ANALYSIS OF THERMAL CHANGES ON NANOCOMPOSITES THERMOELECTRIC GENERATOR DEVICE IN DIFFERENT FLUID DYNAMIC CONDITIONS

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

NOR KHORIHA EMIELIA BT MOHD KHORI

B051810165

990816-03-6352

FACULTY OF MANUFACTURING ENGINEERING

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I hereby, declared this report entitled "Analysis of Thermal Changes on Nanocomposites Thermoelectric Generator Device in Different Fluid Dynamic Conditions" is the result of my own research except as cited in references.

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Date : 29 JUNE 2022

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

……………………………………………………

(DR. KHAIRUL FADZLI BIN SAMAT)

ABSTRAK

Perbezaan suhu yang dituai adalah salah satu faktor yang mempengaruhi kuasa elektrik yang dijana oleh peranti penjana termoelektrik (TEG). Perbezaan keadaan bendalir yang mengelilingi peranti TEG nanokomposit akan menghasilkan perbezaan suhu terkumpul yang tidak serupa dan secara langsung mempengaruhi prestasi peranti TEG. Selain itu, bahan nanokomposit Bismut Telluride (Bi_2Te_3) tertanam dalam peranti TEG boleh meningkatkan suhu penuaian yang berbeza berbanding dengan Bi_2Te_3 tulen kerana sifat kekonduksian terma yang lebih rendah. Walau bagaimanapun, tenaga haba yang dituai oleh peranti TEG mungkin berbeza-beza mengikut keadaan aliran bendalir dan akan menghasilkan kuasa elektrik yang berbeza dijana. Projek ini akan membentangkan kerja simulasi dinamik bendalir untuk menjana suhu penuaian yang berbeza bagi peranti TEG. Suhu yang dijana berbeza akan digunakan untuk mengira kuasa elektrik yang dijana peranti TEG nanokomposit, dan hasilnya akan dibandingkan dengan bahan tulen peranti TEG dalam setiap keadaan aliran bendalir.

ABSTRACT

The harvested temperature difference is one of the factors that influence the electrical power generated by the thermoelectric generator (TEG) device. Difference fluid conditions surrounding the nanocomposite TEG device will result in dissimilar harvested temperature difference and directly influenced the TEG device performance. In addition, the Nickel doped with Bismuth Telluride (Ni- Bi_2Te_3) nanocomposite material in the TEG device could improve the harvested temperature different as compared to the pure Bi_2Te_3 due to lower thermal conductivity properties. However, the harvested thermal energy by TEG device may vary according to the fluid flow condition and will result different electrical power generated. This project will present the simulation works of fluid dynamic to generate the harvested temperature different of TEG device. The generated temperature different will be used to calculate the electrical power generated of the nanocomposite TEG device.

DEDICATION

My endless thanks dedicate to a very precious person in my life:

To my respectful supervisor:

Dr. Khairul Fadzli Bin Samat

For your help and guidance in completing my research project.

To my beloved parents:

Mohd Khori Bin Mat Hassan

Nor Hamidah Binti Arifin

For your support, love, and encouragement, and prays of days and nights make me able to do my best.

ACKNOWLEDGMENT

First of all, I felt very grateful to Allah because held provided me knowledge, skill, and bravery to finish this project. Without His favor, this triumph would not have been possible. I am truly grateful for the encouragement and assistance I've gotten in putting my strategy into this project. On this occasion, I'd like to express my gratitude to everyone who has contributed to this study, whether directly or indirectly.

Primarily, I'd want to convey my thanks to my supervisor in particular Dr. Khairul Fadzli Bin Samat of the Faculty of Manufacturing Engineering at Universiti Teknikal Malaysia Melaka (UTeM). Thank you so much for your invaluable assistance, encouragement, feedback, recommendations, and incentive throughout this research.

In the nutshell, I want to express my recognition to my loving parents for being inspired, encouraged, and confident in the project's success. Finally, I'd want to convey my gratitude for all of my friends' continuous support, especially my classmate, Young Seng Hong and my supporter Muhammad Syafik Bin Pauzi.

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LIST OF ABBREVIATIONS

TEG	-	Thermoelectric generator.
TE	-	Thermoelectric
CAD	-	Computer aided-design
CAM	-	Computer aided
PF	-	Power factor
TSV	-	Total Seebeck voltage
CFD	-	Computational fluid dynamics

LIST OF SYMBOLS

σ	-	standard deviation
$\sum$	-	total
ΔT	-	temperature difference
$^{\circ}$	-	degree
ρ	-	Electrical resistivity
S	-	Seebeck coefficient
A	-	Thermocouple thickness

CHAPTER 1
INTRODUCTION

The background of the study and comprises a problem statement for the project discussed in this chapter. In the context of the problem statement, the objectives and scope are defined, narrowing down the field of study and clarifying the study's designated achievements.

1.1 Background Study

The field study in this project is the production design, focusing on the simulation works of fluid dynamics. The conditions of fluid surrounding the nanocomposite thermoelectric generator device (TEG) are different but in the same material. The TEG device performance is influenced by harvested temperature difference which is the important aspect that influences the electrical power generated. The embedded nanocomposite material in the TEG device could improve the harvested temperature difference. However, power generated temperature may vary according to the fluid flow condition.

Simulation software is currently widely applied in a variety of industries. Simulation software is used in the automotive industry, construction, and general engineering industries (Broy, 2006). Production and support operations, as well as planning and design, can all benefit from simulation technologies.

Simulation is generally used in management, distribution, and planning (Terzi and Cavalieri, 2004) to ensure that the manufacturing process runs smoothly both economically and technically (Quaschning et al., 2001).

The main purpose of the simulation used is to facilitate the affairs of the engineer in identifying the problems encountered safely and effectively. The act of constructing and assessing a digital prototype of a physical model in order to predict its performance in the real world is known as simulation modeling. It provides an important method of analysis that is easy to test, explain, and understand. Unlike physical modeling, such as building a scale model of a structure, simulation modeling is computer-based and uses algorithms and mathematics.

Thermoelectric material is a product that is good in transferring heat become electricity. Thermoelectric material is used in a variety of cooling applications, such as lasers and optical detectors, to maintain extremely stable temperatures, and they may be frequently determined in workplace water coolers. In the 19th century, the converter electricity from heat is named a thermoelectric generator (TEG). In 1821, the operating systems is discovered on the Seebeck effect. The electricity generators primarily based totally on the Seebeck impact do now no longer rely upon on the nature of consumable warmness and, therefore, they may be utilized in distinct areas. As illustrated in Figure 1.1, a typical thermocouple has an interconnected layer that acts as an electrical link between n-type and p-type thermoelectric materials. To have a high efficiency of energy harvesting capability that transforms thermal energy into electrical energy, the TEG device requires a very good performance of thermoelectric materials.

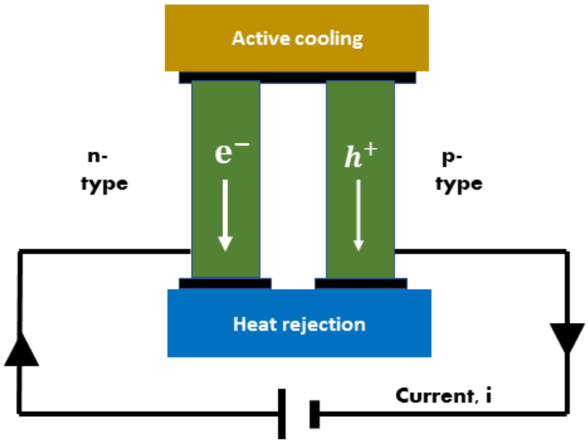

Figure 1.1: Thermoelectric generator

Thermoelectric generator device encompasses the semiconducting legs which are p-type and n-type. The semiconductor is sandwiched among electrically insulating plates. the temperature difference is needed between the top and bottom side of TEG, therefore outside the circuit, the energy will be generated. The performance of the thermoelectric device is essentially decided with the aid of using the properties of the p-type and n-type legs however additionally with the aid of using the temperature distinction with large gradients being preferred.

They use a different type of material that can handle a lot of different temperature performances. For example, once it touches the sunlight, it will up to 800 ˚c, but at night it will reduce to -100˚c. Unfortunately, this kind of material cannot handle only a small temperature difference. As an example, silicon has a higher performance index when they are having a higher different temperature. The primary goal is to generate the TEG device's harvested temperature difference. The electrical power generated by the nanocomposite TEG device will be compared with the pure material of the TEG device.

1.2 Problem Statement

Thermoelectric generator devices are widely used in transfer heat to electricity. The thickness of a film nanocomposite TEG is up to 5micro to10micro that is many used in the microdevice. The TEG application is widely used such as at a certain smartwatch-like SEIKO and more companies had produced the TEG products.

The development of the high performance of the micro-TEG device is needed because nowadays every device become smaller and more compact. The higher performance of the device can generate more electric power depending on how good the material is inside. There are have a few ways to increase the Bismuth Telluride performance, one of the ways using the nanocomposite method. The nanocomposite is the combination of other nanomaterials to increase certain thermoelectric performance. Various applications of TEG devices that represent different fluid flow conditions will be simulated by computational fluid dynamic (CFD) software. The TEG application will be created and applied in CFD software to simulate the application in different fluid dynamic situations.

Only a few studies have been found to perform the experiment in different fluid conditions (Li et al., 2017), due to time consumption and the high cost of the different experimental setups. Moreover, no study has been found performing the TEG simulation embedded with the Bi_2Te_3 nanocomposite in different fluid dynamics applications. Different fluid conditions on simulation of TEG model application offer more data collection in studying the calculated power generation. To resolve this problem, the model of Thermoelectric Generator (TEG) in the different fluid conditions is simulated using the ANSYS software.

1.3 Objective

The objective involves in the study are:

1) To simulate different fluid dynamic conditions of thermoelectric generator (TEG) device by computational fluid dynamics simulation.
2) To analyses the harvested temperature different on embedded nanocomposites materials in TEG devices in different fluid dynamics conditions.
3) To evaluate the electrical power generated by nanocomposites and pure Bi_2Te_3 materials in different fluid dynamic simulations.

1.4 Scope

Generating the harvest temperature difference of the Thermoelectric Generator (TEG) device in the Ansys software by conducting fluent flow (fluent) simulation is the project's scope. This is due to the harvest temperature one of the important aspects that influence the electrical power generated by TEG devices. In this study, the result of the performance TEG device will produce when using the different fluid conditions surrounding the nanocomposite TEG device. However, the power generated temperature may vary according to the fluid flow condition. After that, an investigation will be conducted in this study to calculate the power generated by the modeled applied nanocomposites in the TEG device and compare the value with the pure material used in the TEG device.

1.5 Significant/Important of Study

The importance of this study is to increase the TEG device performance to become better. At the n-type, nickel doped with bismuth telluride material is used, and at the p-type is antimony telluride. Then, the performance of nanocomposite materials gained in the TEG device will be compared with the pure materials used in the TEG device. Different conditions of air-fluid will be set up in the simulation. This study will help in increasing the efficiency of power generated in TEG devices. Thus, get to help in improving the TEG device performance, help in reducing pollution due to other non-environmentally friendly resources, and reducing the nonrenewable energy consumption.

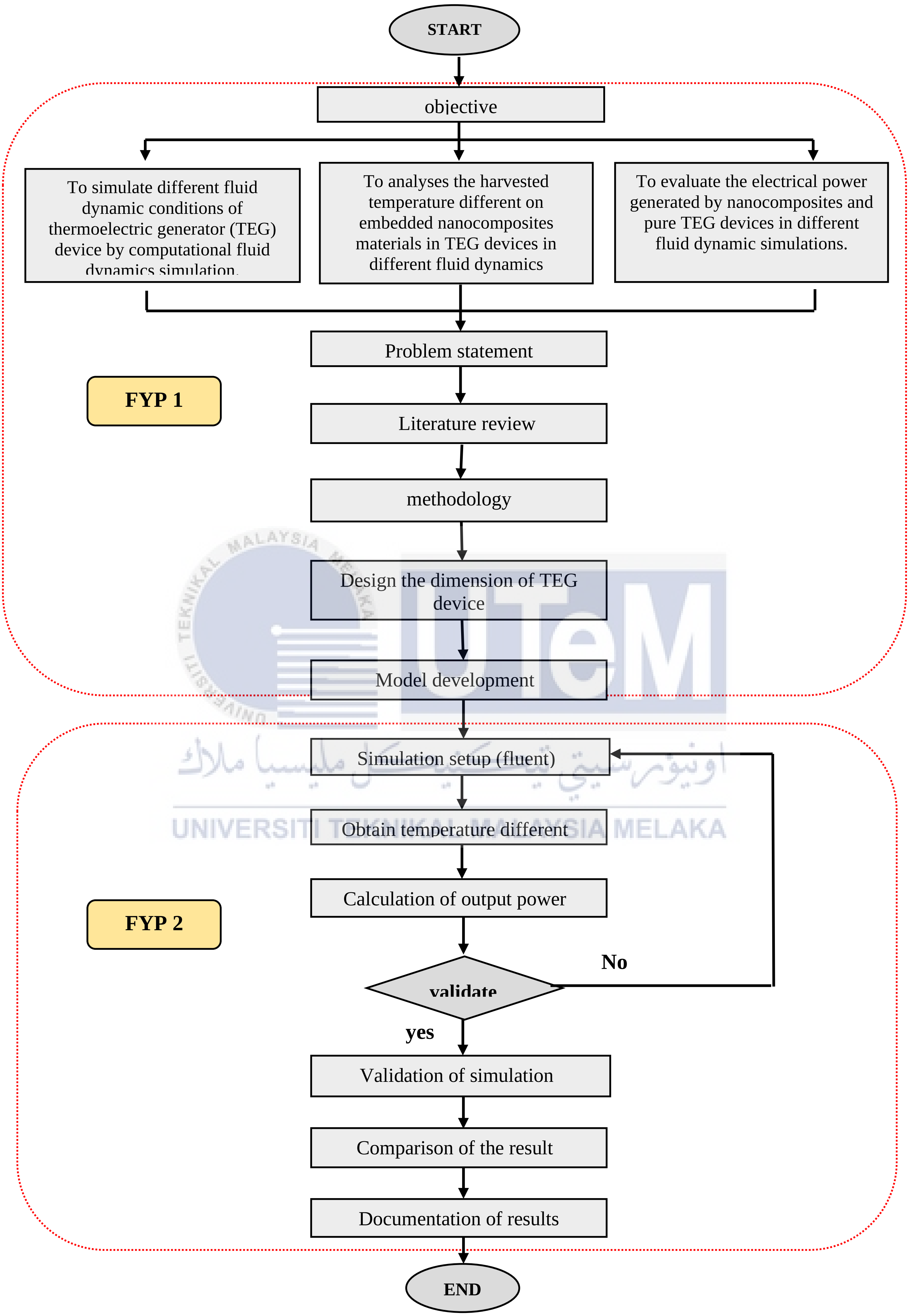

Figure 1.2: Flow chart of the project in respect FYP 1 and FYP 2

CHAPTER 2
LITERATURE REVIEW

This chapter focuses on the theory and research that were defined and carried out by numerous researchers many years ago. Previous studies' related material was retrieved as references, and a discussion was built on the study into various types of techniques.

2.1 Nanocomposites Thermoelectric Generator (TEG)

When electricity is generated in power stations, around two-thirds of the energy is lost as waste, which would be discharged through cooling towers. The major reason for this is that most of the electrical power is generated by gas or steam-powered turbine systems, which create energy in the form of heat by burning fuel. In the turbine, the thermal energy is transferred to mechanical energy, which is subsequently turned to electrical energy into a generator.

As an outcome, only approximately one-third of the energy generated by the fuel ends up leaving the power plant in the transmission lines. The capacity to gather waste heat from these operations and convert it to useable electrical power would greatly improve power generating efficiency. Furthermore, because less fuel is burnt for the same amount of energy generated, the decrease of greenhouse emissions from reduced waste would be helpful to the environment. Due to its incomparable advantages, thermoelectric generator (TEG) systems have gained a lot of attention in the waste heat recovery field in recent years (Børset et al., 2017).