www.ijiarec.com

ISSN:2348-2079

Volume-7 Issue-2

IJIAREC

International Journal of Intellectual Advancements and Research in Engineering Computations

Fabrication of thermoelectric power generation by waste heat recovery in automobiles

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ABSTRACT

Conventional internal combustion engine vehicles (ICEV) generally have less than a 30% of fuel efficiency, and the most wasted energy is dissipated in the form of heat energy. The heat energy maintains the engine temperature for efficient combustion as a good aspect, but the amount of heat generation is excessive and eventually breaks the engine components unless advanced cooling system technologies are supported such as high-capacity radiators, elaborated water jackets, high-flow rate coolant pumps, etc. The excessive heat dissipation plays a key role on a poor fuel economy, but reclamation of the heat energy has not been a main focus of vehicle design.

Keywords: Module - based, Dynamic model, Thermoelectric generator, Automotive waste heat recovery

INTRODUCTION

The cooling system is one of the most essential components in internal combustion engine vehicles (ICEV) that makes it possible to achieve small but powerful engines allowing continuous and long-lasting operations. The excessive heat generation from the engine is theoretically explained by Carnot Limit, and approximately 1/3 of the fuel consumption is wasted in the form of heat. About a half of the generated heat goes through the engine cooling system, which leads to additional energy consumption for releasing the heat [1]. Modern ICEV is equipped with water cooling systems. Coolant flows through the water jacket in the engine block and cylinder head and cools down the engine components such as valves, cylinder block, etc. The hot coolant is cooled down in the radiator, a heat exchanger.

The radiator dissipates heat with natural convection while the vehicle is moving, but forced-convection air cooling is often required under many circumstances, which consumes additional energy. Coolant flow is generated by a coolant pump, which also consumes significant energy. Radiator fans and cooling pumps can be driven either by the engine crank shaft or the vehicle battery, which is again charged by the alternator driven by the engine.

Radiator model

We employ a radiator model as a finned-tube heat exchanger (coolant in tubes, air in cross flow) from [5]. This model is constructed under the following assumptions: (i) the dissipated heat only travels through the radiator; (ii) the coolant flow rate in the coolant tube is uniformly distributed through the radiator, and the coolant is in a fully flowing.

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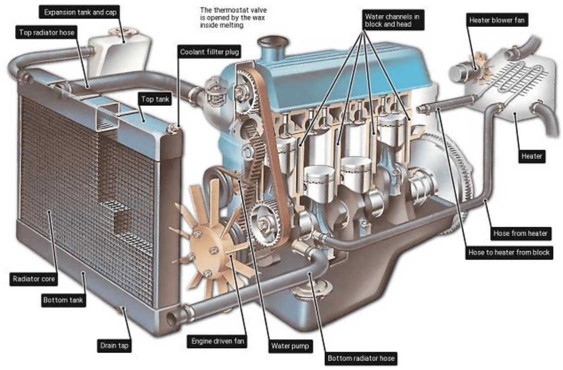

Fig.1 Radiator setup

Model and characterization of a TEG module

A TEG device comprises of a top, a bottom ceramic plates (thermoelectric materials) and internal pellets. A group of TEG devices is packaged together and forms a module. The bottom ceramic plate attaches to the hot side. In this particular application, this side faces with the radiator surface. A heat sink, i.e, a radiator pin, attaches to the top ceramic and exposes into the ambient air, which forms the cool side. The actual installation of the TEG modules requires modification of the radiator. TEG modules reside between the radiator surface and radiator fins while the factory radiators have integrated structure of the radiator surface and fins.

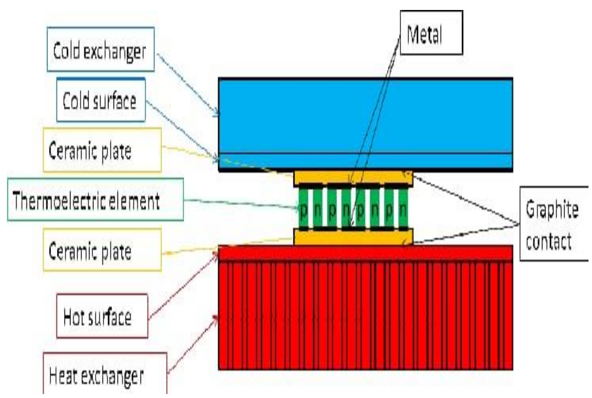

Fig.2 TEG plate

Thermoelectric (Seebeck devices or TEGs) generators will only generate electricity if there is a temperature difference across the module. That means that the "cold" side must be at least colder than the "hot" side for there to be any power generation. The hot side is generally attached to a source of heat while the cold side is typically connected to a heat sink that is air or liquid cooled.

OBJECTIVES

Along with vehicles, waste warmth is additionally produced numerous different spots. Once more the waste warmth can be reused to produce power. Indeed, a few organizations have started ventures in introducing extensive amounts of these thermo electric components.

LITERATURE SURVEY

[1] Birkolz, 2017 Studied implemented the same Thermoelectric power generator principle to recover the heat and to generate power, but the material they used was $FeSi_2$. Yu and Chau has proposed and implemented an automotive thermoelectric waste heat recovery system by

adopting a Cuk convertor and a maximum power point tracker controller into its proposed system as tool for power conditioning and transfer. They reported that the power improvement is recorded from 7.5% to 9.5% when the hot-side temperature of the TEG is heated from 1000℃ to 2500℃. Also, when the hot-side temperature of the TEG is fixed at 2500℃, the power improvement as much as 4.8% to 17.9% can be achieved.

[2] Jackie, 2015 Studied the total waste heat recovering technology, using thermoelectric power generators (TEGs), coupled with a gasoline engine was investigated in this study conducted at Ambrose Alli University, Nigeria. The experimental analysis conducted by suryawanshi et al. The temperature of pipe surface of exhaust gases flowing through exhaust gas pipe is very high and it is around 2000℃ to 3000℃ so a heat exchanger is made, which conducts heat from exhaust pipe to thermoelectric modules, one surfaces of these modules is in contact.

[3] Jorge Vázquez, Miguel A. Sanz - Bobi, 2014, The recovering of heat from exhaust gases in automobiles
is a typical application of electricity generation using thermoelectricity. This paper is focused on reviewing main characteristics and evolution of the different investigations performed over the last three decades concerning thermoelectric generation using the heat from the exhaust gases produced in the combustion process of an automobile. The use and evolution of different materials (silicon germanium, lead telluride and bismuthtelluride alloys) will be presented. Also, several characteristics of the different structures proposed for the thermoelectric generators (TEGs) will be compared.

[4] Saqr, M. K. Mansour, 2017, The potential for thermoelectric power generation (via waste heat recovery onboard automobiles) to displace alternators and/or provide additional charging to a vehicle battery pack has increased with recent advances in thermoelectric material processing. In gasoline fueled vehicles (GFVs), about 40% of fuel energy is wasted in exhaust heat, while a smaller amount of energy (30%) is ejected through the engine coolant. Therefore, exhaust-based thermoelectric generators (ETEG) have been a focus for GFV applications since the late 1980s. The conversion efficiency of modern thermoelectric materials has increased more than three-fold in the last two decades; however, disputes as to the thermal design of ETEG systems has kept their overall efficiency at limited and insufficient values.

[5] Song Lan, Zhijia Yang, 2017, Waste heat recovery using a thermoelectric generator (TEG) is a promising approach for vehicle original equipment manufacturers to reduce fuel consumption and lower CO2 emissions. A TEG can convert otherwise wasted thermal energy from engines to electricity directly for use in the vehicle systems. This paper focuses on the development of a dynamic model of TEG system designed for vehicle waste heat recovery, which is made of counter-flow heat exchangers (HXRs) and commercial thermoelectric modules (TEMs). The model from thermoelectric materials into a TEM and then into a TEG system. Compared to other TEG models, tuning and validation process of the proposed model is more complete.

[6] Suryawanshi, 2016 studied the current research is focusing on a technology, which is able to convert the thermal energy contained in the exhaust gas directly into electric power. Taguchi invented an exhaust gas-based thermoelectric power generator for an automobile application. In this invention, the exhaust gas gases in the pipe provide the heat sources to the thermoelectric power generator, whereas the heat sink (cold side) is suggested to be provided by circulation of cooling water.

PROBLEM IDENTIFICATION

- The Hot Side of the TEG module can work continuously at a maximum temperature of 320℃.
- The Cold Side of the TEG module can work continuously at a maximum temperature of 180℃.
- The radiator dissipates heat with natural convection while the vehicle is moving, but forced-convection air cooling is often required under many circumstances, which consumes additional energy.

EXPERIMENTAL SETUP

Radiator module

We employ a radiator model as a finned-tube heat exchanger (coolant in tubes, air in cross flow) from [5]. This model is constructed under the following assumptions: (i) the dissipated heat only travels through the radiator; (ii) the coolant flow rate in the coolant tube is uniformly distributed through the radiator, and the coolant is in a fully flowing condition in the tube; and (iii) both fluids (coolant and ambient air) are considered as incompressible flow and unmixed at any intersection between paths.

Characterization of a TEG module

A TEG device comprises of a top, a bottom ceramic plates (thermoelectric materials) and internal pellets. A group of TEG devices is packaged together and forms a module. The bottom ceramic plate attaches to the hot side. In this particular application, this side faces with the radiator surface. A heat sink, i.e, a radiator pin, attaches to the top ceramic and exposes into the ambient air, which forms the cool side. The actual installation of the TEG modules requires modification of the radiator.

TEG cooling unit

Exhaust heat passes to the heat-exchanger walls by thermal convection, and then passes to the TMs and water tank walls by heat conduction. Finally, water flow takes the heat away. Every water tank has three surfaces in direct contact with air, so part of heat is dissipated by thermal convection into the atmosphere.

Working

The vehicle is started and the acceleration is to be given, so that the amount of heat leaving the exhaust will be increased. Due to this heat, the surface of the exhaust pipe and the silencer will be heated to very high temperatures.

Seebeck effect

The Seebeck Effect is the conversion of temperature differences directly into electricity. It is a classic example of an electromotive force (emf) and leads to measurable currents or voltages in the same way as any other emf. Electromotive forces modify Ohm’s law by generating currents even in the absence of voltage differences the local current density.

Thermoelectric principle of operation

Thermoelectricity means the direct conversion of heat into electric energy, or vice versa. According to Joule's law, a Jean C. A. Peltier discovered an effect inverse to the Seebeck effect: If a current passes through a thermocouple, the temperature of one junction increases and the temperature of the other decreases, so that heat is transferred from one junction to the other. The rate of heat transfer is proportional to the current and the direction of transfer is reversed if the current is reversed.

Table.1 Properties of Aluminium

Property	Value
Atomic number	13
Atomic value	26.98
Melting point (°C)	660.8
Boiling point (°C)	2480
Density (g/cm^3)	2.6898
Modulus of Elasticity (GPa)	68.3
Poission ratio	0.34

Calculation of voltage produced
Voltage generated
$V=\alpha\ (Th - Tc)$
Where,
V – Voltage Generated in Volts
α – Seebeck coefficient in µV/K
Th-temperature of hot surface (silencer) in Kelvin Tc-temperature of cold surface (atmosphere) in Kelvin

α of Bismuth Telluride - 287μV/K
Tc = 303 k

CALCULATION

Case 1

Th= 403 k
V= (287 × 10-6) × (403-303)
= (287 × 10-6) ×(100)
= 0.0287 V

Case 2

Th= 453 k
V = (287 × 10-6) × (453-303)
= (287 × 10-6) ×(150)
= 0.04305 V

Table.2 Voltage generated for different temperatures

Temperature difference δt (k)	Voltage (volts)
80	0.02296
100	0.0270
120	0.0344
140	0.04018
150	0.04305
160	0.04592
180	0.05166
200	0.05740

CONCLUSION

This paper introduces a novel system-level solution for thermoelectric generator (TEG) modules attached to a vehicle radiator. TEG energy harvesting has been mainly driven by material science and device research groups, and therefore, the proposed dynamic reconfiguration is the first attempt to enhance the power efficiency using a system-level solution while it offers significant performance enhancement at low development cost. Such a system-level solution can be hardly achieved by conventional material and device research. The practical aspects of the proposed research has been strongly backed up by actual vehicle radiator measurement demonstrating up to a 34% performance enhancement compared with common practices.

REFERENCES

[1]. A. Eder and M. Linde, “*Efficient anddynamic-the Bmw group roadmap for the application of Thermoelectric generators”* in Second Thermoelectric applications Workshops, San Diego2011.
[2]. L. Garg and R. Singh, “*Reverse engineering and Design optimization of radiator fan maruti-800”* International journal of engineering science, 4179, 2016.