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A Review: Regenerative Braking System for Electric Vehicles

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Abstract: A detailed study of a reliable and effective regenerative braking system is presented in this paper. The hour of need is to conserve energy. In the case of electric vehicles, energy conservation can be accomplished with the use of regenerative braking systems (RBS). A large amount of kinetic energy is lost while driving a car, brakes are applied, making the start-up very power-consuming. In this paper, a way to use kinetic energy by regenerative braking has been explored and suggested, which is typically lost by either converting it into mechanical energy or electrical energy. Regenerative braking transforms much of the energy that can be retained for future use into electrical energy. Many cases of braking include driving a car, leading to higher losses of energy, with higher potential savings. In addition, it is possible to integrate an anti-lock braking system (ABS) and a traction control system (TCS), as a motor can produce torques of acceleration or deceleration. The position of the distributed motor will improve the performance of Vehicle Stability Control (VSC) such as Direct Yaw Control (DYC). The torque of the motor can be easily measured. The objective of this project is to investigate this new type of braking system that can absorb much of the electric vehicle's kinetic energy and convert it into electrical energy. Regenerative braking converts a fraction of total kinetic energy into mechanical or electrical energy, but with further study and research in the near future it can play a vital role in saving non-renewable energy sources.

Keywords: regenerative braking systems (RBS), Electric vehicles (EVs), hybrid vehicles (HVs), anti-lock braking system (ABS), traction control system (TCS), Electric motor, Kinetic energy recovery system

INTRODUCTION

Electric vehicle (EV) enjoyed success between themid-19th and early 21st centuries, when electricity was among the favoured automobile propulsion methods, offering a level of comfort and ease of operation that the gasoline cars of the time could not achieve. A key benefit of electric or hybrid electric vehicles is their ability to recover energy that is usually lost during the braking process known as regenerative braking. Furthermore, fast and accurate electric motor torque generation has an important advantage with regard to the performance[1] and drivability of the EVs. As energy cannot be created or destroyed by the' basic law' of physics, it can only be transferred from one form to another. During a huge amount of energy, the atmosphere is lost as heat. Regenerative braking refers to a mechanism in which kinetic energy of vehicles (EVs) is temporarily retained as accumulative energy during deceleration and recycled as kinetic energy during acceleration or driving. Regenerative braking is a small but very important step towards eventual release from fossil fuels. These kinds of brakes allow batteries to be used for longer periods of time without the need for an external battery to be attached. These types of braking also expand the driving range of the full-electric vehicle. Regenerative braking is a way of expanding the distance of electric vehicles. The word' breaking' in a moving vehicle means applying the brakes to lower their speed and prevent them from moving, typically by pressing a brake. The braking distance is the time between when the brakes are applied and when the vehicle reaches a complete stop. Friction is used on modern vehicles in braking systems to combat the forward motion of a moving vehicle. As the brake pads rub against the wheels or a disk attached to the axles, excessive heat energy is produced. This heat energy dissipates into the wind, losing up to 30% of the power generated by the engine. This cycle of friction and waste heat energy reduces the fuel efficiency of the engine over time. Additional power from the engine is required to balance the energy lost by braking. Most of it is only emitted and in the form of heat becomes useless. Essentially, the power is wasted and could have been used for science. This form of problem is solved by the regenerative braking method. This is a new type of braking system that can recover much of the kinetic energy of the electric vehicle and transform it into electrical or mechanical power. The generated energy can then be stored as mechanical energy in the flywheels, or as electrical energy in the automotive battery, which can be recycled.

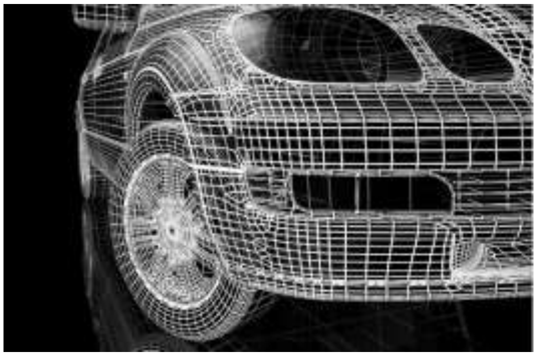

Figure.1: The Figure Portrays the Front View of Electric Vehicle

REGENERATIVE BRAKING SYSTEM FOR AUTOMOBILE

Moving vehicles have a lot of kinetic energy, and all that kinetic energy has to go somewhere when brakes are applied to slow a vehicle. Back in the Neanderthal days of internal combustion engine cars, brakes were based solely on friction and converted the vehicle's kinetic energy into waste heat to decelerate a vehicle. All that energy was lost to the climate. Regenerative braking, ideally, uses the engine of an electric vehicle as a generator to transform much of the kinetic energy lost by decelerating back into stored energy in the battery of the vehicle. Excessive heat energy is created in the conventional braking system, as the brake pads rub against the wheels or a disk connected to the axles. This heat energy dissipates into the air, wasting up to 30% of the power generated by the vehicle. Over time, this period of friction and heat loss reduces the fuel efficiency of the vehicle. There is a need for more energy from the engine to offset the energy lost by braking. It is important to realize that regenerative braking alone for electric vehicles is not a magical range booster. It doesn’t make electric vehicles more efficient per se, it just makes them less inefficient. Basically, the most efficient way to drive any vehicle would be to accelerate to a constant speed and then never touch the brake pedal. Since braking can drain energy and require additional input power to get back to speed. But that's not realistic, of course. Regenerative braking is the next best thing because it has to constantly stop. It takes the braking inefficiency and makes the process simply less wasteful. It can be converted from one form to another whenever it steps on the brakes of the vehicle. So when the vehicle slows down, somewhere has to go the kinetic energy that propelled it in the forward direction. Most of it is simply released and becomes useless in the form of heat. That energy is basically wasted, which could have been used to do work. The solution for this kind of this problem is Regenerative Braking System. This is a new type of braking system capable of recovering much of the kinetic energy of the vehicle and transforming it into electrical or mechanical energy. Regenerative braking is one of the automotive industry's emerging technologies that can be very useful. Using a regenerative braking system in a vehicle not only leads to energy recovery, it also increases vehicle efficiency (in the case of hybrid vehicles) and saves energy that is stored in the auxiliary battery. What the world needs now is a system or technology that saves electricity from waste. Energy conservation is the hour of need. In case of automobiles, energy conservation can be done by using regenerative braking systems (RBS). When driving an automobile, when brakes are applied, a large amount of kinetic energy is wasted, making the start-up quite energy-consuming. This project's main goal was to develop a product that will store and reuse the energy that is normally lost during braking. Using the regenerative braking system in cars provides with the means to restore the vehicle's kinetic energy to some degree that is lost during the braking cycle. The paper's authors discussed and proposed two ways of using the kinetic energy that is usually lost by either transforming it into mechanical energy or kinetic energy[2][3].

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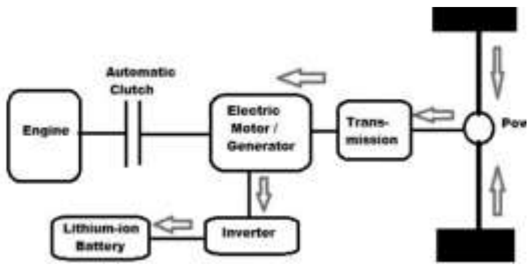

Figure.2: Regenerative Braking System for Automobile

Regenerative braking allows electric vehicles to use the engine as a generator to pump vehicle energy from the brakes into an energy storage system when the brakes are applied. Regenerative braking is an effective approach to expanding the driving range of EV and, depending on the driving period and how it was driven, can save from 8% to as much as 25% of the total energy used by the vehicle. The regenerative braking torque can not necessarily be rendered sufficiently high to provide the vehicle with all the braking torque needed. In addition, the regenerative braking system may not be used under many conditions, such as with a high state of charge State of Charge (SOC) or a high temperature of the battery. The traditional hydraulic braking system works to cover the total braking torque needed in these situations. Cooperation between the hydraulic braking system and the regenerative braking system is therefore a major part of the EV braking control technique design and is known as torque mixing. This strategy of torque blending helps to avoid driveline disturbances. The two broad classifications of techniques for regenerative braking control are as shown in Figure.3. The yellow area represents regenerative braking and the friction braking region in purple. The small yellow section at the bottom that reads the compression region corresponds to regeneration when the accelerator pedal is released and the car coasts when the brake pedal input is not available. Service region reflects regeneration when the brake pedal is applied and it reaches the red region when the full generator torque capacity is reached for parallel strategy in the case of serial strategy and simultaneous braking activation[4].

WORKING PRINCIPLE

It has to produce this model, applying the brake, condition while there is a loss of some energy that is conditions to prevent, it has to manufacture on kinetic energy storage method that is also attached for like sun and planetary gear and scroll spring. Brake condition done stop the wheel and disk contain system and clutch condition is disengaged the wheel and axle that is condition energy loss going on, while model engages the ring gear is rotated the reverse direction, as well as connecting on scroll spring rotate also the same direction that is condition saving the kinetic energy on clutch condition applied. When the clutch is removed, the pick-up and fuel efficiency increased by regenerating the kinetic energy on an axle that is condition. It really needs to look at two different parameters, efficiency and effectiveness, to test regenerative braking. The two are quite different despite sounding identical. Efficiency refers to the way in which regenerative braking captures' lost' braking energy. Wastes a lot of energy as heat, or does it restore all that kinetic energy to stored energy? Effectiveness, on the other hand, refers to the extent to which regenerative braking makes an impact. To summarize the benefits of EVs in the following three points:

1. An electric motor's torque generation is very good and this is an important benefit. The torque output of the electrical motor is several milliseconds, Viz. 10-100 times as effective as the hydraulic braking system or internal combustion engine. In addition, it is possible to integrate an anti-lock braking system (ABS) and traction control system (TCS), as a motor can produce torques of acceleration or deceleration. It will be possible to create a "Super Antilock Brake System (ABS)."
2. Small but powerful electric motors mounted in each wheel can produce even the unidirectional torques on the left and right wheels. The position of the distributed motor will improve the performance of Vehicle Stability Control (VSC) such as Direct Yaw Control (DYC).
3. Motor torque can be easily calculated Compared to an IC engine or hydraulic brake, there is much less variability in the driving or braking torque produced by an electric motor. It can be known from the current of the engine. This benefit would greatly contribute to the implementation of new

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control strategies focused on the assessment of road conditions. Traction control becomes a much simpler problem to solve if the motor torque is controlled correctly and instantly. Some of an electric motor's drawbacks for automobiles include high initial costs and complex motor speed controls. However, the advantages of the electric motor will open new possibility for novel vehicle motion control for electric vehicles.

Serial Regenerative Braking

Serial regenerative braking Serial regenerative braking is based on a combination of friction-based adjustable braking system with a regenerative braking system that transfers power to electric motors and batteries under an integrated control strategy (see figure: 1, 2). The overall design is to estimate the driver's deceleration and distribute the braking force needed between the regenerative braking system and the mechanical braking system. Serial regenerative braking could increase fuel efficiency by 15-30 percent. It requires a brake-by-wire system and because of its good torque blending capability, it has a more consistent pedal feel.

Parallel Regenerative Braking:

Parallel regenerative braking system is based on a combination of friction-based system and regenerative braking system that is worked in conjunction without integrated power. The regenerative braking force is applied to the adjustable mechanical braking force. With the mechanical braking force (Figure.3), the regenerative braking force increases. Only the regenerative braking force is controlled by the starting pedal movement, the usual mechanical braking force is not changed. The regenerative torque is measured by taking into account the motor power, SOC charging status of the battery, and speed of the vehicle. Through comparing the required brake torque and the usable motor torque, the regenerative braking force is determined from the brake control unit. The pressure of the wheel is reduced by the amount of regenerative braking force given by the hydraulic brake module. Parallel regenerative braking could increase fuel efficiency by 9-18 percent. It can be added to a standard braking system. Nonetheless, it may compromise the feeling of the pedal and therefore needs more effort to achieve good mixing of torque.

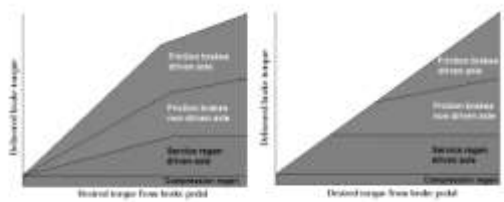

Figure.3: Parallel and Serial Regenerative Braking Control Respectively

BRAKING FORCE DISTRIBUTION STRATEGY

As shown in Figure 3, the vehicle's brake forces are divided into two parts during the deceleration process: the brake force imitating the conventional vehicle's engine brake and the brake force generated by the brake pedal operation. The brake force that imitates the engine brake is generated by the electric motor's regenerative brake torque. And its quantity is determined by the pedal operation of the vehicle speed and accelerator. The purpose of this brake force component is to provide the electrified vehicle driver with a good driving feel comparable to the traditional one and to further maximize the potential for regeneration. Throughout cooperative regeneration, the brake force produced by the brake pedal is given by regenerative and friction brakes, equal to the brake amount required by the driver[5].

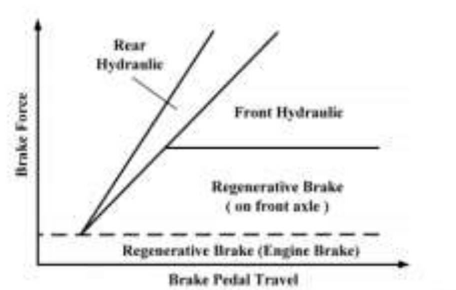

Figure.4: Distribution between Regenerative Brake and Hydraulic Brake

Efficiency:

No machine can be 100% efficient (without violating the laws of physics), as any energy transfer will inevitably result in losses such as heat, light, noise, etc. Regenerative braking process efficiency varies across many vehicles, engines, batteries, and controllers, but is often 60-70 percent efficient somewhere in the neighbourhood[4]. Area usually loses about 10-20 percent of the energy produced, and then, according to Tesla, the car loses another 10-20 percent or so when the energy is converted back into acceleration. This is quite common for most electric vehicles, including buses, trucks, electric bicycles, electric scooters, etc. Keep in mind that this 70 percent does not mean a 70 percent increase in the performance of regenerative braking. This won't bump a range between 100 miles and 170 miles. This simply means that 70% of the kinetic energy lost during the braking action can later be turned back into acceleration. That's why it doesn't really mean much just reporting the machine performance. If they work, someone might be very productive, but if they only work an hour a day, they probably don't do much. What should concerns more is the regenerative braking performance[6]. Fig.4 shows the distribution among the regenerative braking and hydraulic braking.

Effectiveness:

That's where things really get interesting. Regenerative braking's effectiveness is a measure of how much the range can be increased. Does it add 5 percent to the theoretical range? Fifty percent more? Even more? As you probably already guessed, the effectiveness of regenerative braking varies considerably depending on factors including driving conditions, terrain and size of the vehicle. Conditions for driving have a big impact. In stop-and-go city traffic, you will see much better efficiency for regenerative braking than in highway traffic. Regenerative braking can be used almost constantly on long downhill to control speed[7] when charging the battery continuously. For the simple reason that heavier vehicles have much more momentum and kinetic energy, vehicle size may be the biggest factor in regenerative braking efficiency[8]. Just as a large flywheel is more powerful than a small flywheel, when in motion, an electric four-wheel drive has much more kinetic energy than an electric bicycle or scooter. Comparison data can be somewhat difficult to get through. Tesla vehicles have shown the regenerative braking power during hard braking, such as 60 kW, but this does not answer the more interesting question. Luckily, a variety of Tesla drivers used various data tracking apps to report back energy contribution data. Model S drivers registered recovering as much as 32% of their total energy consumption when driving up and down. For example, this would effectively increase the range of a 100-mile car to 132 miles. A Model S P85D owner reported about 28 percent energy recovery (Danish forum) and others reported recovering an average of 15-20 percent of their total kWh use during normal trips.

Advantages:

- Quality enhancement.
- Improved fuel economy, duty cycle based, power train design, control strategy, and individual component performance.
- Reduction of wear on the engine.
- Brake reduction Wear-Reducing expense of new brake lines, labor costs of installation and downtime of vehicles,
- Reduction of engine emissions by decoupling engines, reduction of total engine revolutions and total engine running time.
- The operating range is comparable to conventional vehicles, an issue that electric vehicles have not yet overcome.

Application:

- To recover the vehicle's kinetic energy lost during the braking cycle.
- In a manufacturing plant that moves material from one workstation to another on a conveyor system that stops at each point, regenerative braking would be theoretically applied.
- Some elevator and crane hoist motors are used for regenerative braking.
- Also used in electric rail vehicles (London Underground & Virgin Trains) are regenerative braking systems.

Future Scope:

To order to develop a better system that collects more energy and stops quicker, regenerative braking systems require more work. All moving vehicles can benefit from these systems by recovering energy lost during the braking process. Future regenerative brake technology will include new engine models that will be more effective as generators, new drive train designs that will be designed with regenerative braking in mind, and electrical systems that will be less susceptible to loss of energy.

CONCLUSIONS

The regenerative brake absorbs about half of the energy wasted and is used by the engine in this design of the Regenerative Braking System, while in traditional brakes 80 percent of the energy wasted. As a result, fuel consumption is reduced by 10-25% in regenerative braking. The braking system not only greatly enhances the speed of the car. Driving is a process that is extremely wasteful. Large quantities of kinetic energy turn into heat and leave the car. Fortunately, this heat is used by a regenerative braking system to regenerate the electric vehicle batteries. There is still much room for improvement, despite the amount of research and development that has gone into regenerative braking. Regenerative braking remains very restrictive and relies on uncontrollable variables. Also, if regenerative braking is applied to two-wheel brake systems, there may be a danger. Regenerative braking, however, has various advantages. Regenerative braking system properly implemented extends the driving range, enhances braking performance, decreases brake wear and improves energy conservation.

REFERENCES

[1] J. Ruan, P. Walker, N. Zhang, and G. Xu, "The Safety and Dynamic Performance of Blended Brake System on a Two-Speed DCT Based Battery Electric Vehicle," *SAE Int. J. Passeng. Cars - Mech. Syst.*, 2016, doi: 10.4271/2016-01-0468.

[2] X. Nian, F. Peng, and H. Zhang, "Regenerative braking system of electric vehicle driven by brushless DC motor," *IEEE Trans. Ind. Electron.*, 2014, doi: 10.1109/TIE.2014.2300059.

[3] M. Silva, A. P. Gonçalves, J. Marques, J. Sousa, and U. Nunes, "Modelling an electric vehicle powertrain on bench," 2014, doi: 10.1109/VPPC.2014.7007104.

[4] G. Xu, W. Li, K. Xu, and Z. Song, "An intelligent regenerative braking strategy for electric vehicles," *Energies*, 2011, doi: 10.3390/en4091461.

[5] J. Ko *et al.*, "Development of regenerative braking co-operative control system for automatic transmission-based hybrid electric vehicle using electronic wedge brake," 2014, doi: 10.1109/EVS.2013.6914740.

[6] C. Fiori, K. Ahn, and H. A. Rakha, "Power-based electric vehicle energy consumption model: Model development and validation," *Appl. Energy*, 2016, doi: 10.1016/j.apenergy.2016.01.097.

[7] X. Li, L. Xu, J. Hua, J. Li, and M. Ouyang, "Regenerative braking control strategy for fuel cell hybrid vehicles using fuzzy logic," 2008.

[8] J. Zhang, X. Lu, J. Xue, and B. Li, "Regenerative braking system for series hybrid electric city bus," 2007, doi: 10.3390/wevj2040363.