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Study on Electric Vehicle Regenerative Braking System

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Abstract
The regenerative braking system (RBS) is recognized as an effective way to recover the released energy while reducing vehicle brake emissions. Traditional brakes typically use friction between two pressed surfaces (brake pads) to convert the kinetic energy of a moving object into heat, all of which is dissipated here in the form of heat energy. Regenerative braking can convert much of this kinetic energy into electrical energy and store it for later use. This process is based on the principle of converting the kinetic energy generated by the mechanical energy of the engine into electrical energy by the e-motor working as a generator. This converted electrical energy is stored in the battery for later use. The purpose of this study is to provide the importance, basic working principles, advantages and disadvantages of this new type of braking system, called the regenerative braking system (RBS), which can capture most of thevehicle's kinetic energy and convert it into electrical energy and store itin the battery for later use.

Keywords
Regenerative braking systems (RBS), Electric vehicle, Kinetic energy, Electrical energy

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I. Introduction

By relying solely on non-renewable resources like petroleum and diesel, the ideal of making cars more widely used is not feasible. Therefore, the development of electric vehicles is a key strategy for resolving this issue and is very significant. Batteries serve as the power source for electric vehicles. Although battery technology has advanced significantly as one of the key determinants of driving range, subsequent developments have been limited by both technological and economic constraints. Therefore, the use of brake energy recovery technology is a significant component in reducing energy consumption and increasing fuel economy. According to relevant literature, braking energy can account for up to 50% of the total energy required to drive. The vehicles mileage will be increased if the part of waste energy can be recovered and reused. Due to Brake energy recovery, this technology has grown in popularity.

When a traditional vehicle brakes, the friction between the brake pads and the wheels converts kinetic energy into heat energy. This heat is dissipated by the airflow, effectively wasting energy. The amount of energy lost in this way depends on how often, how hard and how long you apply the brakes. Regenerative braking is the process by which some of the vehicle's kinetic energy is recovered and stored by the battery system. The energy normally consumed by the brakes is sent via the e-motor through the power distribution system (PDU) to the batteries where the energy is stored during deceleration. This energy is retained until the vehicle needs it again, converting it back into kinetic energy, and used to accelerate the vehicle. This is a small savings, even if the system is completely efficiency. If you drive in the city centre, you need much more brakes. This means that the energy loss is much higher and the potential for savings is higher. Regenerative braking increases efficiency by increasing the energy output for a particular energy input to the vehicle. It reduces the amount of work done by the vehicle's engine, which in turn reduces the amount of primary energy required to propel the vehicle.

As compared to the advantages, there are some disadvantages to the Regenerative braking systems (RBS). Like, RBS increase the weight and cost of the electric vehicle. The friction brakes are needed in a situation where the vehicle needs to stop completely or regenerative brake failure. Because, the RBS works efficiently only at high speeds and at low speed, the RBS no longer supply sufficient generative braking torque and the friction brakes must be activated to stop the vehicle completely.

II. The Need for Regenerative Braking System

In traditional vehicle braking systems, friction is used to counteract the forward momentum of a moving vehicle. Excessive heat energy is generated when the brake pads rub against the discs connected to the wheels or axles. This heat energy is released into the atmosphere and wastes up to 50% of the energy produced by the vehicle. Over time, this friction and wasted heat energy cycle reduces the fuel efficiency of the vehicle. More energy is needed from the motor to replace the energy lost during braking. Most of it is simply released in

the form of heat and becomes useless. The energy that could have worked is essentially wasted. The solution to this problem is a regenerative braking system. This is an innovative braking system that can capture most of the kinetic energy from an electric vehicle and convert it into electrical energy and store it in the batteries.

The haul truck (Elektro Dumper) shown in Fig 1uses RBS technology. This truck climbs up the hill with a full charge, loads up with rocks and then goes back down the hill and recovers the lost energy by using the RBS. Due to the use of this technology, most the energy lost during climbing the hill is recovered by converting the kinetic energy to electrical energy when braking down the hill. This electrical energy is used to charge the battery. Hence the frequency of charging the battery reduces. This leads to increase in efficiency of the truck and decrease in the fuel cost. If RBS is not used, the charging of the battery will be expensive cause the batteries used in these haul trucks has massive battery capacity.

Fig 1: Elektro Dumper

III. Working Principle of RBS

The RBS used in the electric vehicles mainly involves the use of an electric motor as an electric generator. The working of the RBS depends upon the working principle of an electric motor, which is the crucial component of the system. Electric motor gets activated when the electric current from the battery,flows through it. But, when some external force is applied or removed (during the braking/ release of accelerator pedal, in case of single pedal drive), the sensor is activated, which in turn activates the electricmotor, then it behaves as a generator and generates electricity. This means that whenever the electric motor rotates in one direction, the electric energy gets converted into mechanical energy, which is then used to accelerate the vehicle and whenever the motor rotates in opposite direction, it performs the functions of a generator, which then converts mechanical energy into electrical energy, by allowing the rotational force of the drive shaft to be used to turn the electric motor, resulting in regeneration of electrical energy for storage in the battery and simultaneously reducing the speed of the car with the regenerative resistance (generative braking torque) of the electric motors. This electrical energy is then used for recharging the battery.

The below Fig 2 shown the working principle of RBS in an electric vehicle.

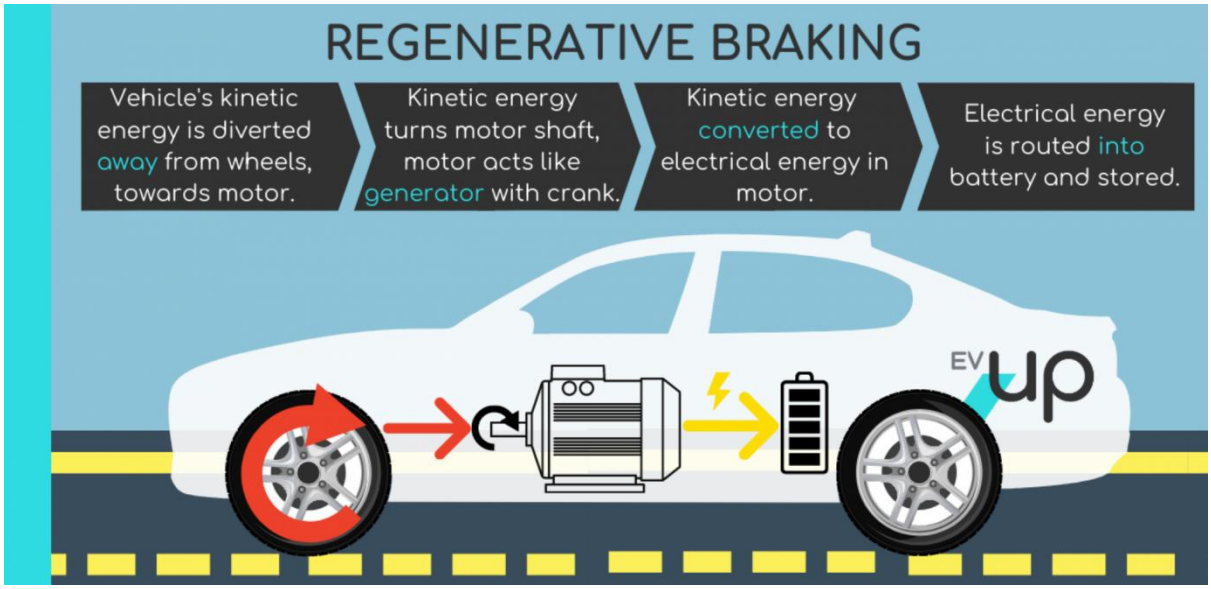

Fig 2: Working principle of RBS

Once the battery is fully charged, further charging the battery with the barking energy may affect or cause damage to the battery. Hence further charging the battery must be limited. For this purpose, we use BRC (Brake chopper) and HPR (High power resistor) to limit the charging of the battery once it's fully charged. The BRC is used to control the HPR circuit and the HPR is used to dissipate the braking energy into the cooling liquid. The working schematic diagram of BRC and HPR incorporated with the RBS is shown in Fig 3. The hardware structure includes PDU (Power Distribution Unit) which govern the flow of charges across the system. When the battery is not yet fully charged, the converted electrical energy from the e-motor, passes to the battery via the PDU and when thebattery if fully charged, the PDU directs the electrical current towards the BRC. The BRC activates the HPR and the excess electrical energy is converted to heat and transmitted to the cooling liquid. Hence the excess energy which was supposed to flow through the battery is now transmitted to the BRC via PDU, thereby preventing the battery from any form of damage caused by overcharging of the battery.

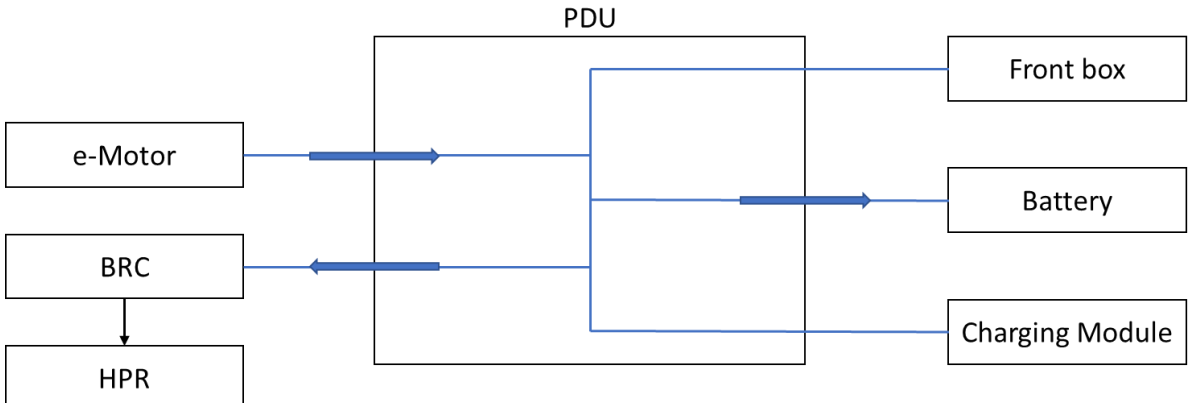

Fig 3: Incorporation of BRC and HPR in RBS

IV. Advantages of RBS

- Improved fuel efficiency – Due to recovery of kinetic energy and storing it as electrical energy, we can use it when required, improves the electric vehicles efficiency.
- Reduction in brake wear – Since the RBS usesgenerative braking torque to stop the vehicle at high speeds, the wear of the brake shoes caused by friction is reduced.
- Single Pedal drive – Dedicated brake pedal is not required as the RBS works as soon as the acceleration pedal is released (force applied is removed).

V. Disadvantages of RBS

- Added weight/bulk – Extra components can increase weight, increasing fuel consumption and reducing the mileage of the electric vehicle.
- Complexity – Complex control system is required for the operation of regenerative braking system.
- Cost – Cost of components, engineering, manufacturing, installation and maintenance is an added expense.
- Need of friction braking system – The friction brakes are needed in a situation where the vehicle needs to stop completely or regenerative brake failure.

VI. Conclusion

This study shows, information about the importance, working principle, advantages and disadvantages of regenerative braking systems. Many automation, electromechanical, and constructive studies have been carried out in this field in order to boost recovered energy efficiency and reduce operating costs. Considering that majority of the economic losses worldwide are caused by mechanical wear,the importance of RBS has become better recognized. When it comes tosafety, comfort, and economic aspects, the technology needs to be increased by further development and research in these brake systems. In the near future the designers and engineers will perfect regenerative braking systems. HenceRegenerative braking systems can capture more energy and stops faster. Regenerative braking systems, currently has limited use in electric vehicles only.

Future technologies in RBS will include new types of motors which will be more efficient as generators, more powerful battery which can bear more frequent charging and discharging, battery with higher storage capacity, new drive train designs which can be built with regenerative braking in mind, and electric systems which will be less prone to energy losses.

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