Summary of Regenerative Braking System

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Abstract

This paper summarizes the current research status of regenerative braking system from three aspects: electric vehicle, urban rail transit vehicle and hybrid electric vehicle; analyzes the main factors affecting regenerative braking by comparison; expounds and compares the control strategies of the main factors affecting regenerative braking; and analyzes the domestic and foreign re-braking. Research on the current situation and development trend of technology in the field of birth brake. Finally, the problems that need to be solved urgently in the braking energy recovery system of electric vehicles, urban rail transit vehicles and hybrid electric vehicles are put forward. This paper introduces various kinds of brake energy recovery technologies at home and abroad, analyzes the characteristics of different brake energy recovery technologies, points out the solutions to the problems existing in the brake energy recovery technology and the hot research directions at home and abroad, and discusses the development trend in this field.

Keywords

Regenerative braking system; energy recovery; electric vehicles; urban rail transit vehicles; hybrid electric vehicles.

1. Introduction

Nowadays, the pressure on energy and environment caused by automobiles has become a common concern of all countries. The braking energy of automobiles is still a kind of undeveloped energy. In the braking process, a large amount of kinetic energy can only be dissipated by transforming friction into heat energy consumption, which not only wastes valuable energy but also leads to premature grinding of the braking system of automobiles. The related literature shows that the braking energy accounts for about 50% of the total driving energy under urban driving conditions. In order to eliminate the excess kinetic energy, the thermal degradation of the brake becomes a potential safety hazard under these driving conditions. With the increasingly stringent requirements for energy consumption, environmental protection and safety performance of automobiles, the recovery and reuse of braking energy has become a hot issue in automotive technology research. The most expressive of braking energy recovery is the performance of electric vehicles, urban rail transit vehicles and hybrid vehicles.

2. Working Principle of Automobile Regenerative Braking

The principle of regenerative braking is that the inertia energy of the vehicle is transmitted to the motor through the transmission system when braking. The motor works in the form of a generator and charges the power battery to realize the regenerative utilization of the braking energy. At the same time, the resulting motor braking torque can be applied to the drive wheel through the transmission system, resulting in braking force. When considering several application occasions of regenerative braking power generation, braking, downhill taxiing, high speed operation and low speed operation should be considered comprehensively.

Compared with the high braking torque requirement, the motor can only provide a small braking torque, so the braking system of EV not only includes regenerative braking system, but also retains the traditional hydraulic braking system. The regenerative braking system can be fully utilized when the vehicle is running under the condition of frequent braking and low braking intensity. If the braking strength of the vehicle is high, the traditional hydraulic braking should be used as much as possible to keep the braking safety of the vehicle, while the motor is less involved or not involved in the braking.

As shown in the figure, when the vehicle needs to decelerate, through the control system, the driving wheel back-drive motor, driving motor into the generator working state, generating reverse current, while generating the braking torque acting on the driving wheel, the braking power can be recovered through the power battery.

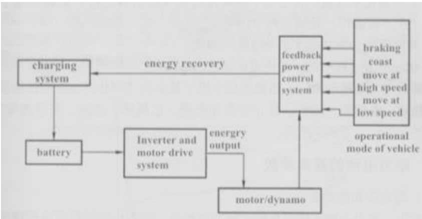

Fig. 1 Energy recovery

3. Regenerative Braking of Electric Vehicle

3.1 Regenerative Braking System Structure

Electric vehicle braking system consists of mechanical braking system and regenerative braking system. The structure of regenerative braking system can be divided into three types according to the layout of driving motor: central motor regenerative braking system, rim motor regenerative braking system and hub motor regenerative braking system. For the front wheel drive electric vehicles, the specific structures of these 3 types of braking systems are shown in figure 2~4.

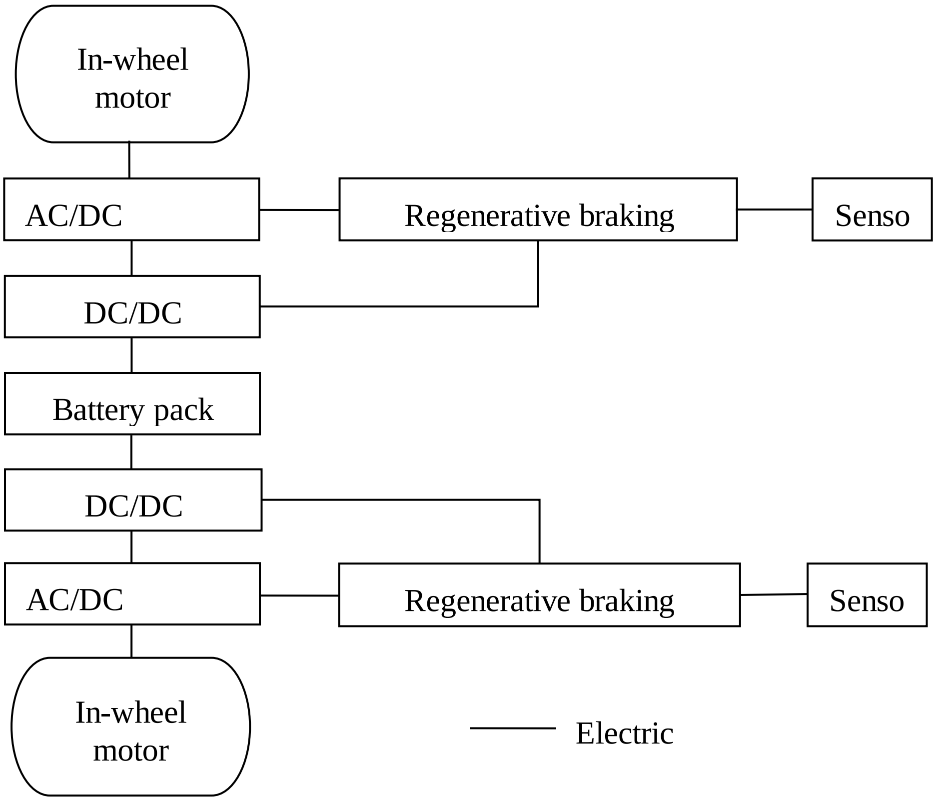

Fig. 2 Central motor regenerative braking system

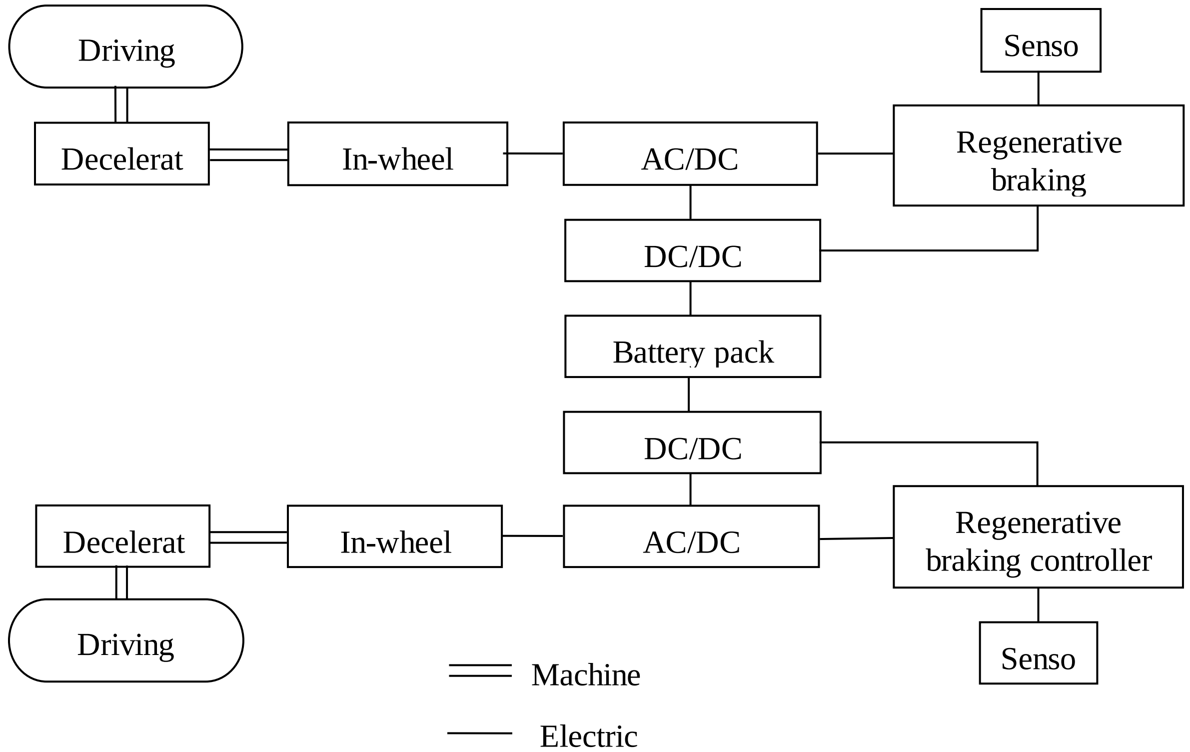

Fig. 3 Wheel side motor regenerative braking system

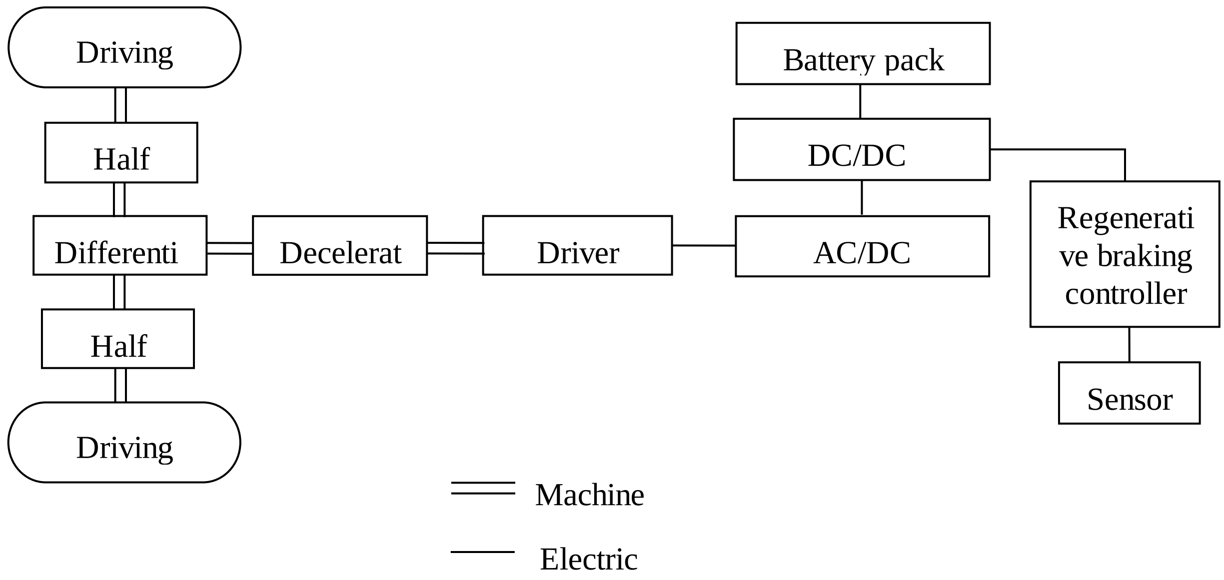

Fig. 4 Wheel hub motor regenerative braking system

3.2 Best Control Strategy

The optimal braking energy recovery control strategy focuses on maximizing the energy recovery of the braking system. The control idea is that the braking torque of the system is provided by the driving wheel completely on the premise that the front and rear wheels do not lock. When the maximum braking strength provided by the motor can meet the needs of the braking system, give full play to the power generation of the motor, all the braking force is provided by the regenerative braking system, maximizing the recovery of energy. When the maximum braking strength provided by the motor is lower than the braking strength required by the braking system, the motor provides the maximum regenerative braking force, and the insufficient braking force is supplemented by the mechanical braking force. The distribution relationship between the front and rear wheels is shown in Figure 5.

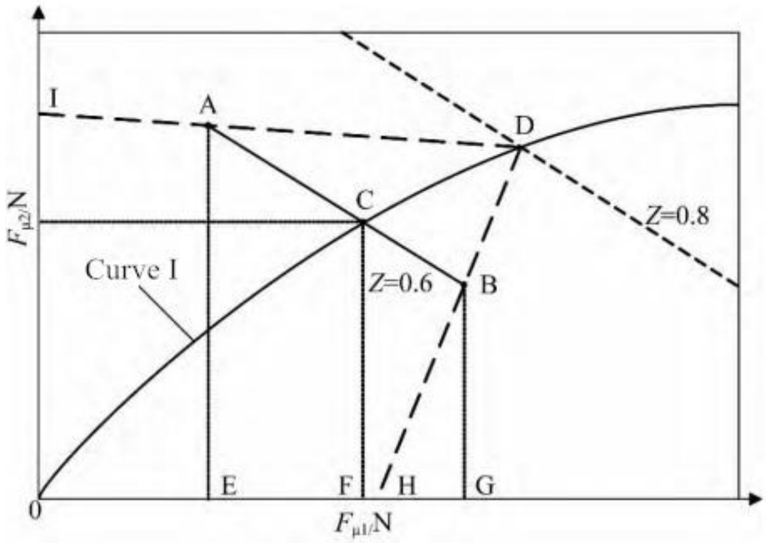

Fig. 5 Optimal braking energy recovery control strategy

4. Urban Rail Vehicles

At present, the popular regenerative braking schemes at home and abroad are mainly composed of two types of device energy storage and inverter energy supply. Both schemes have their own unique advantages, so there are application examples in the world, but there are also some shortcomings, which need to be further improved and improved.

4.1 Device Energy Storage Type

The schematic diagram of device energy storage type braking energy recovery is shown in Figure 6. The energy storage device uses the resistive energy dissipation device as the standby system, and mainly uses bidirectional DC / DC converter to absorb the regenerative braking energy of the vehicle into the energy storage device. When the electricity demand appears in the power supply section, the stored energy is released. The miniaturization and diversification of energy storage devices provide a reliable technical guarantee for the energy recovery technology of energy storage brake, and point out the development direction for the future application of this technology.

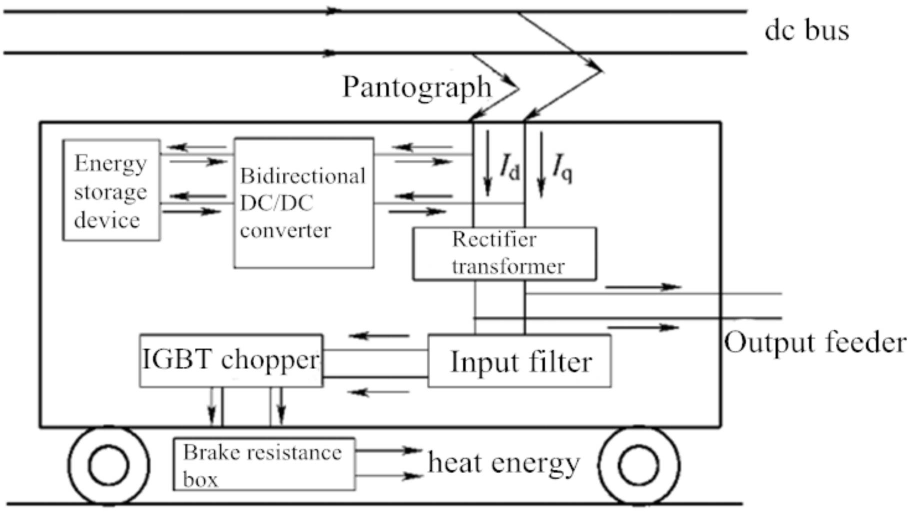

Fig. 6 Schematic diagram of energy storage type braking energy recovery device

4.2 Inverting Energy Supply Type

In the inverter power supply scheme, high-power thyristor three-phase inverter is used to connect DC bus and AC grid. When the rail vehicle realizes regenerative braking, it can be divided into two types: inverter feedback type and inverter load type according to the direction and use of the current inverter.

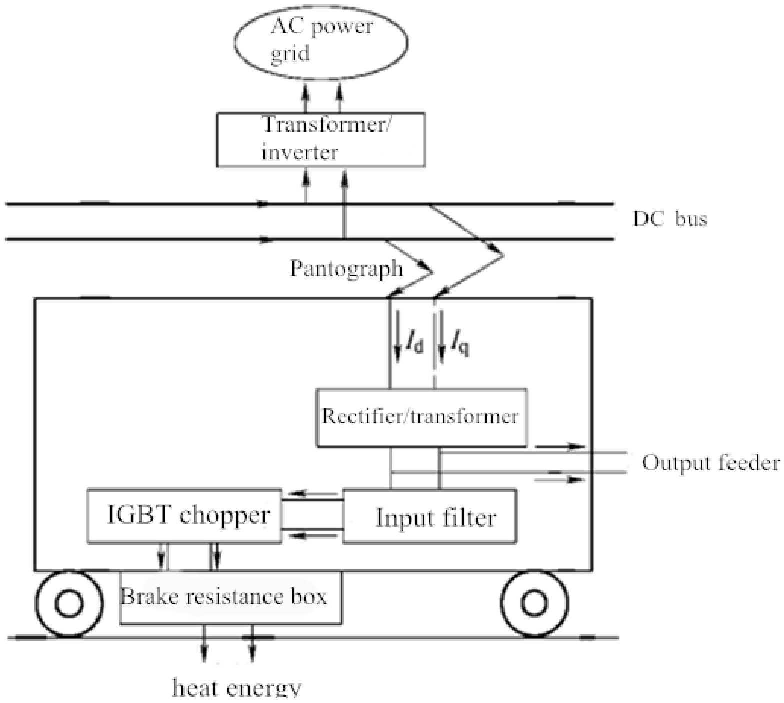

Fig. 7 Schematic diagram of inverter feedback braking system

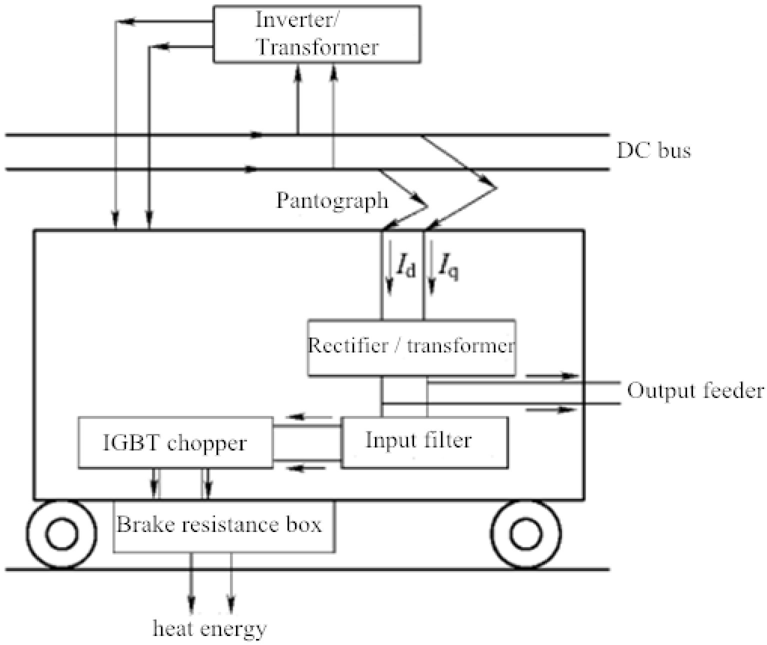

Fig. 8 Schematic diagram of inverter load braking system

5. Hybrid Electric Vehicle

5.1 Series Braking for Optimum Braking Effect

The series braking system with the best braking effect controls the braking force applied to the front and rear wheels by the controller, so as to minimize the braking distance, and the driver feels good. This requires that the braking force exerted on the front and rear wheels follow the ideal braking force distribution curve I. When the given brake pedal stroke is less than a certain value, only regenerative braking is applied to the front wheel to simulate the delayed ignition effect of the engine in traditional automobiles. When the brake pedal stroke is greater than this value, the brake force applied to the front and rear wheels follows the ideal brake force distribution curve I, as shown in the thick line of Figure 9.

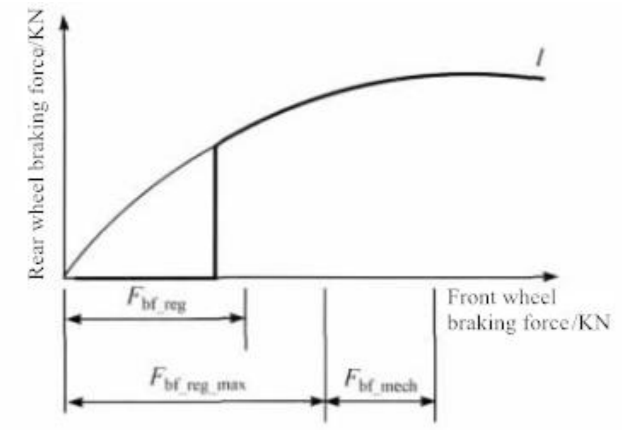

Fig. 9 Front and rear wheel braking force corresponding to the best braking effect.

5.2 Tandem Braking for Optimal Energy Recovery

Series braking with optimal energy recovery is to recover as much braking energy as possible under the condition that the total braking force corresponding to a given brake pedal stroke instruction is satisfied.

When the braking strength Z is less than the road adhesion coefficient braking (as in Figure 3 = 0.9, z = 0.7), as long as the sum of the front and rear wheel braking forces is equal to the total braking force, the braking force applied to the front and rear wheels can vary within a certain range. The variation range is shown in Figure 3, AB. Regenerative braking should be preferred at this time; if the braking force applied on the front wheel is only obtained by regenerative braking in this range (point C in the figure), it is not necessary for mechanical braking to meet the total braking force requirement, and if the braking force of the rear wheel is less than the corresponding value of point A, the maximum regenerative braking force is generated by controlling the motor. The braking power of the front and rear wheels should be controlled at point F to optimize the driver's sensation and reduce the braking distance. At this time, the mechanical friction braking force must be generated on the front wheel, and the braking force of the point H will be generated on the rear wheel.

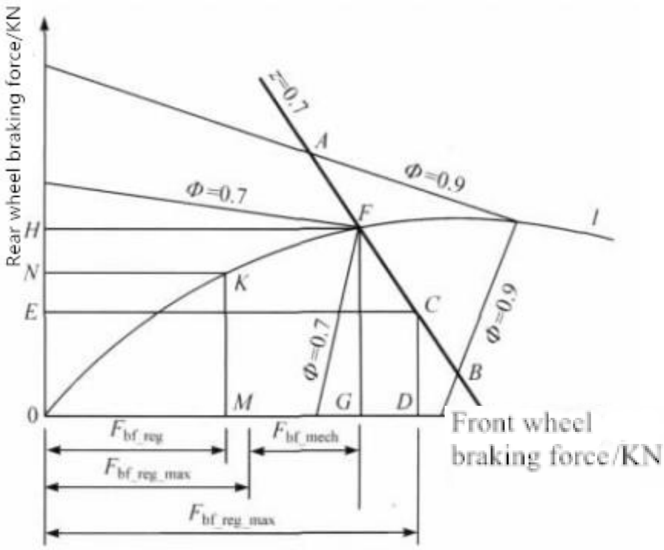

Fig. 10 Corresponding front and rear wheel power for optimal energy recovery

5.3 Parallel Brake

Parallel braking system has a traditional mechanical braking device which distributes the front and rear wheels at a fixed braking force ratio. The regenerative braking adds the additional braking force applied on the front wheel, resulting in the total braking force distribution curve. The mechanical braking force exerted on the front and rear axle is proportional to the brake pedal travel. The regenerative braking force produced by the motor is a function of the stroke of the brake pedal, therefore, a function of the braking strength. Since the effective regenerative braking force is a function of the motor speed and there is little recoverable kinetic energy at low speeds, the regenerative braking force is designed to be zero at higher braking strength (e.g., z = 0.9) to ensure a balanced braking when the required braking strength is less than the braking strength. Brake is effective.

The parallel braking system does not require an electrically controlled mechanical braking system. A pressure sensor detects the brake pedal travel, which indicates the requirement of braking strength. The pressure signal is reshaped and transmitted to the vehicle controller to control the motor to produce the required braking torque. Compared with series braking with the best braking sensation and the best energy recovery rate, the parallel braking system has a simple structure and its control system, but the driver's sensation and energy recovery are compromised.

6. Conclusion

In this paper, the working principle and basic structure of electric vehicles, urban rail transit vehicles and hybrid electric vehicles are analyzed. The regenerative braking system of electric vehicles, urban rail transit vehicles and hybrid electric vehicles is analyzed and illustrated. It is concluded that regenerative braking system is the most rapid development direction in this worsening environment and increasingly urgent energy.

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