UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF WASTE HEAT RECOVERY UNIT FOR LIGHT WEIGHT (MOTORCYCLE) BY USING THERMOELECTRIC GENERATOR (TEG)

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Automotive) with Honours.

By

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I hereby. Declared entitled this report "DEVELOPMENT OF WASTE HEAT RECOVERY UNIT FOR LIGHT WEIGHT (MOTORCYCLE) BY USING THERMOELECTRIC GENERATOR (TEG).

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Date : ……………………………….

DEDICATION

First off all, I would like to thank Almighty Allah for everything. Without his guidance I may not able to do anything and accomplish anything in my whole life.
I dedicate my dissertation work to my family. A special feeling of gratitude to my beloved parents, Norizah binti Ishak and Rossman bin Abdulrashid that have word of encouragement, support, patient and moral support.

To my honoured supervisor, Mr Khairul Azri bin Azlan and co-supervisor Che Wan Faizal Bin Che Wan Mohd Zalani. Thank you for always giving me guidance and persistence help to complete this project.

APPROVAL

This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of UTEM as a partial fulfilment of the requirement for degree of Bachelor Mechanical Manufacturing (Automotive). The supervisory member is as follow;

……………………………………….

Khairul Azri Bin Azlan

(Project Supervisor)

ABSTRACK

Since they were discover over 180 year ago, thermoelectric devices have found extensively application in various areas because they are solid state, maintenance free and noiseless. The concept of this generation is proposed to highlight on using waste heat recovery unit on motorcycle through the exhaust pipe. This project purpose is to design and fabricate the thermoelectric generator on motorcycle and investigate the performance of thermoelectric generator in exhaust pipe due to the loss of heat energy that can be harvest. The scope of the project is comprises of energy harvesting from waste heat power generation produce from the exhaust motorcycle. The project also had developed generation using finest thermoelectric generator electricity for light weight motorcycle. In order to choose the best design for thermoelectric generator device, several analysis had been done to give out idea of design analysis and systematic matter. The process of fabrication thermoelectric generator device include fabrication on TEG base for the contact surface on hot side and also fabrication on cooling system. The experiment studies had been carried out in order to identify power generation based on temperature range and feasibility requirement. The prototype of thermoelectric generator have relationship between heat increases, the power generation will be increase in term of voltage and current produce.

ABSTRAK

Memandangkan para penyelidik telah menemui lebih 180 tahun yang lalu, peranti thermoelectric telah menemui aplikasi secara meluas dalam pelbagai bidang kerana ia adalah keadaan pepejal, bebas penyelenggaraan dan tiada henti. Konsep generasi ini dicadangkan untuk mengetengahkan penggunaan unit pemulihan haba sisa pada motosikal melalui paip ekzos. Tujuan projek ini ialah untuk mereka bentuk dan mengarang penjana thermoelectric pada motosikal dan menyiasat prestasi penjana thermoelectric dalam paip ekzos kerana kehilangan tenaga haba yang boleh menuai. Skop projek ini terdiri daripada penuaian tenaga dari hasil pembangkit tenaga haba buangan dari motosikal ekzos. Projek ini juga akan membangunkan generasi menggunakan elektrik penjana thermoelectric terbaik untuk motosikal ringan. Untuk memilih reka bentuk terbaik untuk peranti penjana termoelektrik, beberapa analisis telah dilakukan untuk memberikan idea analisis reka bentuk dan perkara sistematik. Proses fabrikasi alat penjana termoelektrik termasuk fabrikasi pada pangkalan TEG untuk permukaan kontak pada sisi panas dan juga fabrikasi pada sistem penyejukan. Kajian percubaan telah dijalankan untuk mengenal pasti penjanaan kuasa berdasarkan julat suhu dan keperluan kelayakan. Prototaip penjana termoelektrik mempunyai hubungan antara kenaikan haba, penjanaan kuasa akan meningkat dari segi voltan dan hasil semasa.

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In the name of Allah. The most Gracious, The Most Merciful. First and foremost, highest gratitude to Allah s.w.t for granting me strength, resilience, and knowledge to finish to complete the PSM report fluently and successfully. A thanks to my family for supporting me through the whole process of my PSM report. My deepest appreciation goes to my supervisor Khairul Azri Bin Azlan and co-supervisor Che Wan Faizal Bin Che Wan Mohd Zalani for his enormous support, excellent guidance, patience, providing full information and advice to finish up my report.

I would like to convey my great appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for giving me an opportunity and chance to full fill my PSM report. I am also using opportunity to express my warm gratitude to everyone who support me throughout this report. Last but not least, I would like to thank all my friends for the knowledge sharing, their aspiring guidance and friendly advice to successful completion of this report.[i]

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CHAPTER 1

INTRODUCTION

1.1 Background

The terms of harvesting energy can be referred as the process by which the energy is derived from the ambient source, captured and being stored. Solar, wind, and thermal energy are the common ambient energy sources used for energy harvesting. As the sources of energy are becoming more scarce and expensive, the energy harvesting is receiving more global interest and is currently a growing field.

About two third of the energy generative by conventional power station is actually lost in the form of waste heat which escape up of the cooling tower. Part of the problem is that the gas steam in the turbine system that were used most of the electricity work by first burning of fuel to produce heat energy, then converting heat energy into mechanical energy in the turbine and then turning mechanical energy into electrical energy in the generator. And because of this process is waste full. But if we can 'Mop UP' the wasted heat converted into use full electricity, this will make power generation much more efficient and be best for the environment.

This is where thermoelectric generator or TEG coming. This devices can directly convert heat energy into electrical energy without needed any moving part such as turbine. But the TEG efficient only produce about ten percent but still contribute a huge of fuel saving. And this technology give an idea for auto industry. Just like the power plant, over seventy percent energy lock up in three fuel that putting in vehicle exits along the exhaust pipe as waste heat.

1.2 Problem Statement

The difficulty in finding electricity while riding a motorcycle is the factor in designing a device for power storage or other use. There must be a device where the device can generate electricity from the motorcycle and also can harvest the energy waste from the motorcycle. Outdoor enthusiasts usually rely only on electricity banks as a source of electricity, but at a time when power source are rare. The electricity use will last in three times, according to some estimation. The project will explore the potential of thermoelectric generator to harvest and generate electricity from natural resource while riding motorcycle.

1.3 Objective

1. To fabricate and design a portable energy harvesting device for light weight vehicle (motorcycle) application by utilizing heat energy to electrical.
2. To harvest energy from light weight vehicle (motorcycle) from the exhaust pipe
3. To investigate the performance of TEG in different source of heat energy and cooling system.

1.4 Study Scope

The project consist of three main components which are power management, energy harvesting and power consumption. Automotive for light weight vehicle, the technique for energy harvesting is important. The heat from the light weight vehicle or waste heat will be used to convert the heat into electrical charges by using the TEG. The next step is to manage of the power generated by the TEG. This step is very important because the power produce by TEG is small and not enough to power the electrical appliance. Power management will therefore compromise the optimization and conversion of power.

The project also will develop generating system using the finest thermoelectric generator to generate electricity for light weight motorcycle vehicle. Data will be analysing in term of power, current and efficiency. The scopes of this project are:

a) Measure and maintain voltage, power consumption, and electrical storage of system.

b) Design and fabrication of thermoelectric generator device at exhaust compartment.

c) Effective cooling system to get maximum amount of energy produce.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

The purpose of literature review, is to attract the reader what thought and learning have been guaranteed on a subject, and what their shortcoming and quality are. Research objective, the issue of problem, or the argumentative of the thesis are include in the literature review. It is not just a set of summarise or imaginative list of the material existing (libguides,2018). The chapter literature review is depends on a few past research led by specialists that are reasonable based on several previous researchers that are suitable, relevant and can be identified to the present study that being carried out.

This chapter is to providing theoretical search for the study. The theoretical search is to dive deep into beyond the search for information on it on the explanation of the main issue of the research. In this study, the important things is exposed relating to the study conducted.

2.2 Introduction

Using the thermoelectric power generators (TEGs) of waste heat recovery is another attempt. TEGs have the advantages of light weight, no noise, and no mechanical vibration and can directly convert thermal energy to electrical energy. Waste heat from automotive vehicles is considerable as well. For a characteristic gasoline-engine vehicle, about 40% of the fuel vitality is released from the fumes pipe and about 30% is lost into the coolant. Making great utilization of these waste heats improves the energy efficiency and sets aside some cash (X. Liu, Li, Deng, & Su, 2015). With no moving parts, thermoelectric generators (TEGs), or Seeback components allow transformation of thermal energy into electricity. The Seeback elements can be used for power generation applications and temperature sensing.

The TEG generate electric current in closed-circuit through a load when temperature gradient develop between two end of the device. (Nguyen & Pochiraju, 2013). A thermoelectric generator (TEG) involves a pairs of n- and p thermoelectric legs based on Figure 2.1 which are connected in parallel thermally and in series electrically in order to convert heat into electricity. The flow of heat from hot to cold site drive the free electron (e-) and holes (h+) generating electrical power from heat. The temperature difference across the element high when the heat transfer through the thermoelectric is high because of high power input (Durand, Dimopoulos Eggenschwiler, Tang, Liao, & Landmann, 2018).

Thermoelectric generators (TEGs) have attracted extraordinary consideration the vehicle field, since they can directly convert waste heat release by engine into electricity. It discovered that TEG power is highly affected by mass flow rate and exhaust temperature. Considering the paratic losses, it can be concluded that if the TEG system is applied to heavy duty vehicle, the TEG weight for light duty vehicle should be as low as possible (Luo, Wang, Yu, Sun, & Meng, 2019).

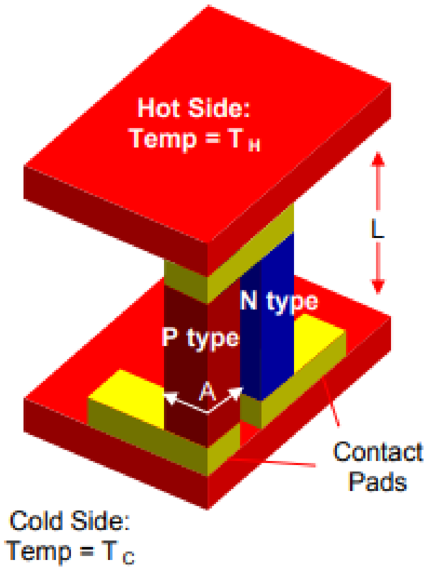

Figure 2.1: View of the TEG

2.3 Working Principle of Thermoelectric Generator

In 1821, Seebeck impact was found which uncovered that two joint disparate metals have the different temperature(ΔT) at the joints, and the electromotive force and corresponding current existing in the joint circuit are called the thermo-electromotive force and thermo-current. Enlarges the temperature difference (ΔT) between two joint can expanding the voltage difference (ΔV). The propotional with the material's fundamental properly is known as coefficient seebeck. This coefficient is relatively low at around 0 μV/K for material such as metals, whereas it would be much larger for semiconductor at around ±200 μV/K.

$$\alpha = \frac{\Delta V}{\Delta T}$$

Peltier effect, which was discovered in 1834 where the joint of different conductors absorbs or rejects the heat when there is the current in the circuit depending on the direction of the current because of difference of the Fermi energies between two materials. The property of the two dissimilar conductors and the temperature of the joint is largely related the capacity of the heat absorption or rejection. When defining the heat absorbed in per area of the joint per second, a dimensionless parameter, ZT, is usually used to determine the Peltier performance of a thermoelectric materia (He et al., 2015).

$$\mathrm{ZT}= \frac{\alpha}{\kappa} \sigma \mathrm{T}$$

α is the Seebeck coefficient, κ is the thermal conductivity that can be separate into two parts (κ_e and κ_l, the electrical and lattice respectively) and T is the temperature.

The TE innovation can therefore be separated into two classifications according Seebeck and Peltier individually : (1) thermoelectric generator (TEG) for generating electricity when both material are uncovered at different temperature as shown in Figure 2.2 ; (2) thermoelectric cooler (TEC) for cooling when the voltage is included in Figure 2.3 on the two material.

The TEG efficiency can be estimated by:

$$\eta_{max} = \frac{T_H - T_C}{T_H} \cdot \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+\frac{T_C}{T_h}}$$

Where TH is the hot side temperature and TC is the cold side temperature

TEC's maximum performance coefficient (COP) is approximately determine by:

$$COP_{max} = \frac{T_C}{T_{C} - T_H} \cdot \frac{\sqrt{1+ZT}-\frac{T_C}{T_h}}{\sqrt{1+ZT}+1}$$

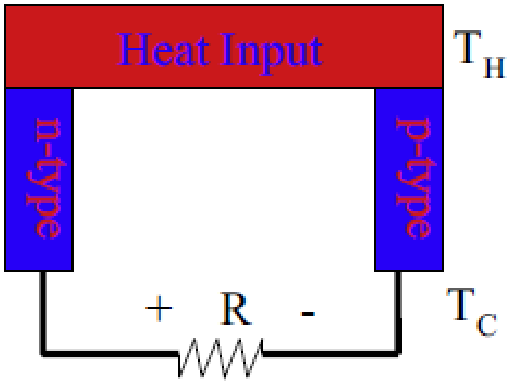

Figure 2.2 The thermoelectric generator schematic diagram

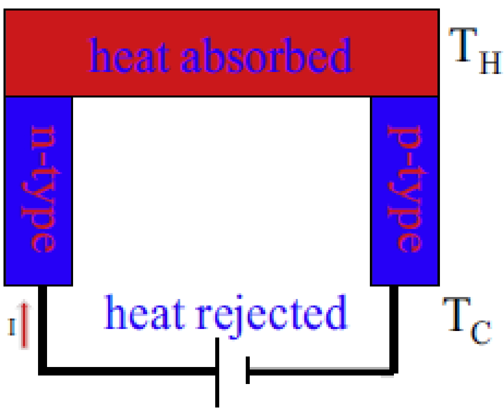

Figure 2.3 The of thermoelectric cooler schematic diagram.

2.4 TEG Model Cooling Method

TEG framework consists of a series of legs connected to a heat source of high and low temperature that respectively sink. The design needs to guarantee high heat flux through the TEGs. The heat source is the exhaust gas in vehicle exhaust application and the heat sink the cooling water. Starting contemplations respected the wind current around the vehicle as the perfect heat sink, having lower temperature as the cooling water. However, the low convection heat transfer was insufficient and therefore only the cooling water considered for further consideration. The thermoelectric elements are connected to the exhaust gas for cooling water (Durand et al., 2018).

- Exhaust gas to hot side wall: Convection + Radiation
- Inside the hot side wall: Conduction
- Through TEG Legs: Conduction
- Inside the cold side wall: Conduction
- Cold side wall to cooling water: Convection
- Hot side wall to cold side wall: Radiation

A general design of the thermoelectric generator system. The use of heat sink on the hot side of the thermoelectric is intended to improve the transfer of heat from the exhaust gases and to increase the overall heat transfer area or smokestack to the thermoelectric module's hot surface. In fact, the use of a heat sink is one of the best system to expand the transfer quantity measurement (Mostafavi & Mahmoudi, 2018).

The TEG is established by a few thermoelectric modules, every single one of them being packed between a heat source and a heat sink, as shown in Figure 2.4(a). The cooling water, flowing through a duct of rectangular cross section, behaves as the cold source. The exhaust gases of the diesel engine, which flow through a duct with fins, constitute the heat source. It is accepted that the two liquids stream a similar way Commonly referred to as thermocouples, each thermoelectric module also is established by a rectangular array of $nx \times nz$ thermoelectric units which are connected thermally in parallel and electrically in series, as shown in Figure 2.4(b). The thermoelectric units consist of a pair of parallel elements: a p-type and an n-type semiconductor elements made of different material (Marvão, Coelho, & Rodrigues, 2019).