

Design of Automobile Brake Waste Heat Recovery Device

Jie Zhang

School of North China Electric Power University, Baoding 071000, China

a1213526050@163.com

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Abstract. Energy saving, emission reduction and boost energy utilization efficiency have long been the research hotspots of automobile industry[1]. In the thesis the principle of semiconductor thermoelectric power generation is briefly expounded to raise one solution of using thermoelectric power generation material to recover the high temperature energy produced at brake disc during automobile braking, and the structure of the automobile brake waste heat recovery device and layout detail are elaborated.

1. Introduction

Under the increasing pressure of energy crisis and climate warming, it has become a trend of using energy recovery to boost energy utilization efficiency[2]. Current research has mainly been focused on the recovery of mechanical energy during braking and the utilization of waste heat produced at motor and contained in the tail gas, research results on recovery of braking system waste heat can barely be found[3].

Therefore based on this, the idea of recovering brake waste heat was introduced and concrete program was given in the thesis, by using thermoelectric material layer to realize heat recovery and applying phase change heat pipe and extended fitting axle to realize cooling at the cold junction of power generation chip. By distributing the thermoelectric power generation material layer designed on the inner surface of braking disc to convert braking waste heat into electric energy and store for utilization, which could effectively boost energy efficiency, reduce the manufacture cost of power generation module and reduce carbon emission, to serve the purpose of energy saving and emission reduction.

2. Organization of the Text

2.1 Basic Principle of Thermoelectric Power Generation.

Thermoelectric power generation technology is classified as a new energy technology which utilizes thermoelectric conversion materials to convert thermal energy into electric energy. The basic principle of thermoelectric power generation is as shown in Fig. 1. Loop can be formed with two different kinds of semiconductors, while one end of semiconductor is in high temperature state and the other end in low temperature state, temperature difference can be produced, which then generates direct voltage (Seebeck Effect). Semiconductor thermoelectric power generation is of the features of noiselessness, long service life and stable performance etc[4].

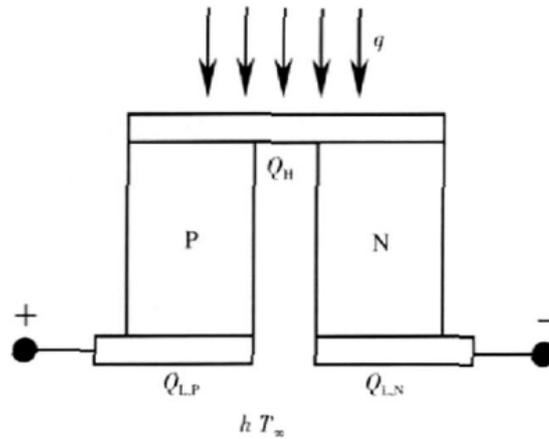


Fig. 1 The basic principle of semiconductor thermoelectric power generation

2.2 Basic Principle of Phase Change Heat Transfer.

Phase change heat pipe[5] utilizes the phase change of water and methanol medium and capillary effect to realize self-circulation heat dissipation. Typical heat pipe is composed of pipe shell, fluid absorption chip and end cap, working fluid is filled in after the inner pipe is pumped to negative pressure. The fluid in capillary chip evaporates when one end of the heat pipe is heated, and the vapor flows to the other end due to differential pressure and is condense to fluid while radiating heat, then the fluid flows back to evaporation zone along cellular materials by the effect of capillary action. Heat is transferred from one end to the other end of heat pipe as this process is repeated.

2.3 Automobile Braking Waste Heat Recovery Device.

Currently the braking waste heat recovery system design is mainly based on the Seebeck Effect of system thermoelectric materials. Seebeck effect is also known as thermoelectric power, which indicates the phenomenon of two different kinds of conductors or semiconductors inducing electric current resulted from temperature difference.

By distributing the thermoelectric power generation material layer designed on the inner surface of braking disc to convert braking waste heat into electric energy and store the power for utilization with the loop of automobile and storage battery. For the heat dispersing surface of thermoelectric material layers, we could consider using capillary phase change heat pipe combined with the forced air cooling during driving for dispersing to realize the continued temperature difference at both ends required during the functioning of thermoelectric materials. The energy transfer direction while braking process is as shown in Fig. 2.

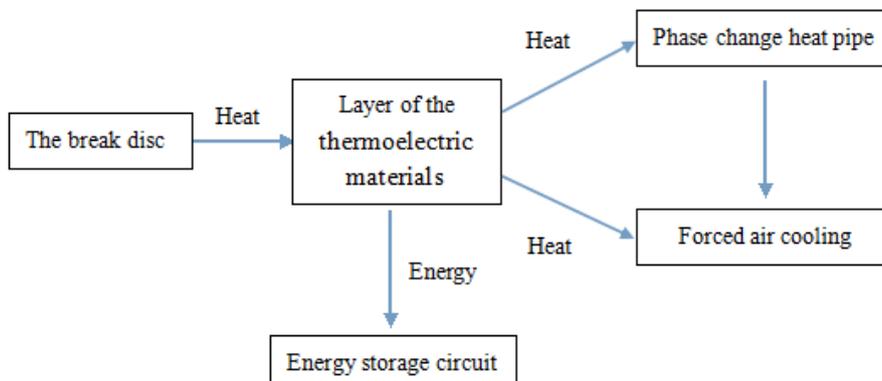


Fig. 2 The direction of energy transfer

2.3.1 Structure of Braking Disc.

Automobile braking system is divided into disc type and drum type brakes. Disc type first appeared in 1950s, with the principle of brake pad on static calipers rubbing against rotating brake disc to realize braking effect while brake applied. On account of the outstanding braking effect and heat dissipation ability of disc brake, majority of automobiles are equipped with disc brake. This

thesis is also based on disc brake for systematic analysis.

The structure of disc type brake is as shown in Fig 3, 4, one complete set of braking disc is composed of inner disc and outer disc which are fastened with a pole. Heat produced from the friction action between brake pad on calipers and inner and outer disc surfaces while brake applied is rapidly converted to the entire brake disc.

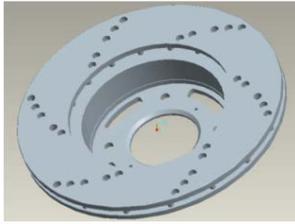


Fig. 3 The inner face of the disc

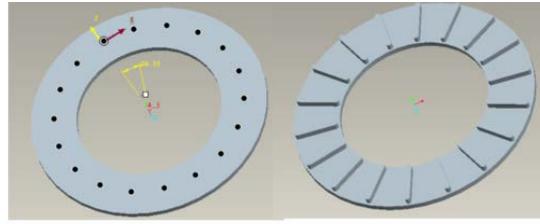


Fig. 4 The outside of the disc

2.3.2 Brake Disc Waste Heat Power Generation Parts.

In order to facilitate experiment implementing, the initial model of the device applies thermoelectric power generation chip to replace thermoelectric material crystal layer for simulation. The core components of the device are thermoelectric power generation chip and phase change heat pipe. The basic theory is to fit the hot end of power generation chip onto the inner surface of brake disc and the cold end onto heat pipe, and the heat is dispersed through heat pipe. The thermoelectric power generation chip is fitted onto the faces between two brackets of the inner surfaces of cast iron disc, at interval positions, as shown in Fig. 5.

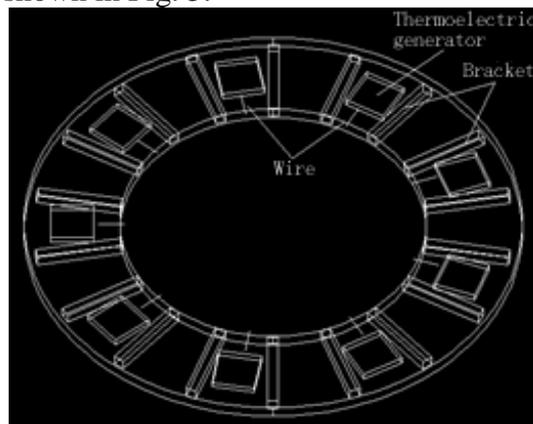


Fig. 5 The separation of the thermoelectric generator

Heat conducting mucilage glue is used for fitting between generator and disc surface, due to the high working temperature, heat conducting mucilage glue needs relatively better heat resistance. Lead is wrapped with thermal insulation tape and led into vehicle by wheel axle. The lead on braking disc and lead in wheel axle are assembled with plugs which can be pulled out for the convenience of braking disc dismantling, lead in wheel axle is connected to vehicle circuit with conductive slip ring, as shown in Fig. 7.

One end of heat pipe is fitted onto the heat dispersing surface of power generation chip, and the other end is protruded outside brake disc and fitted onto wheel axle in crooked position to be exposed in the air for forced cooling air dispersing. In between heat pipe and wheel axle, hard insulation board and heat insulation coating are added to prevent heat pipe from being influenced by wheel axle temperature and fix the heat pipe.

The location relationship of all components and position of conductive slip rings are as shown in figure below:

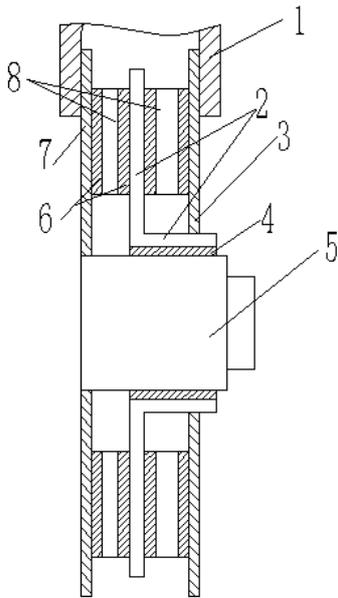


Fig. 6 The overall structure of the disc

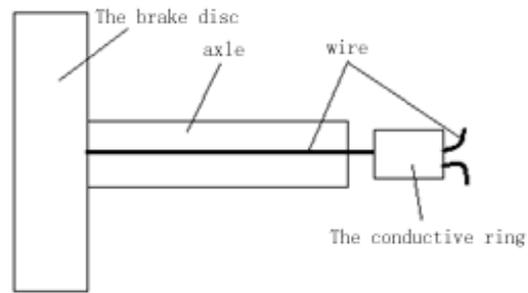


Fig. 7 Rotating parts

Fig 6: 1. Brake caliper 2. Radiating tube 3. Outer disc 4. Heat insulation board 5. Wheel axle 6. Heat conductive silicone grease 7. Inner disc 8. thermoelectric power generation chip

During the dispersing process of generator chip cold surface, the heat generated by friction on brake disc is transferred to thermoelectric power generation chip and then dispersed in the air between heat pipe and two cast iron disc, and the forced air cooling during driving is also beneficial for heat dispersing.

The overall structure of the device is as follows: the hot surface of thermoelectric power generation chip is fitted onto brake disc, heat pipe exchanger is arranged closely on cold surface, and heat conductive silicon gel is used at the contact point of both sides; heat pipe is bended into certain shapes, with the front end in contact with cold surface of generator chip and the other end protruded along the gap between brake disc and wheel hub for cooling.

For the device, the heat source is the waste heat generated by brake disc friction, the cold source is outside air, the forced convection produced during driving further improves the heat transfer effect, the temperature difference between both sources is converted into electric energy for use by thermoelectric generator. Therefore, the device made certain use of the inevitable frictional loss during braking process, and the temperature difference between heat and cold source is increased using heat pipe and air motion, which improves the effect of waste heat utilization.

2.3.3 Stored Energy Control Parts.

Braking waste heat recovery system includes brake disc, thermoelectric power generation chip and energy storage circuit, the output end of thermoelectric power generation chip is connected to energy storage circuit.

Circuit diagram of storage device as follows:

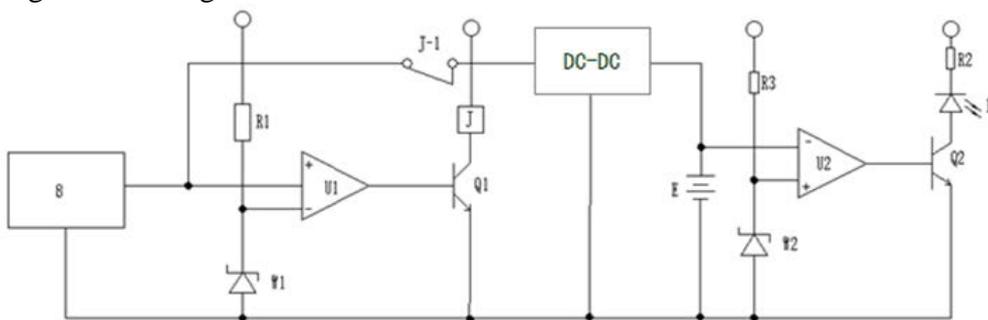


Fig. 8 Energy storage circuit

Energy storage circuit includes storage battery E and DC-DC boost chip 10; the input of DC-DC boost chip 10 is connected to the output of thermoelectric power generation chip 8, the

output end is connected to both ends of storage battery E. Besides, over current protection is added on the device, over current protection includes first comparator UI, first audion Q1 and relay J. In order to enhance the prompt facility of the device, under-pressure alarm circuit is added, which includes second comparator U2, second audion Q2 and LED light D.

2.4 Application Prospect.

Theoretic research indicates that 20% of fuel oil could be saved if thermoelectric power generation technology is applied to automobile industry, and the percentage is enough for the electric energy consumption of mid-sized vehicles. The power generated could be used for all kinds of vehicle mounted electric appliance such as GPS and air conditioners etc, if combined with other vehicle mounted new energy technology it could be possible to supply power for automobiles separately. Meanwhile, compared with other vehicle mounted new technologies, this system costs less and is easier to be dismantled for maintenance. To promote this technology will greatly reduce the entire society energy consumption and tail gas emission.

3. Summary

In the paper, a kind of automobile brake waste heat recovery device is introduced, and the device adopts thermoelectric crystal material and capillary heat pipe and has integrated design with automobile brake disc, with the connection method of conductive slip ring, and is easier to dismantle compared with other automobile energy recovery device and can be applied to both traditional internal combustion engine automobile and power-driven automobile.

4. References

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