ENERGY FROM HEAT USING HEAT RECOVERY MODULES

MUHAMMAD HAZWAN BIN RUSLAN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of

Bachelor of Mechanical Engineering (Automotive)

Signature: ………………………………

Supervisor: Dr Musthafah Bin Mohd Tahir

Date: …………………………………

DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged"

Signature: ……………………………….

Author: ………………………………….

Date: ……………………………………

To Beloved Family

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ABSTRACT

Engine of vehicle produce waste heat from the combustion of engine. This waste heat can be converting to electricity to increase the efficiency of engine. Heat recovery systems that consist of thermoelectric generator function to convert heat from exhaust into electric energy that can be used in vehicle appliances. Thermoelectric module generates electricity when there is temperature different at the surface of module. Heat recovery system can improve efficiency of fuel up to 6 percent by doing some improvement on how to maximize the power output from heat recovery system. Heat recovery system mounted on the exhaust pipeline of Perodua Kancil's engines after design and fabrication process of thermoelectric generator (TEG). Data collection and analysis on electricity power that generated from TEG and also the efficiency of TEG were done at the end of project.

ABSTRAK

Enjin kenderaan menghasilkan haba buangan dari pembakaran enjin. Ini haba buangan boleh ditukarkan kepada tenaga elektrik untuk meningkatkan kecekapan enjin. Sistem pemulihan haba yang terdiri daripada fungsi penjana termoelektrik untuk menukar haba dari ekzos menjadi tenaga elektrik yang boleh digunakan dalam peralatan kenderaan. Termoelektrik modul menjana elektrik apabila terdapat suhu yang berbeza di permukaan modul. Sistem pemulihan haba boleh meningkatkan kecekapan bahan api sehingga 6 peratus dengan melakukan beberapa penambahbaikan kepada bagaimana untuk memaksimumkan keluaran kuasa dari sistem pemulihan haba. Sistem pemulihan haba dipasang pada paip ekzos enjin Perodua Kancil selepas proses reka bentuk dan pembikinan penjana termoelektrik (TEG). Pengumpulan data dan analisis pada kuasa elektrik yang dijana dari TEG dan juga kecekapan TEG telah dilakukan pada akhir projek.

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LIST OF SYMBOLS

η	=	Thermoelectric Efficiency
T_H	=	Temperature of Heat Source
T_C	=	Temperature of Heat Sink
ZT	=	Figure of- Merit
S^2	=	Seebeck Coefficient
K_T	=	Thermal Conductivity
ρ	=	Electrical Resistivity
V	=	Voltage
A	=	Ampere

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION INTO GENERAL TOPICS.

Nowadays, there are many source of new form of energy can be found and be uses as alternative ways for existing energy. Now is critical time for human to replace the existing source of energy such as petroleum with renewable energy because no longer yet human will be faced ran out of petroleum. Because of that, many researchers in the world try to find a way or method to replace the old energy that will ran off soon.

Vehicle is one of the machines that use petroleum energy to move on the vehicle. Energy from petroleum in form of fuel will be burn in combustion chamber of vehicle engine thus convert the fuel energy to mechanical energy. Not all the energy is converted to mechanical energy and thermal efficiency is one of the ways to rate the percentage of energy taken from the combustion that actually converted to mechanical energy. During engine's combustion process, heat was generated. Around 33 percent of thermal efficiency of engine was used in the combustion and converted to mechanical energy. Meanwhile 33 percent of thermal efficiency was loss though cooling process by radiator of vehicle. Other 33 percent of thermal efficiency is loss though exhaust system in from of exhaust gas.

33 percent of waste heat from heat is a big loss in term of efficiency since this heat can be used to another application. Today, there is a method to convert heat energy to an electrical energy. According to Martin Lovvik from University of Oslo (2011), modern vehicle needs a lot of electricity and by covering the exhaust system with thermoelectric plates and heat from exhaust will increase the car's efficiency by almost ten percent at a single stroke. To solve the thermal efficiency problem, it can use a waste heat from exhaust pipe line as a source of energy by converting the heat into electric energy.

In this final year project, heat recovery system is introduced as one of the method to make use the waster from exhaust pipe line of normal passenger car. Heat recovery system consists of thermoelectric generator that can convert heat into electricity. Thermoelectric generator (TEG) is made up of thermoelectric modules which are solid – state integrated circuits that use a basic concept of Seebeck Effect in order to generate electricity. Seebeck effect creates a different in temperature across the module by dividing it to hot side of module and the other side for cooling. Heat recovery system will be mount at the exhaust's pipeline of car and heat waste from exhaust will be absorb by the hot side of Thermoelectric module and coolant like water will be at cooling side of module then creates a different in temperature at the thermoelectric module thus electricity is generated.

In this project, it only covers on heat recovery system design, how to maximize the power generated from it and fabrication part of heat recovery system. The heat recovery system will be mount on the exhaust pipeline of Perodua Kancil's engine and after data collection, there is some energy analysis regarding the power of electric generated from the heat recovery system.

1.2 PROBLEM STATEMENT

According to John Lagrandeur and Doug Crane (2005), over 50 percent of total fuel energy waste thought engine radiator and exhaust system. Heat recovery system is introduce to improves the car efficiency six to ten percent by using of Thermoelectric Generator (TEG) that will be mount at the exhaust pipe line as waste heat from exhaust will be converted to electrical energy. Heat recovery system that consists of TEG will be a device that can produce electric energy that can be use in the vehicle or can be store in the battery. With good design of heat recovery system, this can lead to the better vehicle efficiency as waste heat can be use to generate alternative energy for vehicle.

1.3 OBJECTIVE OF THE PROJECT

The objectives of this project are:

1. To design the heat recovery system for passenger car.
2. To apply the heat recovery system for passenger car.
3. To measure and maximize the electric power obtained from the heat recovery systems.

1.4 SCOPES OF PROJECT

In this project, it will cover all the element as follows:

1. Design of Thermoelectric Generator (TEG) for passenger car.

2. Fabricate parts of TEG.
3. Apply the Heat Recovery system to the Perodua Kancil's exhaust pipe line.
4. Data collected from Heat Recovery system and analysis on electricity power generated from Thermoelectric Generator of Heat recovery system.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY OF THERMOELECTRIC GENERATOR

In 1821, Thomas Johann Seeback made a found electrical current induced when dissimilar metal with junctions at different temperature. He found that the temperature difference can produces electrical potential which can drive an electric in a closed circuit. Today, his theory is known as Seebeck effect and this theory was been used in principle working of thermo-electric module ("History of thermoelectric,”). Thermoelectric generators that consist of thermoelectric module are all solid- state devices that can convert heat from engines and contain no moving parts. This generator has been used in NASA space probe over 30 years of maintenance- free operation. With small and compact size, thermoelectric generators can be use in automotive waste heat recovery or home co- generation of heat and electricity (Snyder, 2008).

Thermoelectric generators have a big potential to increase the efficiency of fuel economy by recovering waste heat into electricity. For typical engine basically, two third of vehicle fuel waste is use for combustion energy and in form of heat. Other waste of heat is transferred to coolant system. Although this can be a potential to recover the waste heat from coolant system, difficulties in getting the high temperature difference between cold and hot side of TEG module would make the efficiency of thermoelectric generator very low. So if the TE generator can be mount on exhaust system, which has the highest temperature so it could be the most thermodynamically available waste heat. More than that, convectional vehicle can used this extra electric power to reduce alternator load and electrically drive accessories such as power steering and can be use in the hybrid vehicle propulsion. In most vehicle application that currently under exploration, TE generator employ heat exchanger to carry heat from the exhaust system to the hot side of thermoelectric module as well to prepare a low temperature at other side of module. This can be done by using coolant type of ethylene glycol that commonly been use as working fluid or just share the engine cooling loop or using its own dedicated radiator (Smith &Thornton, 2009).

2.2 THERMOELECTRIC GENERATOR WORKING PRINCIPLES

Thermo-electric generator (TEG) consists of thermo-electric module that functions to convert heat energy to electricity. This module has a flat surface and one side of this flat surface will act as heat source and the other side of surface is for heat sink. In this working principle, heat source is surface that function to absorb heat from system, for example in this case, exhausts system. Heat from exhaust pipe line will be absorbed by the Thermo-electric module through heat exchanger. Mean while at the heat sink, cooling system will creates at this flat surfaces thus down the temperature surface. The different of temperature between heat source and heat sink will creates magnetic deflect at the module thus induced the current. The HZ-14 thermo-electric module that uses bismuth telluride based alloys and consists of 98 couples required a heat flux about 8 watts per cm^2 to convert 5 percent of thermal energy that passes through module to electricity with minimum temperature different of 200^o C. under this condition, the module can generate a minimum of 14 watts of electrical power. Thermoelectric module also can run for ten thousands of hours if it been installed correct and properly (Leavitt, Elsner & Bass, 2009).

Thermo-electric module can function in two different ways. It can be apply to function as power generation and it also can be apply as a cooling system. For cooling application, the bottom plate of TE module will be heat sink and with help of Dc current application for proper polarity. Heat is pumped from top of plate to the bottom plate and into the heat sink, where heat then will be dissipated to ambient. Thus this will result the top of surface becomes cold and for heat supply application, it can be done by simply reversing the DC polarity. For power generation application, it can be done replacing the DC source with the load or device to receive power and then apply heat at the top surface of TE modules. The power generated is opposite to the polarity for cooling and electrical power is derived from the movement of electrical carriers brought by heat flow through the TE pellets. TE for power generation has maximum efficiency at high temperature different but TE for cooling application has maximum cooling efficiency at small temperature different (Buist & Lau, 1997).

2.3 THERMOELECTRIC MODULE’S MATERIALS.

The types of materials that can be use for TE module can be divided into three category based on the temperature range operation according to Rowe (2006). All this types of material based on temperature range operation can be seen on figure 2.1. Based on the figure 2.1, Alloy based on Bismuth (Bi) in combination with Antimony (An), Tellurium (Te) or Selenium (Se) are referred to have low temperature materials and can be used for temperature up to 450 K. for intermediate temperature, it’s range cover up to around 850K and this temperature range is for material based on alloys of Lead (Pb).

Although the above mentioned material still remain under groundwork for commercial and applications in thermoelectric generation, latest and ongoing research had been made in synthesizing new material and fabricating materials structures with improved the performances of thermoelectric module. Current research had been made that focused on improving the material's figure of merit and regarding conversion efficiency by reducing the lattice thermal conductivity.

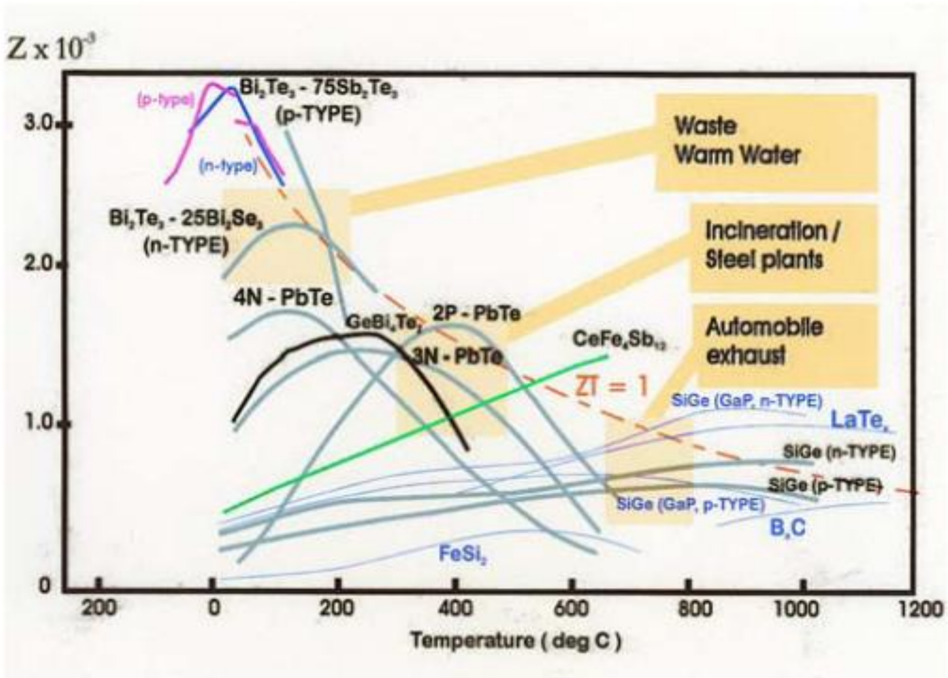

Figure 2.1: Figure of –merit of selection of materials

(Source: Rowe (2006))

For material requirement of Thermo-electric generator, it must consist of bulk materials and operating under temperatures of 400K to 800K. For Thermoelectric module, it must have p- and n-type thermoelectric in order to determine the polarity. Besides that, the module must have low lattice thermal conductivity and high values of ZT than bigger than 1. If thermoelectric generator have a good mechanical properties and readily available for market, it can accepted by the consumer (Meisner, 2010)