Design of an Efficient Power Generation System Using Thermoelectric Generators and Heat Pipes from Hot Exhaust Gases

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***Abstract*—This paper deals with one of the key challenges in designing the next generation of vehicles with Waste Heat Recovery System. Much of the fuel energy in an internal combustion engine is lost as heat, mainly through hot exhaust gas. The high energy losses, and high temperatures of the exhaust gas, provide favorable conditions for applying a waste-heat recovery system. The most commonly discussed heat sources of the combustion engine are the engine coolant, charge air cooler, tailpipe exhaust gas and the exhaust gas recirculation (EGR) system. Typical internal combustion engines lose about 75% of the fuel energy through the engine coolant, exhaust and surface radiation. Most of the heat generated comes from converting the chemical energy in the fuel to mechanical energy and in turn thermal energy is produced. In general, thermal energy is unutilized and thus wasted. This project deals with the analysis of using thermoelectric generators and heat pipes in automotives for efficient waste heat recovery system used again by the system to increase fuel efficiency of the vehicles. Investigations have found that an appropriate way of improving the overall efficiency of the fuel use in a car is to recover some of the wasted heat. Two Technologies identified to be of use for waste heat recovery are TEGs and heat pipes. Both TEGs and heat pipes are solid state, passive, silent, scalable and durable. Heat pipes have various advantages when used with TEG.**

***Keywords*—Heat pipes; TEGs; Waste heat recovery**

I. INTRODUCTION

Before a new car is released to the market, testing is undertaken to ensure it meets the latest emissions regulations. The regulations differ from country to country, but they are always getting more stringent. The CO2 emissions of a car are proportional to its fuel consumption. Therefore, to meet these tightening regulations, car companies must reduce the fuel consumption of their cars.

Current ICEs are on average approximately 25% efficient under typical driving conditions (i.e.: European driving cycle) but can range from 20% to 45% depending on the engine type and operating conditions. The remaining 55%– 80% will be wasted as heat in both the coolant and the exhaust gases. A waste heat recovery system has the potential to convert some of this waste heat into electricity and consequently reduce the fuel consumption of the car by reducing the load on the car alternator. Heat pipes and TEGs could be used in conjunction for use in a waste heat recovery system. Their compact size and solid state design make them ideal for automotive applications.

II. OBJECTIVE

The main objective of my project is to design an efficient system that can generate electricity from waste exhaust gases using thermoelectric generators and heat pipes.

III. DESIGN METHODOLOGY

TEGs make use of what is known as the Seebeck effect which is explained in Fig. 1. A TEG is made up of many elements of N type and P type semiconductor materials which are connected electrically in series but thermally in parallel. When one side of the TEG is heated and the other side cooled, a voltage is generated. The voltage generation means there are applications for these TEGs to generate electricity where temperature differences are present. Their efficiency is typically 5% and they can generate power from any temperature difference. Their efficiency is limited by the Carnot efficiency so the higher the temperature difference, the more efficient they will be. A TEG operates at approximately 20% of the Carnot efficiency over a wide temperature range.

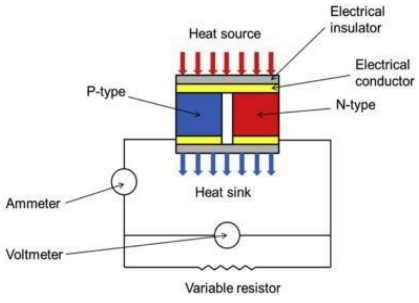

fig. 1 Shows the Seebeck Effect.

Compared to other waste heat recovery technologies, the use of TEGs in a waste heat recovery system has many desirable attributes such as silence, small size, scalability and durability. Their key attribute is that they have no moving parts and no chemical reactions therefore there is little maintenance required due to wear and corrosion.

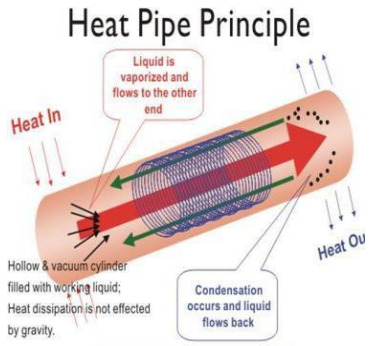

fig. 2 Show the Heat Pipe Principle

III. INNOVATION

The basic innovation behind this power generation system is optimum utilization of both heat pipes and thermoelectric generators to generate maximum electricity using low surface area from hot exhaust gases.

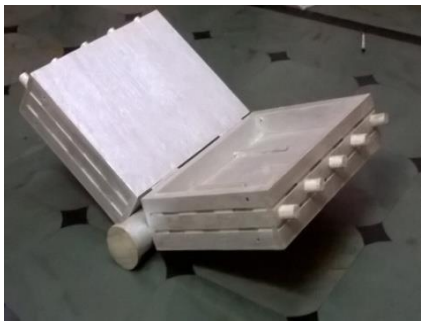

Fig.3 Shows the Prototype Model

IV. NUMERICAL ANALSYIS

This section involves numerical modeling and analyzing of power generation system using commercial CFD code ANSYS FLUENT. The objective of the analysis is to validate the design of the power generation system.

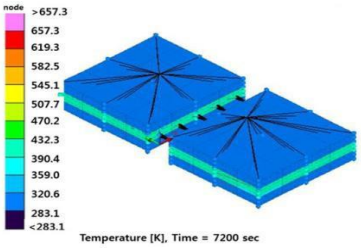

Fig. 4. Shows the Solid Temperature View of the System

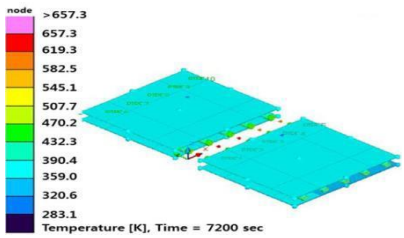

Fig.5. Shows the Temperature View of the Heat Pipe and TEGs

V. ADVANTAGES

1. A completely **passive and solid state** exhaust heat recovery system can be developed using both TEGs and Heat pipes.

2. Both TEGs and Heat pipes are **solid state, passive, silent, scalable and durable.**

3. Heat pipes can **reduce the pressure losses** in the gas stream due to a reduced fin surface area.

4. Heat pipes can **reduce the thermal resistance** between the TEG and gases.

5. The use of heat pipes allows for more **design flexibility** because TEG placement is not limited to the exhaust surface.

6. Heat pipes can be used for **temperature regulation** of the TEGs.

VI. DISADVANTAGES

1. TEGs have limitations such as relatively low efficiency and maximum surface temperatures.

2. Heat pipes have limitations such as maximum rates of heat transfer and working temperature ranges.

VII. RESULTS

By analyzing various parameters of power generation system and its superior performance by directly converting thermal energy into electrical energy using hot exhaust gases. This system will provide good amount of electricity by maintaining maximum temperature difference between TEGs.

VIII. FUTURE WORK

A model simulation using **Computational Fluid Dynamic (CFD)** should be used in the future to study detail air flow characteristic of the HP-TEG system. The effect of various flows speed could easily manipulated using the CFD. Using the CFD, the effect of different heat pipe and fins configurations could be further studied.

IX. CONCLUSION

After discussing various parameters of the thermoelectric generators, we come to the conclusion of using this effective heat recovery system in the automotives to increase the fuel efficiency of the vehicles. Hope this technology will be used in future.

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