESU)
- Continuously Variable Transmission (CVT)
- Controller
- Regenerative Brake Controllers

3.1.1 Energy Storage Unit (ESU):

The ESU performs two primary functions

a) To recover & store braking energy
b) To absorb excess engine energy during light load operation

The selection criteria for effective energy storage include:

i. High specific energy storage density
ii. High energy transfer rate
iii. Small space requirement

The energy recaptured by regenerative braking might be stored in:

- An electromagnetic battery
- A flywheel
- hydraulic accumulator
- spring

3.1.2 Battery:

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.

With this system, traditional friction brakes must also be used to ensure that the car slows down as much as necessary. Thus, not all of the kinetic energy of the car can be harnessed for the batteries because some of it is "lost" to waste heat. Some energy is also lost to resistance as the energy travels from the wheel and axle, through the drive train and electric motor, and into the battery. When the brake pedal is depressed, the battery receives a higher charge, which slows the vehicle down faster. The further the brake pedal is depressed, the more the conventional friction brakes are employed.

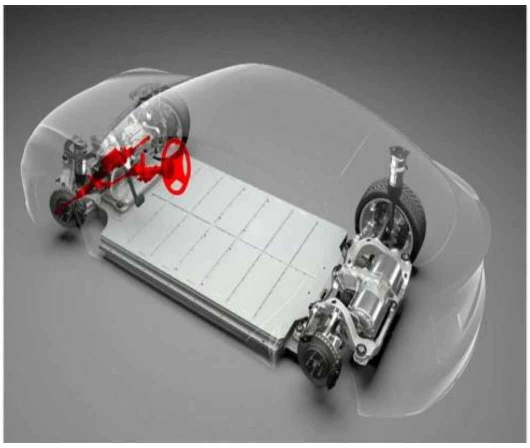


Fig 3.1: The battery pack used in Tesla cars

3.1.3 Flywheel:

In flywheel RBS, 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. It is usually used as KERS in sports vehicles.

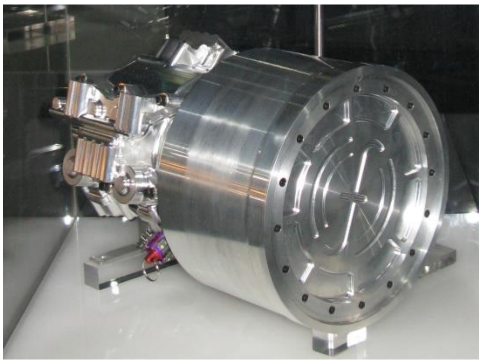


Fig 3.2: A KERS flywheel used in Formula car

3.1.4 Spring:

The spring loaded regenerative braking system is typically used on human powered vehicles, such as bicycles or wheelchairs. In spring RBS, 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.

Fig 3.3: A bike equipped with torsional spring for RBS

3.1.5 Hydraulic:

The hydraulic RBS slows the vehicle by generating electricity which is then used to compress a fluid. Nitrogen gas is often chosen as the working fluid. Hydraulic RBSs 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 RBS.

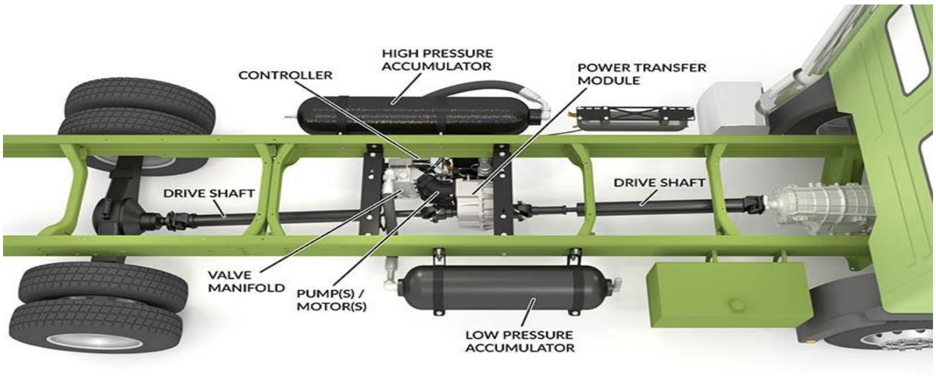


Fig 3.4: A hydraulic storage system used in trucks

3.1.6 Electromagnetic-flywheel:

Electro flywheel regenerative brake is a hybrid model of electromagnetic and flywheel RBSs. 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.

3.1.7 Continuously Variable Transmission (CVT):

The energy storage unit requires a transmission that can handle torque and speed demands in a steeples manner and smoothly control energy flow to and from the vehicle wheels.

Fig 3.5: a CVT transmission

3..1.8 Regenerative Brake Controllers:

Brake controllers are electronic devices that can control brakes remotely, deciding when braking begins ends, and how quickly the brakes need to be applied. During the braking operation, the brake controller directs the electricity produced by the motor into the batteries or capacitors. It makes sure that an optimal amount of power is received by the batteries, but also ensures that the inflow of electricity isn't more than the batteries can handle.

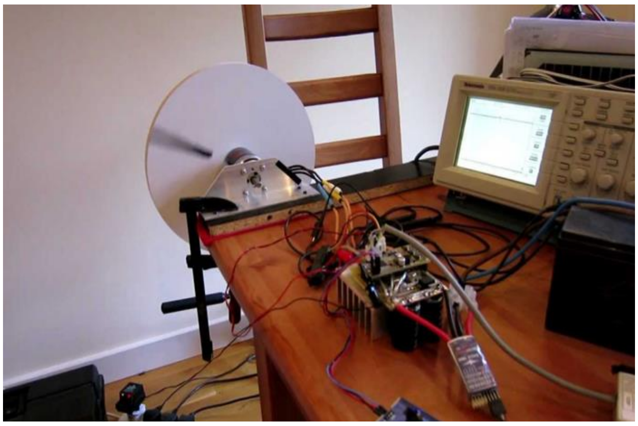


Fig 3.6 A RBS controller

3.1.9 Controller:

An “ON-OFF” engine control system is used. That means that the engine is “ON” until the energy storage unit has been reached the desired charge capacity and then is decoupled and stopped until the energy storage unit charge fall below its minimum requirement.

3.2 REGENERATIVE BRAKING SYSTEM WITH FRICTION BRAKING

Traditional friction-based braking is used in conjunction with mechanical regenerative braking for the following reasons:

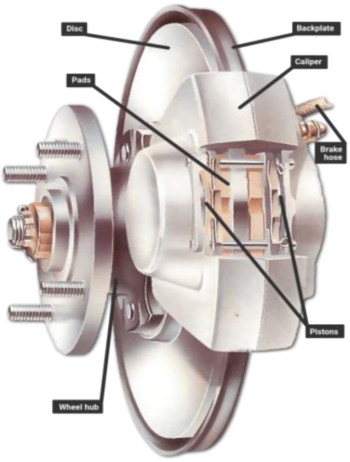


Fig 3.7: a traditional disc brake

- The regenerative braking effect drops off at lower speeds; therefore the friction brake is still required in order to bring the vehicle to a complete halt. Physical locking of the rotor is also required to prevent vehicles from rolling down hills.

- The friction brake is a necessary back-up in the event of failure of the regenerative brake.

- The amount of electrical energy capable of dissipation is limited by either the capacity of the supply system to absorb this energy or on the state of charge of the battery or capacitors. No regenerative braking effect can occur if another electrical component on the same supply system is not currently drawing power and if the battery or capacitors are already charged. For this reason, it is normal to also incorporate dynamic braking to absorb the excess energy.

- Under emergency braking it is desirable that the braking force exerted be the maximum allowed by the friction between the wheels and the surface without slipping, over the entire speed range from the vehicle's maximum speed down to zero.

CHAPTER – IV

METHODOLOGY

There are certain necessary requirements for regenerative braking, irrespective of the method of regeneration. They are:-

- Sufficient momentum in the vehicle
- A system capable of storing energy
- A controller

Regenerative energy can be produced only when the vehicle is in motion. The axles must have enough momentum which will be utilized by the system.

The energy (electricity) produced using regenerative braking, should either be utilized immediately or be stored in a battery for future use.

There must be a controller which turns ON or OFF the process of regeneration based on the requirement and availability.

There must be a provision of frictional braking to stop the vehicle, which should be used when regenerators fail or during an emergency.

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. This forms a hybrid braking system, 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 behaviour and its characteristics with respect to speed, braking power, deceleration rate etc. must be made.

4.1 FABRICATION

list of materials used

S. No	Name of the part	Quantity
1	D.C. MOTOR	2
2	BRAKE WHEEL	2
3	BREAK SPINDLE	1
4	LED	1
5	WIRES	Required
6	WOOD	Required
7	SCREWS	Required
8	CLAMPS	Required

4.1.1 D.C. MOTOR

One of the two motors is used as the main motor. This is connected to the gear using a spindle shaft. The motor's tip is connected to a gear which can be meshed with the braking gear. It has a capacity of 12v.
The other motor is used as the dynamo. The motor tip is connected to another gear and when the gears mesh, 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.

4.1.2 BREAK WHEEL

One of the brake wheels (gears) is connected to the main motor. It is in continuous motion along with the wheel of the vehicle. It has an internal diameter of 12 mm and is made of Polyvinyl Chloride (PVC).

The other brake wheel (gear) is used to stop the movement of the shaft. This gear is connected to the shaft and has an internal dia. of 12mm.

The Brake wheel is made of Polyvinyl Chloride (PVC).

4.1.3 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.

4.1.4 LED

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

4.1.5 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.

4.1.6 WOOD

Wood for making the frame for the system.

4.1.7 SCREWS

Screws, to fix the frame and the parts in place.

4.1.8 CLAMPS

Clamps to fix the motors to the stand and the spindle.

4.2 EQUIPMENTS USED IN FABRICATION

4.2.1 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.

4.2.2 CUTTING

Cutting is a process by which the excess material is removed from the work piece. There process we used in order to get the work piece of the required dimension was by using a hacksaw blade.

4.3 PROCEDURE

1. First the wooden plank is cut to the required dimensions for plank and stands.
2. Wooden pieces of the required size are cut for the stand and the spindle.
3. The main motor is fixed with the stand using a clamp and screws.
4. The braking motor is attached to the spindle using a clamp and screws
5. The main stand is fixed with the base and a spindle stand is fixed to the base.
6. The spindle is attached to the spindle stand.
7. LEDs are connected to the braking motor with the wires.
8. The main motor is supported by an additional spindle.
9. The brake wheel is attached to the motors.

4.4 PRECAUTIONS

1. The Apron is worn at every process during Fabrication.
2. Gloves are used to protect one's hands during drilling and grinding.
3. All the connections must be soldiered and well insulated.

CHAPTER – V

RESULT AND DISCUSSION

5.1 RESULT

A model of regenerative braking system is fabricated .After successful testing, the system is able to stop the vehicle by producing energy in return.

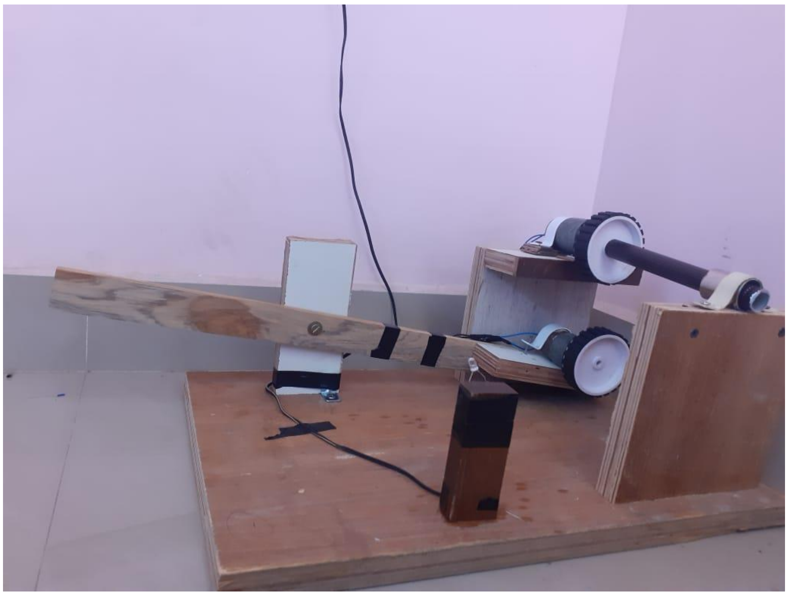


fig 5.1: when RBS brake is not applied

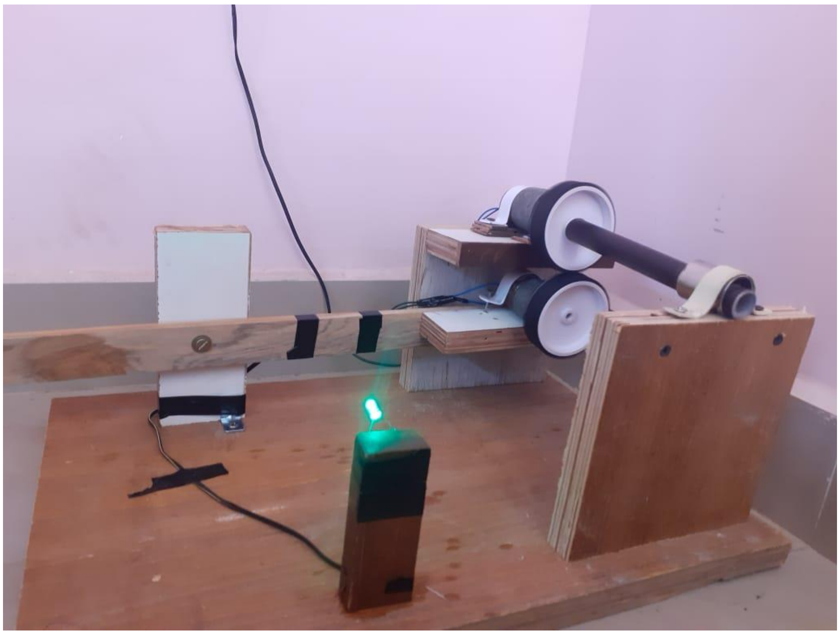


Fig 5.2: when RBS brake is applied

5.2 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 – VI

EQUATIONS FOR REGENERATIVE BRAKING SYSTEM

6.1 REGENERATIVE BRAKES

Regenerative braking has a similar energy equation to the equation for the mechanical flywheel. Regenerative braking is a two-step process involving the motor/generator and the battery. The initial kinetic energy is transformed into electrical energy by the generator and is then converted into chemical energy by the battery. This process is less efficient than the flywheel. The efficiency of the generator can be represented by:

$$\eta_{gen} = \frac{W_{out}}{W_{in}}$$

where

- W_{in} is the work into the generator.
- W_{out} is the work produced by the generator.

The only work into the generator is the initial kinetic energy of the car and the only work produced by the generator is the electrical energy. Rearranging this equation to solve for the power produced by the generator gives this equation:

$$P_{gen} = \frac{\eta_{gen} m v^2}{2\Delta t}$$

where

- Δt is the amount of time the car brakes.
- m is the mass of the car.
- v is the initial velocity of the car just before braking.

The efficiency of the battery can be described as:

$$\eta_{batt} = \frac{P_{out}}{P_{in}}$$

where

- $P_{in} = P_{gen}$

- $P_{out} = \frac{W_{out}}{\Delta t}$

The work out of the battery represents the amount of energy produced by the regenerative brakes. This can be represented by:

$$W_{out} = \frac{\eta_{batt}\eta_{gen}mv^2}{2}$$

6.2 KERS FLYWHEEL

The energy of a flywheel can be described by this general energy equation, assuming the flywheel is the system:

$$E_{in} - E_{out} = \Delta E_{system}$$

where

- E_{in} is the energy into the flywheel.
- E_{out} is the energy out of the flywheel.
- ΔE_{system} is the change in energy of the flywheel.

An assumption is made that during braking there is no change in the potential energy, enthalpy of the flywheel, pressure or volume of the flywheel, so only kinetic energy will be considered. As the car is braking, no energy is dispersed by the flywheel, and the only energy into the flywheel is the initial kinetic energy of the car. The equation can be simplified to:

$$\frac{mv^2}{2} = \Delta E_{fly}$$

where

- m is the mass of the car.
- v is the initial velocity of the car just before braking.

The flywheel collects a percentage of the initial kinetic energy of the car, and this percentage can be represented by η_{fly}. The flywheel stores the energy as rotational kinetic energy. Because the energy is kept as kinetic energy and not transformed into another type of energy this process is efficient. The flywheel can only store so much energy, however, and this is limited by its maximum amount of rotational kinetic energy. This is determined based upon the inertia of the flywheel and it's angular velocity. As the car sits idle, little rotational kinetic energy is lost over time so the initial amount of energy in the flywheel can be assumed to equal the final amount of energy distributed by the flywheel. The amount of kinetic energy distributed by the flywheel is therefore:

$$KE_{\text{fly}} = \frac{\eta_{fly} m v^2}{2}$$

6.3 CARS

A diagram by the United States Department of Energy (DoE) shows cars with internal combustion engines as having efficiency of typically 13% in urban driving, 20% in highway conditions. Braking in proportion to the useful mechanic energy amounts to 6/13 i.e. 46% in towns, and 2/20 i.e. 10% on motorways.

The DoE states that electric cars convert over 77% of the electrical energy from the grid to power at the wheels. The efficiency of an electric vehicle, taking into account losses due to the electric network, heating, and air conditioning is about 50% according to Jean-Marc Jancovici (however for the overall conversion see Embodied energy in the energy field).

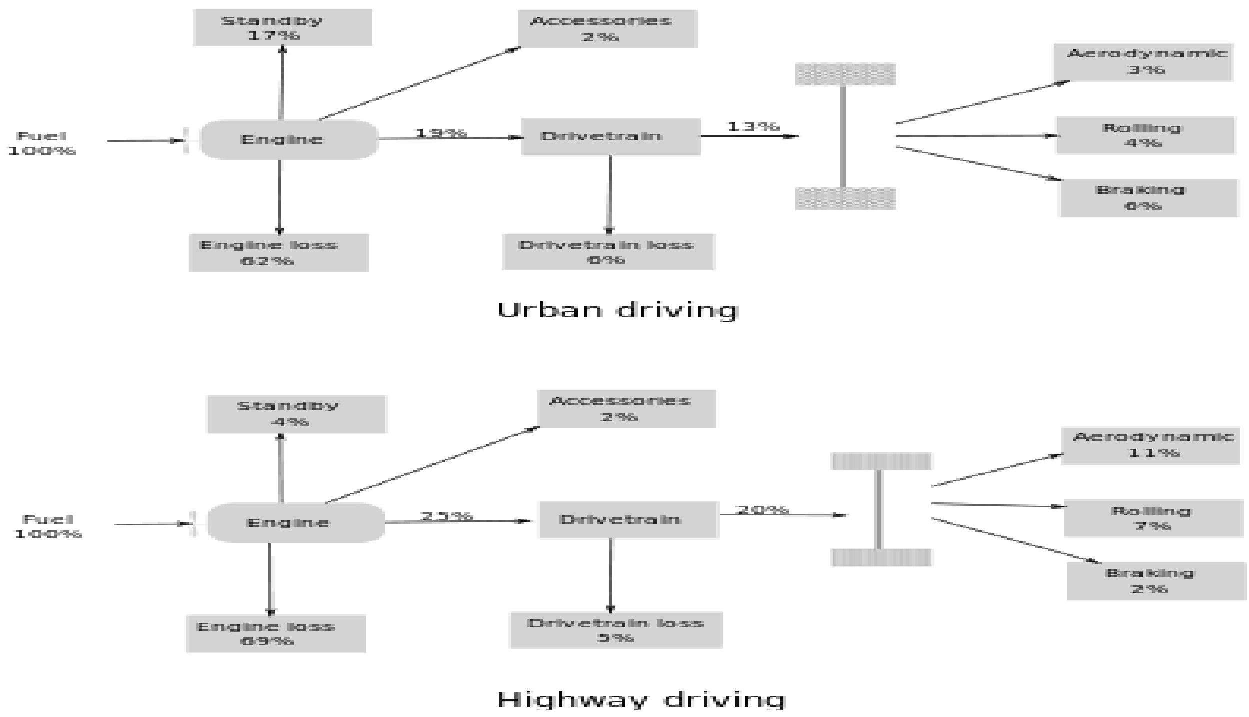


fig 5.1 Energy efficiency of cars in towns and on motorways according to the DoE

Consider the electric motor efficiency η_{eng} = *0.5* and the braking proportion in towns $p = 0.46$ and on motorways $p = 0.1$.

Let us introduce η_{recup} which is the recuperated proportion of braking energy. Let us assume $\eta_{recup} = 0.6$

Under these circumstances, E being the energy flux arriving at the electric engine, $E_{braking}$ the energy flux lost while braking and E_{recup} the recuperated energy flux, equilibrium is reached according to the equations

$E_{braking} = (E + E_{recup}).\eta_{eng}.p$ and $E_{recup} = \eta_{recup}.E_{braking}$

thus $E_{braking} = \frac{E.\eta_{eng}.p}{1-\eta_{eng}.p.\eta_{recup}}$

It is as though the old energy flux E was replaced by a new one

$E.(1-\eta_{eng}.p.\eta_{recup})$

The expected gain amounts to $\eta_{eng}.p.\eta_{recup}$

The higher the recuperation efficiency, the higher the efficiency between the electric motor and the wheels, the higher the recuperation. The higher the braking proportion, the higher the recuperation.

On motorways, this figure would be 3%, and in cities it would amount to 14%.

CHAPTER - VII

CONCLUSION

7.1 CONCLUSION

The regenerative braking system used in 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.

These types of brakes also extend the driving range of fully electric or hybrid vehicles. In fact, this technology has already helped bring us car manufactures like the Tesla, which runs entirely on battery power. Sure, these cars may use fossil fuels at the recharging stage. That is, if the source of the electricity comes from a fossil fuel such as coal but when they're out there on the road, they can operate with no use of fossil fuels at all, and that's a big step forward. As designers and engineers perfect regenerative braking systems, they will become more and more common. All vehicles in motion can benefit from utilizing regeneration to recapture energy that would otherwise be lost.

Regenerative braking system have significant room for improvement. Regenerative braking is still very limited and dependent on uncontrollable variables. Also, danger can arise if regenerative braking is applied to two-wheel-drive brake systems. However, regenerative braking does have various benefits. A proper implementation of regenerative braking system extends driving range, improves braking efficiency, reduces brake wear, and improves energy conservation.

7.2 RECCOMENDATION

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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