Research on regenerative braking energy recovery strategy of electric vehicle

Chunhui Liu\textsuperscript{1a}\textsuperscript{*}, kun Zhang\textsuperscript{1b}

\textsuperscript{1} School of mechanical engineering, Shandong Huayu Institute of Technology, Dezhou, Shandong, China
\textsuperscript{a}email: 18953465089@126.com, \textsuperscript{b}email: 297162997@qq.com,
\textsuperscript{*}Corresponding author’s e-mail: 18953465089@126.com

Abstract. In the braking process of electric vehicles, the speed will be reduced due to braking friction. How to use the principle of braking energy recovery to recover the braking energy, and convert the recovered braking energy into electrical energy for storage, and then convert the chemical energy into electrical energy when the motor is rotating forward. The state pays more and more attention to energy conservation and environmental protection, and the electric vehicle technology will make a major breakthrough. In the near future, electric vehicles will become the mainstream of urban transportation.

1. Introduction
With the arrival of winter, the short board of electric vehicle application is highlighted. The driving mileage marked by the manufacturer reaches 300 km, and the current normal driving mileage is less than 100 km. Therefore, the promotion obstacle in the popularization of electric vehicles appears, that is, short driving range.

The braking energy recovery technology of electric vehicles is to use the dual-mode working characteristics of the driving motor currently used. When driving the wheel to brake, the dual-mode motor changes to the power generation state, converts the braking force generated during braking into electric power to recharge the energy storage battery, converts the braking force into electric energy, and replenishes the on-board battery, thus indirectly increasing the driving range of electric vehicles.

The essence of automobile braking energy recovery technology is that in the process of automobile deceleration or braking, the motor reverses to provide braking torque. In this case, the motor runs in the form of a generator, which converts the mechanical energy into electrical energy to complete the charging of the battery and store the energy, to achieve the purpose of improving energy utilization.

Regenerative braking technology refers to the process that when the vehicle decelerates or brakes, the motor of pure electric vehicle is controlled to operate as a generator, which converts part of the kinetic energy of the vehicle into electric energy or other forms of energy and stores it in the energy storage device for driving.

The regenerative braking energy recovery is affected by the driving motor, battery, vehicle parameters, driving environment, braking recovery control and other factors. Automobile braking energy recovery is a new compound braking system which is formed by adding motor regenerative braking system on the basis of original braking system. In the braking process of electric vehicles, the motor is used as a generator in turn. In this case, the kinetic energy of the vehicle can be converted into electric energy and stored in the energy storage device. Through the above analysis, the
requirements for the braking system of pure electric vehicles to achieve braking energy recovery should not only meet the braking requirements of traditional vehicles, but also realize the braking energy recovery at the same time.

2. Basic principle of braking energy recovery

Regenerative braking energy recovery of electric vehicles means that the driving motor should be in the working state of the generator during the braking or deceleration process of the electric vehicle, so that the kinetic energy of the vehicle can be converted into electrical energy and stored in the energy storage device (vehicle battery). In the battery, the electrical energy is converted into chemical energy for storage, and achieve the purpose of using the reverse torque generated by the motor to provide braking torque for the vehicle to make the vehicle decelerate and brake.

The core components of the electric vehicle power system are the motor and battery. In the process of driving the electric vehicle, the battery on the electric vehicle supplies power to the driving motor, which drives the vehicle through the transmission mechanism; In the process of braking, the driving motor turns into a generator for power generation, which converts part of the kinetic energy into electric energy and stores it in the battery, so as to achieve the purpose of energy saving and efficiency improvement. When the speed of the driving motor is greater than the base speed, the driving motor will provide the battery with the electric energy converted from energy and the braking torque, which belongs to the downhill situation; When the speed of the driving motor is less than the deceleration braking of the base speed, the driving motor is in the state of generator. In this case, the battery can be charged only when the brake energy conversion voltage is higher than the battery voltage.

In the normal motor feedback braking, the feedback torque generated by motor power generation alone cannot meet the total braking demand, which can meet the driver's braking demand under the condition of ensuring the braking performance, and ensure the braking comfort and stability, which needs to be completed together with hydraulic braking. The vehicle braking system must have the participation of the drive system, in order to achieve accurate and stable control of the brake fluid pressure.

The electro-hydraulic braking system can solve this problem perfectly. The electro-hydraulic braking system can identify the driving style of different drivers according to the braking force of different drivers under the same working conditions. For different types of electronic control braking system, the corresponding braking force can be generated according to different electrical signals to adjust the pedal power ratio to adapt to the driving style of different drivers.

3. Structure classification of regenerative braking for pure electric vehicles

3.1. Tandem braking

The tandem braking mechanism is shown in Figure 1. According to the driver's pedal command, in order to keep the front and rear wheel braking force required for stable braking, the torque controller calculates the front and rear wheel braking force, distributes the front wheel hydraulic braking force and motor braking force, and then sends the torque demand command to the hydraulic braking system and the motor controller respectively. If the motor braking torque cannot reach the required torque, the hydraulic braking system is needed to supplement to ensure the total braking force demand, so as to stabilize the braking.
3.2. Parallel brake

As shown in Figure 2, the parallel braking lacks active braking control, and the coordinated control between motor braking and hydraulic braking cannot be realized. Therefore, the use of parallel braking on motor braking torque is insufficient, and the energy recovery is less.

4. Problems in braking energy recovery

When the driver steps on the brake pedal in the normal driving process, the control unit obtains the relevant information of the braking strength according to the pedal speed signal, and then the control unit intelligently distributes the front and rear axle braking force, friction braking force and regenerative braking force according to the set control strategy. Thus, the vehicle speed signal is obtained through the speed sensor, and according to all aspects of the information of the control unit, the maximum braking torque of the driving motor, the maximum charging power of the battery, the current charging state of the battery and other limiting factors are comprehensively collected, and the electromechanical composite braking is realized through the motor and hydraulic braking system.

The power generated by the driving motor as a generator is transmitted to the battery through the inverter. Under the condition of ensuring the good braking performance of the electric vehicle, how to correctly distribute the braking feedback torque generated by the driving motor and the hydraulic braking torque generated by the hydraulic braking system (whether the hydraulic control torque is used for energy utilization), So as to achieve the maximum energy recovery on a certain basis. At the
same time, the braking process of electric vehicles is very vulnerable to environmental factors such as the temperature of relevant components during braking, and the braking can make the brake pad strength decline. When the torque is too large in the braking process, it is easier to cause the temperature rise too fast and the braking recession, thus increasing the burden of the cooling system, consuming more energy to a certain extent and reducing the energy utilization rate. This situation should be avoided as far as possible.

5. Optimal braking energy recovery control strategy
For the recovery of braking energy, the purpose of most researchers is to improve the efficiency of braking energy recovery as much as possible, so as to provide greater driving force to a greater extent. According to the research findings, the core of the optimal braking energy recovery control strategy is to perfectly provide the braking torque required by the vehicle braking in the normal driving process of the electric vehicle, and to improve and meet the relevant braking safety performance requirements. The good distribution of the braking force of the front and rear axles of the electric vehicle should meet the performance requirements of the total braking torque, and at the same time, the maximum energy recovery efficiency should be used for energy recovery under the premise of ensuring that the wheels do not lock. When the braking strength is less than the road adhesion coefficient, the front wheel should bear the perfect effect of braking torque as much as possible.

The safety of braking is the goal that researchers must pursue. In the aspect of ensuring the safety of braking, the braking force of the front and rear axles of electric vehicles should be distributed according to the ideal braking force distribution curve in the braking process, so as to achieve the maximum braking force strength that can be provided by the road, which can ensure the shortest braking distance to a great extent. The purpose of braking efficiency is the best.

At the same time of braking, the driving capacity of the electric vehicle should be turned off. During the braking process, the vehicle moving forward is mainly maintained by the inertia force of the vehicle itself. Therefore, braking kinetic energy recovery is to further recover a large part of the inertia kinetic energy. In this case, the recovery is mainly through the electric vehicle energy conversion device to control the regenerative braking state of the motor energy utilization efficiency to complete the mutual conversion of braking energy, so as to achieve the purpose of improving the energy utilization efficiency, to a certain extent, improve the efficiency of energy utilization.

6. Limiting conditions of vehicle braking energy recovery
The size of the car's braking performance is related to the safety and comfort of the car. The large-scale application of electric vehicle braking energy recovery technology can improve the energy-saving efficiency to a great extent, and achieve the current concept of green, environmental protection and energy saving. The regenerative energy-saving braking of electric vehicles can also affect the safety performance of the vehicle, but it can not affect its handling, comfort and the reliability of vehicle operation. Through the current electric vehicle manufacturing technology, there is still a big contradiction between the braking energy recovery strength and the driving safety, handling flexibility, riding comfort and operation reliability of the electric vehicle. If it can be solved comprehensively, the technology will be greatly improved. Not all the braking energy can be recycled. Only when the driving wheel of electric vehicle is in the process of braking, the relevant braking energy can be transmitted to the wheel through the relevant connecting mechanisms such as the driving shaft and the half shaft, so as to transfer the energy to the energy storage device.

7. Significance of electric vehicle braking energy recovery
With the increase of national subsidies for new energy vehicles, the development of electric vehicles, as one of the new energy vehicles, will usher in a big blowout, the recovery technology of braking energy will be more and more perfect, and the efficiency will be greatly improved. In the final analysis, the purpose of the development of electric vehicle braking energy recovery technology is to reduce the energy loss of electric vehicles in the braking process, and improve the energy utilization efficiency.
The higher the energy recovery efficiency, the more obvious the energy saving effect, so as to achieve the purpose of improving the range of electric vehicles to a greater extent. We know that the greater the initial driving speed of an electric vehicle during braking, the more energy that can be recovered during braking. How to make the brake energy recovery and the use of various types of vehicle related performance to achieve a more perfect match. Of course, there is still a big gap in the perfect coordination of other performance of electric vehicles. In this case, it is necessary to sacrifice some aspects of performance to improve energy utilization. Because the regenerative braking process of electric vehicle motor participates in the whole braking process of electric vehicle during braking, the share of braking is reduced. At present, the "forced braking" generated by high-intensity energy recovery is obviously not worth the loss, which will reduce the efficiency of braking energy. Smooth sliding braking is the driving experience that the driver needs, It is necessary for various vehicles to brake. With the increase of braking strength, the value of braking energy recovery decreases and the efficiency of energy recovery decreases.

At present, the major vehicle lines in the world are making great efforts to study the braking traffic recovery of electric vehicles. At the same time, the application and transformation of patent technology related to braking energy recovery technology of relevant research institutions are also increasing year by year. According to the current use status of electric vehicles, it is relatively clear that there are some insurmountable difficulties in the current braking energy recovery technology. However, the braking energy recovery technology is still of great significance to improve the endurance of electric vehicles, which is a hot topic in the industry.

8. Conclusion
With the further tightening of the world's policies on energy conservation and environmental protection, the state pays more attention to the new energy vehicle industry. The research on the regenerative braking technology of electric vehicles will become the mainstream of the development of the electric vehicle industry, and the energy utilization will be further improved. The braking energy recovery is a key technology for new energy vehicles, Improving fuel efficiency is a key technology in the automotive industry, especially in the electric vehicle industry.

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