Vehicle Exhaust Gas Treatment And Energy Recovery And Utilization Device Based On Turbine Dynamic And Static Cascade

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Abstract: At present, the energy utilization efficiency of automobile engines is generally low. Only about 1/3 of the chemical energy released by engine fuel is effectively used. Most of the energy is lost or discharged into the atmosphere in the form of waste heat, which causes a great waste of energy. Based on the above problems, this work proposes a device for the purification of automobile exhaust gas and the efficient use of automobile residual energy. This design effectively increases the contact area of the harmful gas and the catalyst and improves the catalytic efficiency. At the same time, a thermoelectric power generation system is arranged in the electrostatic precipitator room, which converts the heat energy of automobile engine exhaust into electrical energy, and realizes energy recovery and utilization. The device of the invention realizes the recycling of the exhaust energy of the engine exhaust, effectively solves the defects existing in the traditional three-way catalyst, and reduces the pollution and harm caused by the exhaust gas.

1. Introduction
Automobile exhaust is one of the main sources of air pollution in the near-Earth space. The existing exhaust purification device uses a traditional porous three-way catalyst carrier structure [1]. The exhaust resistance of the exhaust is large, and the small holes are easy to block, which leads to the reduction of engine combustion efficiency and vehicle power performance; secondly, the high-temperature and high-pressure residual energy of automobile exhaust cannot be effectively recycled, and most which are is converted into heat energy and discharged into the atmosphere; again, it cannot effectively deal with solid particulate matter, one of the exhaust pollutants. In order to solve the above problems, a new high-efficiency and low-resistance automobile exhaust purification device was designed [2]. The basic idea of the design of the works is as follows: The device is mainly composed of four groups of series turbine dynamic and static cascade three-way catalyst, flat plate electrostatic precipitator, thermoelectric power generation system and muffler. Using the principle that the turbo mechanical impeller can convert pressure energy and heat energy and reduce drag, the static carrier of the traditional porous three-way catalyst is designed as 4 sets of turbine dynamic and static cascades in series to convert the stratified flow into rotating turbulent flow [3]. This design can effectively increase the contact area of harmful gas and catalyst, and improve the catalytic efficiency; the use of turbine moving cascades can convert high-pressure exhaust gas into impeller kinetic energy, set up a small impeller power generation system, and use the temperature difference power generation system to recover high-temperature and
high-pressure residual energy, to achieve energy gradient utilization. A plate-type electrostatic precipitator is installed in the muffler to absorb the solid suspended particles in the exhaust gas. In addition, we also conducted numerical calculations and established three-dimensional models and physical experiments. By comparing and analyzing the effects of exhaust gas purification and drag reduction to confirm the feasibility of the program.

2. Design

Multiple sets of series dynamic and static cascade three-way catalyst devices. The device is mainly composed of a gradually expanding stainless steel outer shell, 4 sets of cascade turbine dynamic and static cascade three-way catalysts, stainless steel support shaft, ceramic flow guide (wheel hub), etc. A support shaft is installed in the casing, and 4 sets of dynamic and static cascade three-way catalyst carriers are installed on the support shaft and the rotation shaft in series. The shell provides a reaction space for the catalytic conversion of the three-way catalyst, and the support shaft provides support for the blades. During the exhaust stroke, high-pressure residual energy exhaust enters the turbine static and cascade three-way catalyst from the engine exhaust valve through the exhaust manifold. The pressure difference on the opposite side, this pressure difference generates lift, which causes the impeller to rotate and continuously cross the wind flow. The blade acts as a carrier for the three-way catalyst and is covered with a catalyst coating. During this process, harmful gases such as carbon monoxide, nitrogen oxides, and hydrocarbons are converted into harmless carbon dioxide, nitrogen, and water under the action of the catalyst [4].

Small turbine power generation system. When the high-temperature and high-pressure automobile exhaust flows through the turbine dynamic and static cascade three-way catalyst, the small turbine power generation system can convert the residual energy of the high-pressure exhaust flowing through, and convert it into electrical energy for storage in the battery [5].

The device consists of turbine dynamic and static cascade (the main carrier of three-way catalyst), small DC generator, battery, controller, inverter, electric wire and other components. According to the principle of fluid mechanics, the high-temperature and high-pressure exhaust gas is guided by the static cascade and enters the turbine cascade. Due to the pressure difference between the blade working surface and the back, the airfoil lift is generated. The turbine rotates and continuously cuts the tail gas flow to increase the contact probability of the tail gas with the catalyst. The rotation of the turbine drives the generator to generate electricity. The electricity generated by the turbine power generation system is rectified by the controller to charge the battery [6].

Thermoelectric power generation system. After passing through the turbine cascade power generation system, the high-pressure energy of the exhaust gas is utilized, and the remaining high-temperature exhaust gas will continue to enter the thermoelectric power generation system through the exhaust pipe. The thermoelectric power generation system converts the heat energy of the exhaust gas of the car engine into electrical energy. Other vehicle-mounted electrical equipment supplies power to realize the gradient utilization of energy [7]. When the car is running, the exhaust heat of the exhaust of the engine is continuously discharged from the exhaust gas channel, the temperature is as high as 600 ~ 650 °C, through the spoiler, the exhaust gas temperature is evenly distributed on the surface of the exhaust gas channel, forming a heat source for thermoelectric generation. A part of the engine cooling water is maintained at 85 °C by designing the water tank, forming the cold end of temperature difference power generation. The thermoelectric power generation thermopile system generates electromotive force at both ends, uses the generated electrical energy for storage and storage battery, and provides the required electrical energy for the electrostatic precipitator.

Combining one end of the two semiconductors and putting it in a high temperature state (hot end), and the other end is open and in a low temperature state (cold end), there is an open circuit voltage at the cold end. This efficiency is called the Seebeck effect. Thermoelectric power generation is Using the Seebeck effect of thermoelectric materials, it is the theoretical basis of thermoelectric power generation technology. When the temperature difference of the junction is within a certain range, there is the following relationship:
\[ \Delta U = \alpha_{NP} (T_H - T_C) \]  

In the formula: \( \Delta U \) is the electromotive force generated by the circuit, \( V \), \( \alpha_{NP} \) is the relative Seebeck coefficient of the two semiconductor materials, \( T_H \), \( T_C \) are the high temperature state temperature and the low temperature state temperature, respectively.

When the semiconductor element is working, the output power can be obtained from the load resistance, namely:

\[ P = I^2 R_L \]

A flat PN link can generate limited electromotive force, and multiple PN links can be connected in series and parallel to obtain enough voltage to become a thermoelectric generator. Such thermoelectric power generation does not rotate at all, so it is very reliable.

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**Flat plate electrostatic precipitator.** This part is composed of two sets of flat plate electrostatic precipitator, muffler and so on. Install two sets of flat-plate electrostatic precipitator in the muffler shell, combined with the flow path and characteristics of the exhaust gas in the muffler cavity, install a set of flat-plate electrostatic precipitator at the front and rear ends and in the middle, one set near the muffler the position of the air inlet, another group is placed close to the air outlet of the muffler. This arrangement makes the exhaust gas more easily contact with the electrostatic precipitator and will have a significant dust suction effect. According to the characteristic that fine particles are deposited on the anode during electrostatic adsorption, a small groove is opened under the anode plate of the flat plate electrostatic precipitator and the cylinder wall of the muffler, and a slice valve is provided at the groove opening. Install a sensor control switch in the circuit. When the car is in working state, there is exhaust gas passing through, the sensor receives the transmission signal, the switch is closed, the circuit is in the on state, at this time the suspended particles are adsorbed on the electrostatic precipitator, and the slotted valve is closed. When the car stops running, there is no exhaust gas passing through, the sensor receives the transmission signal, the switch is disconnected, the circuit is in a power-off state, the suspended particles adsorbed on the electrostatic precipitator fall, the slotted flap valve opens, and falls into the set Inside the dust box.

### 3. Discussion

The automobile exhaust purification device is designed to solve the defects existing in the traditional porous medium ternary catalytic converter. First, transform the three-way catalyst from the structural level: change the three-way catalyst of the original porous medium structure into 4 groups of higher density turbine dynamic and static cascade structures, and connect them in series to achieve better purification effect. This will effectively reduce the resistance of the exhaust gas in the exhaust system (fig. 1). Secondly, a flat plate electrostatic dust removal device will be added to the exhaust system to use the principle of electrostatic dust removal to remove suspended particles carried in the exhaust gas.

**Advanced design.** It is calculated that when the blade spacing is twice the pore size of the original three-way catalyst, the catalyst contact area of the dynamic and static cascade three-way catalyst is twice that of the traditional porous three-way catalyst, thereby improving the conversion efficiency of the oxide in the exhaust gas. Achieve emission reduction; the dynamic and static cascade catalyst carrier structure reduces the flow resistance of the exhaust emission system by more than 18%, which
effectively improves the combustion efficiency and automotive power performance of the automobile engine; the dynamic and static cascade three-way catalyst converts most of the exhaust pressure energy of the automobile exhaust. It is converted into mechanical energy when the blade rotates, and is further converted into electrical energy by the generator, which is used for electrostatic dust removal to realize the recovery and utilization of the exhaust pressure energy of the vehicle; at the same time, this design adds an electrostatic dust removal device, using the principle of electrostatic dust removal to absorb exhaust gas suspended particles to achieve secondary emission reduction.

The innovation and technical key of the work. The three-way catalyst carrier adopts dynamic and static cascade structure. The effective contact area of the exhaust gas and the catalyst carrier is increased by more than 2.17 times, and the flow state is changed from stratified flow to turbulent flow, which not only effectively improves the efficiency of exhaust gas purification, but also reduces the flow resistance of the exhaust pipe by more than 18%, increasing the engine power and effectiveness; The mechanical energy of the rotating cascade is used to convert the high-pressure residual energy of automobile exhaust into electrical energy through a generator. At the same time, a thermoelectric power generation system is arranged in the electrostatic precipitator room to convert the high-temperature residual energy of automobile engine exhaust into electrical energy to realize the gradient recovery of energy. A flat-plate electrostatic dust removal device is installed in the muffler to save space, absorb solid suspended particles in the exhaust gas, and effectively reduce the emission of dust in the exhaust gas.

4. Conclusion
This product is used to solve the defects of the traditional porous three-way catalyst. Compared with the original porous structure three-way catalyst: the dynamic and static cascade exhaust gas purification device realizes the reduction of emission and resistance of automobile exhaust gas, and improves the efficiency of exhaust gas purification. At the same time, the high-temperature and high-pressure residual energy of the exhaust gas of the engine is recycled, and the recycling reduces the emission of dust in the exhaust gas. The promotion of the product can effectively improve the power performance of the car and alleviate the environmental pollution of PM2.5 particles in the exhaust.

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