IJNRD.ORG ISSN : 2456-4184

INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG

An International Open Access, Peer-reviewed, Refereed Journal

FABRICATION OF REGENERATIVE BRAKING SYSTEM FOR AUTOBOBILES

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Abstract- Regenerative braking systems (RBS) are the effective method of recovering the energy produced and at the same time it will decrease the waste gases and brake emissions of vehicles. This system is based on the principle of converting the kinetic energy produced by the mechanical energy of the motor into electrical energy. The converted electrical energy is stored in the battery for later use. This braking system must meet maximum energy recovery criteria by performing its function safely within the shortest braking distance. This study was conducted to provide more relevant information about regenerative energy systems. These systems provide economic benefits as fuel savings and preventionof material loss. Their use also contributes to a clean environment and renewable energy sources, whichare among the most important issues on the global agenda. A brake-pad assembly, mounted concentrically with the hub of a ground-engaging wheel, is actuated upon braking to supply frictionalengagement 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 generator when using regenerative braking and its output is supplied to an electrical load. The transfer of energy to the vehicle provides the braking effect and regenerate power.

Key words: Regenerative braking, motor generator, Energy recovery.

I. INTRODUCTION

The regenerative braking system is the method which converts the kinetic energy into the electrical energy with the help of motor generator. In a conventional braking system, the motion is 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 .The kinetic energy is wasted. 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 electrical 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.

1.1 CONVERSION OF KINETIC ENERGY INTO ELECTRICAL ENERGY

The most common form of regenerative brake involves using an electric motor as an electric generator. This works by converting electric energy into mechanical energy, which is then used to accelerate the vehicle. When an external force is applied to activate the motor, it acts as a generator and generates electricity. This electricity is then used for storage in the battery and reducing the speed of the car with the regenerative resistance of the electric motors. There are some methods which convert kinetic energy into electrical energy such as Electromagnetic, Flywheel, Electromagnetic flywheel , Spring , Hydraulic

1.2Electromagnetic

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. Electromagnetic system shown in Figure 1

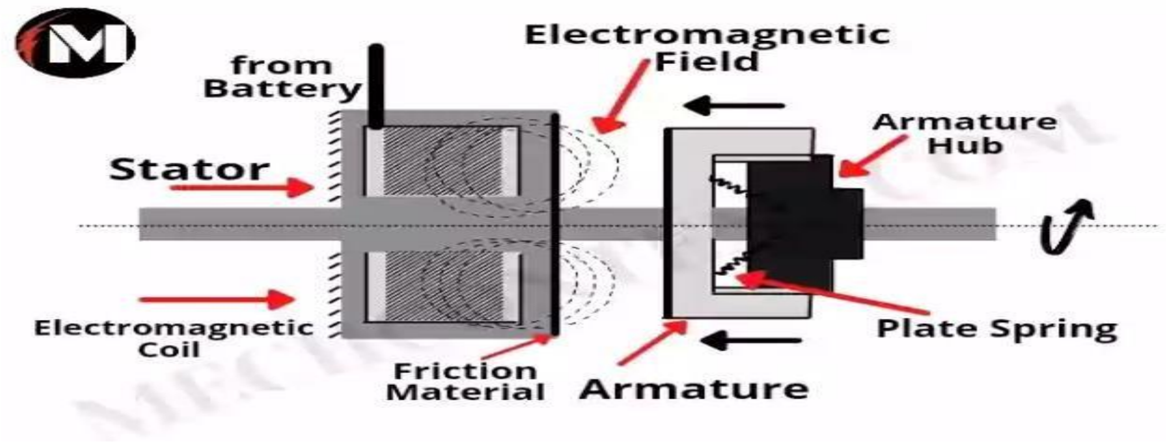

Figure 1 Electromagnetic system

1.3 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 Flywheel Regenerative Braking System shown in Figure 2

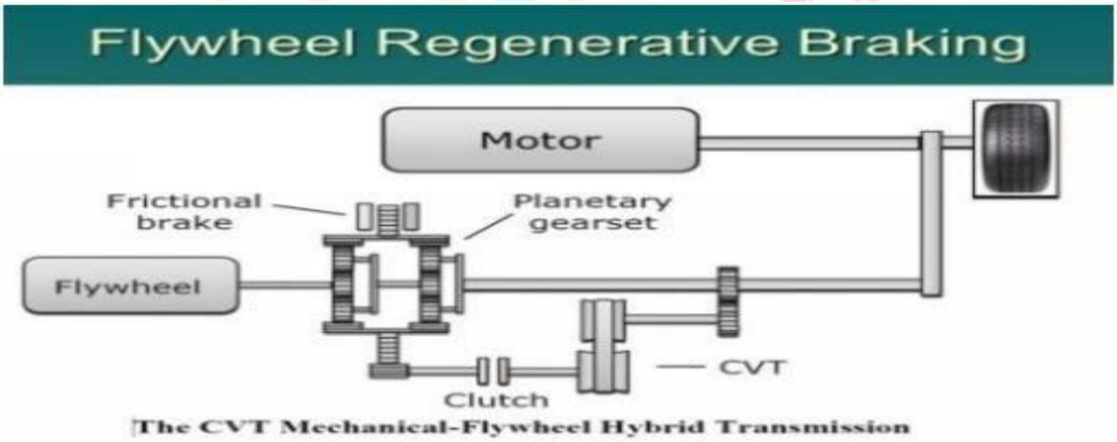

Figure 2 Flywheel Regenerative Braking System

1.4 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 fluid does not dissipate energy over time. Hydraulic assisted RBS as shown in figure 3

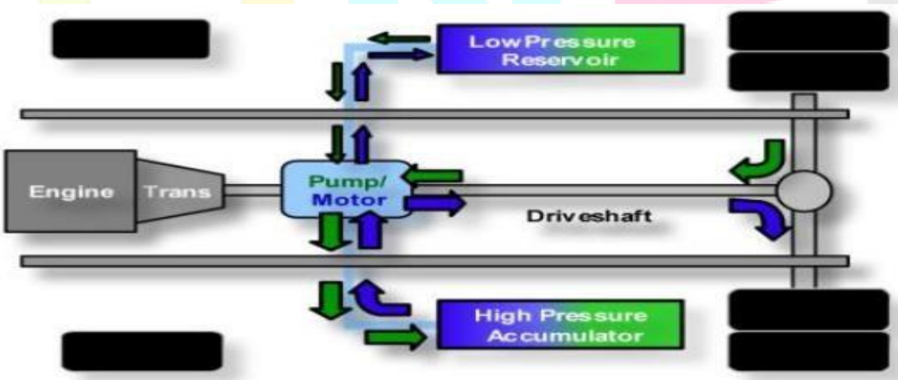

Figure 3 Hydraulic assisted RBS

1.5 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.

1.6 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.

II. LITERATURE REVIEW

Zhengwei ma et. al., [1] Wrote that The authors propose an energy recovery strategy based on ideal braking force distribution and analyse its effectiveness under different braking strength. During driving, kinetic energy of the vehicle can be recovered under decelerating, braking, and coasting situations. In the regenerative braking of a HEV in coasting mode was investigated, and a braking energy motor braking strategy was proposed, which applied maximum braking torque to speeds above a certain threshold. The authors studied the coasting control for EV based on the driving feeling. There is a conflict between the braking energy recovery efficiency (RBS) of front-drive and rear-drive versions of electric vehicles (EVs) in terms of vehicle braking stability. The simulation results show that the proposed braking energy recovery strategy is able to effectively achieve the regenerative braking function under different braking conditions while ensuring the braking efficiency and braking stability **Anurag Bhatt et. al., [2]** Wrote that the kinetic energy is transmitted in the brakes through drive train and is directed by a mechanical system to the potential store during deceleration. That energy is held until required to the vehicle, wherein it is transformed back into energy and stored in the battery of the vehicle using the BLDC motor used in electric vehicles due to their robustness and high efficiency this paper they proposed BLDC motor, which has power saving and controllability relative to other motor drives. Theoretically in regenerative braking system there is 30% saving on the fuel consumption **Shoeib Heydari et. al., [3]** Wrote approach for dynamically detecting the lowest speed threshold at which regenerative braking is effective in electric vehicles (EVs). The control is based on real time sensing of the motor controller's link current. It shows how a dynamic low-speed cut off (LSCP) detection method is proposed for EV braking Different methods have been proposed to maximize the regenerative braking capability of electric vehicles (EVs) and hybrid vehicles (HEVs). The maximum energy that can be harvested through the regeneration process depends on the speed at which the vehicle is being driven. motor controller dc link current monitoring was proposed to overcome this 9 limitation and enable dynamic detection of LSCPS.so that vehicle controller unit (VCU) is required to determine the period of RBS. The result The maximum charging current at 10 Hz enable frequency is 37.51 A that it exceeds **Warunchit Chueprasert et. al., [4]** Wrote that aims to develop regenerative braking using pulse width module (PWM) control. The research will study electric braking systems. In this studied the development of various control systems for braking force during regenerative energy and electronic brake directly affects to the vehicle movement the limitation of battery pack in the first period when regenerative braking is enabled **Emiliano Pipitone et. al., [5]** Wrote that An electric kinetic energy recovery system (e-KERS) for internal combustion engine vehicle (ICEV) is presented, and its performance evaluated through numerical simulations. The KERS proposed is based on the use of a supercapacitor as energy storage, interfaced to a brushless machine through a properly designed power converter. Energy savings of the order of 20% were found, with a slight increase in vehicle weight (+2%) and with an overall commercial cost that would be compensated in 5 years thanks to the fuel economy improvement, to which corresponds an equal reduction of CO_2 emissions **Liang Zhang et. al., [6]** Wrote Three typical braking distribution strategies are proposed for parallel hybrid vehicles, namely parallel, optimal sensory series and optimal energy recovery series braking strategy. As the actuator of mechanical and electric braking apart, the hydraulic actuator and the generator realise the baking process under the control of controllers. The management level is made up of an electronic controller unit, a battery management system, a motor controller, and a brake controller that communicate via the CAN protocol. We use MATLAB/Simulink simulation and analysis to validate the proposed control strategy. The effectiveness of the control strategy has been established. Downhill driving can be used to successfully recover energy from regenerative braking **Soniya et. al., [7]** Wrote The main aim that has been focus on having influence on brake energy that is usable is discussed. It helps in save energy and provide higher efficiency for a car. Electric Vehicles (EVs) use mechanical brake for the increase the roughness of wheel for the decelerate purpose. From the position of saving energy, the mechanical brake dissipate much energy, since the EV's kinetic energy is renewed to In electric energy. The easy to control motors are capable of regenerating. The controller I DCDC converter, which work as buck-boost converter. To control this a dc-dc controller is design, the controller decide that battery is full of charge and then, the charge is to supply to capacitor. The boost operation is used for acceleration while buck-operation is use for braking. It has the ability to save the waste energy up to 8-25%. **Liang Li et. al., [8]** Explains that The proposed strategy can ensure vehicle safety during emergency braking situation and improve the recovery energy almost 17% compared with the conventional 10 strategy. There are two parts of braking system. The pneumatic braking system is composed of the air compressor, tank, braking valve, modulating valve, braking pan and pressure sensor. Every wheel is equipped with the modulating valves, so that every wheel can be controlled independently of the braking controller. The system is divided into three levels gathering each part. The vehicle controller is put in the highest level, which contains the integrated braking control strategy through model simulation. This Journal includes a simulation and HIL test to evaluate the safety and energy recovery capability of RBS with the proposed NMPC strategy. **Chengqun Qiu et. al., [9]** Wrote the design and control of a regenerative braking system for electric vehicles. The mechanism and evaluation methods of contribution brought by regenerative braking to improve electric vehicle's energy efficiency are discussed and analysed by the energy flow. A new regenerative braking control strategy called ''serial 2 control strategy is introduced .They describe the energy flow on vehicle level with the regenerative brakes, and compare their efficiency to that of the battery during charging and discharging. They Find contribution ratio to regenerative braking energy transfer efficiency improvement and the contribution ratio to regenerative driving range. **ChaofengPan et. al., [10]** Wrote Rotational speed signals acquisition and processing techniques are widely used in machinery. Obtaining accurate motor rotational speed signal will contribute to the regenerative braking force control steadily and realized higher energy recovery rate. Rotational speed sensor usually output signal in analog mode, analog signal is conditioned by circuit and suitable for measurement applications. Multiple channels of speed can be measured simultaneously using a multichannel ADC board, the ADC converts the analog speed signal into digital data. Motor rotational signals obtained during the sliding and Regenerative braking are precise and accurate, and the requirements for the regeneration braking control can be satisfied. **Dongsheng Sun et. al., [11**] Wrote about Dual-mode regenerative braking control strategy of electric vehicle based on active disturbance rejection control. The proposed regenerative braking control strategy can achieve higher regeneration efficiency under the dynamical limitation of battery charging current, which further expands the operating range of the regenerative braking system. strategy includes regenerative torque closed loop control mode and ADRC-based regenerative current closed-loop control mode which integrates charging safety, regeneration efficiency, and ride comfort. simulation and experiment prove the effectiveness of the control strategy, which can guarantee the safety of charging and the smoothness of braking. **Pratik Bhandari et. al., [12]** Wrote work done by the engine of the vehicle is reduced, in turn reducing the amount of energy required to drive the vehicle. The objective of our project is to study this new type of braking system that can recollect much of the car's kinetic energy and convert it into electrical energy or mechanical energy. Regenerative braking converts a fraction amount of total 11 kinetic energy into mechanical or electrical energy but with further study and research in near future it can play a vital role in saving the non-renewable sources of energy. **Mohamed N et. al., [13]** Wrote about Low Vehicle Speeds Regenerative Anti-lock Braking System. The study is the first to assess enhancing regenerative braking performance at low speeds. The proposed system detects the type of the road condition and adapts braking performance with road condition. RABS comprehensive model is constructed using Matlab/Simulink simulation for optimization of the control system performance during braking on different terrains. The new RBS is simulated and practically tested at very low speed rates lower than 10 km/h. **Jian Wu et. al., [14]:** Du Wrote about hierarchical control strategy with battery aging consideration to solve the problem. In the up-level controller, the control targets 14 are to recover more energy and minimize aging of the battery in general braking mode, and ensuring the vehicle braking safety in 15 emergency braking mode at the same time. The low-level controller receives the commands of the up-level controller, and 16 controls the pneumatic braking system and the electric motor (EM). Simulation tests are designed to indicate the effects of 18 regenerative braking on battery aging and the control effectiveness of the proposed method, and controller-inthe-loop tests are 19 carried out to verify the real-time calculation performance. **Jonathan Nadeau et. al., [15]** Explains novel controller design for a dual electro-hydraulic regenerative brake system featuring on/off solenoid valves which track an ''ideal'' brake force distribution. As an improvement to a standard brake force distribution, it can provide the reach of the maximum braking adherence and can improve the energy recovery of a rear-wheel-drive electric vehicle. The improvement in energy recovery is possible with the complete substitution of the rear hydraulic brake force with a regenerative brake force until the reach of the electric powertrain constraints. It is done by performing a proper brake pressure fine regulation through the proposed variable structure control of the on/off solenoid valves provided by the hydraulic platform of the vehicle stability system. **CS Nanda Kumar et. al., [16]** Wrote that a rear-wheel-driven series hybrid electric vehicle which has a mechanically operated friction brake system is studied. A new cooperative control of regenerative braking and friction braking called 'combined braking' is proposed for this vehicle configuration. A mechanism to adjust the proportions of regenerative braking and friction braking was proposed. under urban driving and across the Modified Indian Driving Cycle and vehicle road testing results show that the proposed combined braking can regenerate more than twice the braking energy of conventional parallel braking **Najmuddin M Jamadar et. al., [17]** Wrote that , mechanical braking mechanism results in friction which in turn, into heating losses and reduces the efficiency of EV. regenerative braking system (RBS) and energy management system are employed in addition to mechanical braking for increasing the braking efficiency of the EV system. They presents a review of regenerative braking and braking energy management techniques by considering different driving situations and road conditions. **Yang yang et.al., [18]** Wrote about Dynamic Coordinated Control for Regenerative Braking System and Anti-Lock Braking System for Electrified Vehicles Under Emergency Braking Conditions. The method of logic threshold control combined with phase plane theory to analyse the relationship between the slip rate and the braking torque during the ABS braking process and to obtain the composition rule of the braking torque required for ABS braking. Based on this rule, a control strategy to coordinate RBS and ABS when triggering ABS is proposed to improve the efficiency of braking energy recovery. Studied the ABS for the emergency conditions how it works and it uses advantage of it. **Yogesh Abhale et. al., [19]** Explains about how the regenerative braking system works. The braking is improved by using flywheel, DC-DC converter, ultracapacitor as well as super capacitor. The principle and various types of controllers have been studied to improve energy saving of electric vehicles **Qinghai zaho et. al., [20]** Explains Control Strategy of Hydraulic Regenerative Braking of Electro hydraulic Hybrid Electric vehicles. By using the numerical simulation the research is done. The electrohydraulic hybrid transmission system is studied. According to the operation mechanism of the electric hydraulic hybrid electric vehicle, the power transmission system structure of the electric hydraulic hybrid electric vehicle is deeply explored and vehicle model was built. By considering all the above-mentioned journals, as per our knowledge we observed that the using regenerative braking system in the vehicles we can minimize the energy lost and save the energy which can be used further. Then the vehicles efficiency will be increased

III. METHODOLOGY USED FOR RBS

In this the methodology involved in the Regenerative braking system and its results. It requires sufficient momentum in the vehicle, a system capable of storing energy, a controller to turn ON or OFF the process of regeneration, and frictional braking to stop the vehicle when regenerators fail or during an emergency. Regenerative braking systems may not suffice the basic requirement of braking system alone due to limitation of energy dissipation at very high power. To co-exist with electrical regenerative braking systems, a hybrid braking system can be formed, with many design configurations and control strategies. Regenerative brakes are electric vehicles that convert kinetic energy into electric energy which can be stored in a battery and reused later .Electric trains, cars, and other electric vehicles are powered by batteries connected to motors, which turn the wheels and provide us with kinetic energy. When we stop and hit the brakes, electronic circuits cut the power to the motors, so the motors work like generators and start producing electricity instead of consuming it. This energy is returned to the batteries and can be reused when we start off again. However, regenerative brakes take time to slow things down, so most vehicles that use them also have ordinary (friction) brakes working alongside. This is one reason why regenerative brakes don't save 100 percent of our braking energy.

3.1 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 it the produced energy into the battery source. Theoretically, the regenerative braking system can convert a good amount of its kinetic energy to charge up the battery used for other electrical purposes in the vehicle 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, then the electric motor works in reverse direction thus, slowing it. In the Figure 4 Normal forward driving Figure 5: Regenerative action during braking The figure .4 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 5. By using regenerative braking, it vastly reduces the reliance on fuel, boosting fuel economy and lowering the emissions. The electric motor reverse direction becoming a generator which then stores the energy in vehicle battery Figure 6 wheel position while braking and accelerating. While the brake is applied on the vehicle the rotation of the motor is changes to reverse direction and it will works as the generator then the electrical energy is produced by the generator the produce energy is used for further purposes.

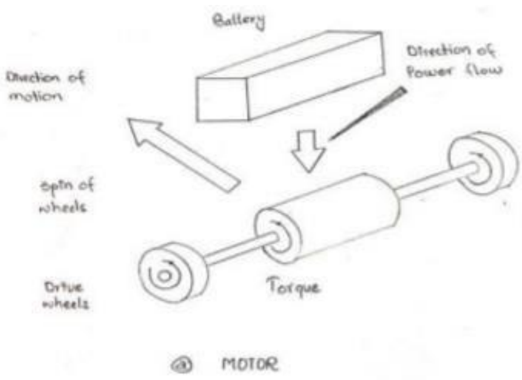

Figure 4 normal forward driving condition

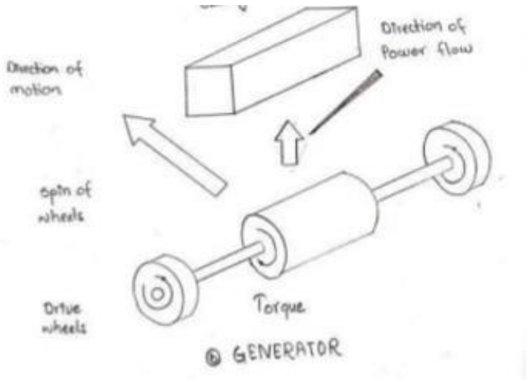

Figure 5. regenerative action during braking condition

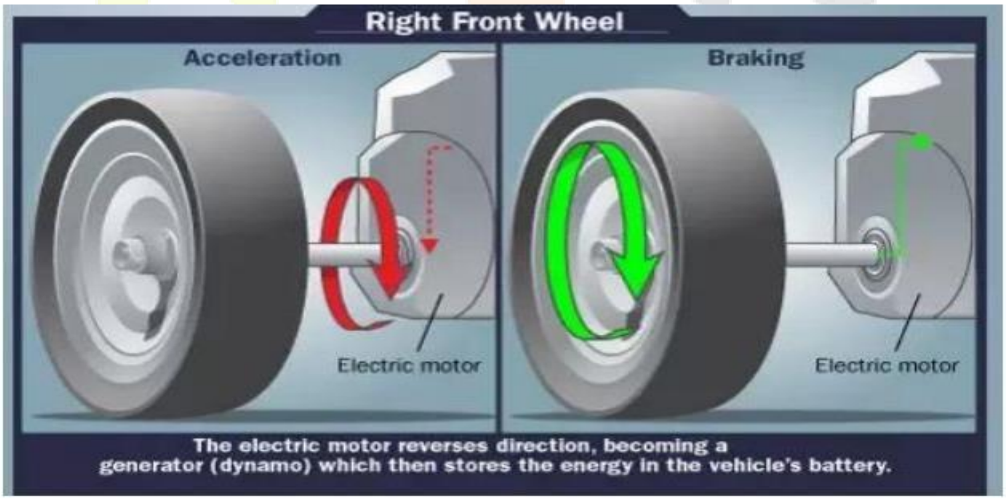

Figure 6. wheel position while braking and accelerating

IV. FABRICATION

The main objective of our paper is to design and implement a regenerative braking system that helps to regenerate the amount of energy wasted during braking with the help of generator that energy is stored back in the battery which can be used for further driving. Our goal is to design and implement a regenerative braking system that will handle the task described For the testing the model is made , it is made of the following parts. A new model of regenerative braking in EV is presented in this paper. The modelling of every component is presented with their corresponding parameters The construction of the RBS involves D.C. Motor and Generator, Brake wheel ,Battery, LED, Electrical wires, Wood Screws ,Clamps. By using all the parts the model of regenerative braking system is produced. First the wooden plank is cut to the required dimensions for plank and stands. Wooden pieces of the required size are cut for the stand and the spindle. The main motor is fixed with the stand using a clamp and screws. The braking motor is attached to the spindle using a clamp and screws The main stand is fixed with the base and a spindle stand is fixed to the base .The spindle is attached to the spindle stand. LEDs are connected to the braking motor with the wires. The main motor is supported by an additional spindle. The brake wheel is attached to the motors. The DC generator is an electrical machine whose main function is to convert mechanical energy into electricity. 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. One of the brake wheels (gears) is connected to the main motor. It is in continuous motion along with the wheel of the vehicle. The battery is used to run the motor, then the wheel will start rotates. The battery specifications are 12volts 1.5 Ampers. It can store the energy and generate the energy when required. These are used in order to show the power generated from the regenerative brakes. Wood for making the frame for the system. The wood is used to make the needed frame. After the assembly of all the parts the motor will be started running with the help of the battery. The battery will produce 12v ,1.5 amps .while the brake pedal is pressed against the wheel the motor is acts as the generator and produces the energy and it will be stored in battery or used for light, electrical parts in the vehicles. Fig 7 shows the final testing model working.

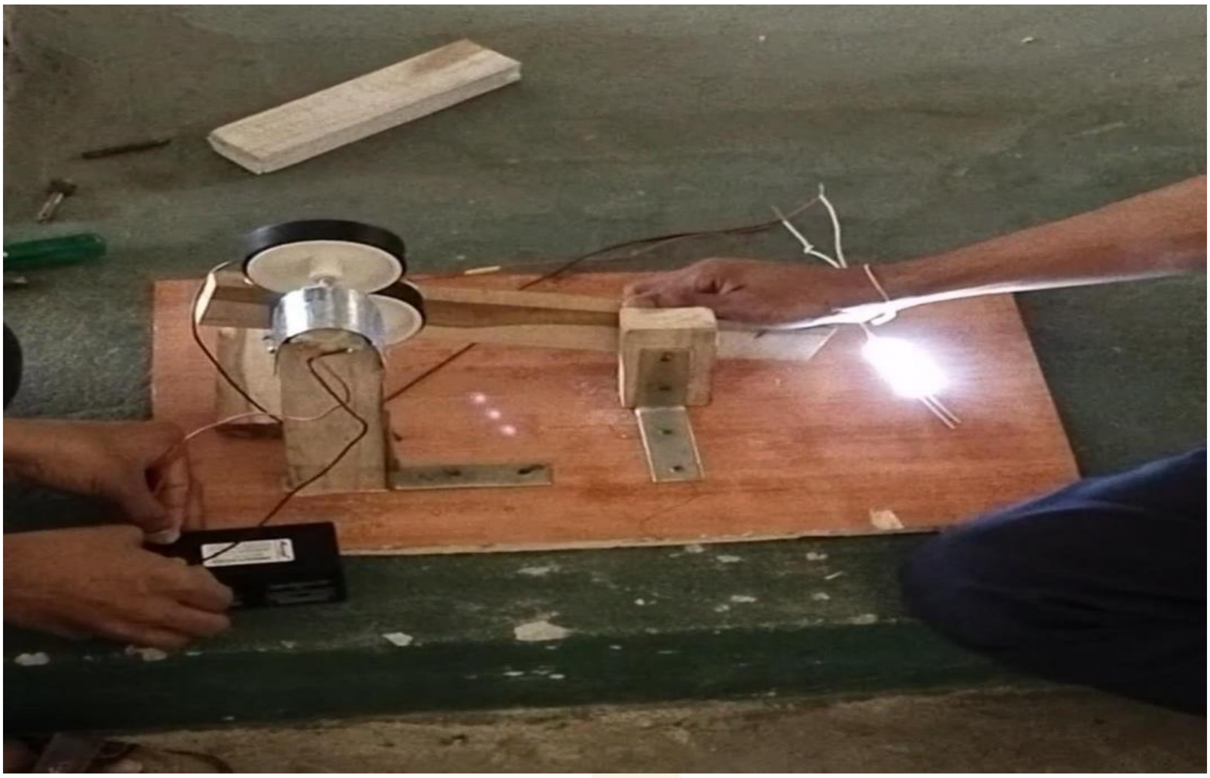

Figure 7 Testing model of RBS

V. RESULTS AND CALCULATIONS

5.1 results

The Tables 1 shows the results of the testing of the model of regenerative braking system

TABLE 1

S.NO	RPM BEFORE BRAKE PEDAL PRESSED	RPM AFTER BRAKE PEDAL PRESSED	VOLTAGE
1	500	460	7.12
2	1000	870	14.10

r

In the first trail While the motor runs at a speed of 500 rpm ,the brake wheel pressed against the wheel then the rpm will be decreased and the energy is produced in the form of electrical energy in 7.12 volts. In the second trail While the motor runs at a speed of 1000 rpm ,the brake wheel pressed against the wheel then the rpm will be decreased and the energy is produced in the form of electrical energy in 14.10 volts. This shows that when the vehicle runs at high speed the energy produced is also more

5.2calculations

. 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

: η gen = $Wout/ Win$ where
• Win is the work in the generator.
•Wout 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 = $\eta genmv$ 2/ 2Δt

• Δt is the amount of time the car brakes = 5.

- m is the mass of the car. = 1.5KG x 9.81 =14.7N
- v is the initial velocity of the car just before braking = 0.844 m/s
- η gen efficiency of generator
- η batt efficiency of battery

The efficiency of the battery can be described as:

η batt = $Pout\ /Pin$ where

- P in = P gen

P out = $Wout\ \Delta t$

The work out of the battery represents the amount of energy produced by the regenerative brakes.

Trail 1

At 500 rpm

. The efficiency of the generator can be represented by

: η gen = $Wout/ Win$

W in = RCF = RPM^2 x 1.118x10^-5xr

= 500^2 x 1.118x10^-5 x 40

=11180 N-M

W out = 460^2x1.118x10^-5x40 .

= 9462.75N-M

η gen =84%

the power produced by the generator gives this equation:

Pgen = ηgen x mv^ 2/ 2Δt

= 84x14.7x0.84^2/(2x5)

=1.2kw

ηbatt = $Pout\ /Pin$ where

- Pin = Pgen
- Pout = $Wout\ \Delta t$

Pin = 1.2kw

Pout =0.9kw

ηbatt = 0.9/1.2 = 75%

Trail 2

At 1000 rpm

. The efficiency of the generator can be represented by

: η gen = $Wout/\ Win$

W in = RCF = RPM^2 x 1.118x10^-5xr

= 1000^2 x 1.118x10^-5 x 40

=447.2 N-M

W out = 460^2x1.118x10^-5x40

=338.48N-M

η gen =75%

the power produced by the generator gives this equation:

Pgen = ηgen x mv ^2/ 2Δt

= 75x14.7x1.68^2/(2x5)

=3.1kw

ηbatt = $Pout$ /Pin where

- Pin = Pgen
- Pout = $Wout\ \Delta t$

Pin =3.1kw

Pout =2.6kw

ηbatt = 83%

The efficiency is increased by increase in the speed. More energy is produced when the speed of the vehicle is more.

VI. CONCLUSION

In this paper how the regenerative braking system works and converts the wasted energy into useful work is done. The regenerative braking system used in vehicles is designed to partially recover the battery charge wasted in braking. This energy is converted into heat by friction brakes which are dissipated to the environment. Regenerative braking is still limited and dependent on uncontrollable variables, and danger can arise if applied to two-wheel-drive brake systems. However, it does have various benefits, such as extending driving range, improving braking efficiency, reducing brake wear, and improving energy conservation. As designers and engineers perfect regenerative braking systems, they will become more and more common .These systems can be used in developing countries like India where buses are the preferred means that of transport within the cities. Regenerative braking could be a little, however important, step toward our freedom from fossil fuels.

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