POWER GENERATED ANALYSIS OF THERMOELECTRIC GENERATOR DEVICE BASED ON ELECTRODEPOSITED NANOCOMPOSITES THROUGH FLUID FLOW SIMULATION

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

By

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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)

ABSTRACT

The project which titled “Power Generated Analysis of Thermoelectric Generator Device based on Electrodeposited Nanocomposites Through Fluid Flow Simulation” has been carried out. The overall aim of this project is to find out which type of nanocomposite material embedded on the Bismuth telluride (Bi_2Te_3) will results in a higher output power generated in the thermoelectric generator (TEG) device. The power generated analysis of thermoelectric generator device with bismuth telluride that embedded with different type of nanocomposite materials through fluid flow simulation has been successfully carried out. The fluent simulation was conducted by using the Ansys Fluent software with the help of Solidworks to design and draw the 3D TEG and heatsink model. In a result, the highest output power generated by nanocomposite is Pt-SWCNTs/Bi_2Te_3 with results of 627.38µW and 635.45µW in fluid velocity of 0.01m/s and 1m/s.

DEDICATION

TO MY DEAREST PARENTS,

YOUNG FOOK YEW AND LEE PEI HUANG

TO MY ADORED SISTER AND BROTHER,

YOUNG WAN LOK AND YOUNG SENG ONN

TO MY HONOURED SUPERVISOR

DR. KHAIRUL FADZLI BIN SAMAT

For his advice, support, motivations and guidance

during accomplishment of this project

TO ALL STAFF AND TECHNICIANS

For their direction and advice during completion of this project

TO ALL MY BELOVED FRIEND

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LIST OF ABBREVIATIONS

ALD	:	Atomic layer deposition
BEM	:	Building energy management
CFD	:	Computational fluid dynamics
DOS	:	Density of states
ECD	:	Electrochemical deposition
EIA	:	Energy Information Administration
EMF	:	Electromagnetic field
ESD	:	Electrospray deposition
FEA	:	Finite element analysis
FEM	:	Finite element method
FYP	:	Final Year Project
IMDs	:	Implanted medical devices
MMRTG	:	Multi-Mission Radioisotope Thermoelectric Generator
PLD	:	Pulsed laser deposition
RGO	:	Reduced graphene oxide
RTGs	:	Radioisotope Thermoelectric Generators
SI	:	International system of unit
SWCNTs	:	Single-Wall carbon nanotubes
TEG	:	Thermoelectric Generator
US	:	United States
VOD	:	Chemical vapor deposition

WSNs	:	Wireless sensor networks
ZEM-3	:	Ulvac Riko Inc.
ZT	:	Figure of merit

CHAPTER 1

INTRODUCTION

This chapter serves as an introduction to the entire study on Power Generated Analysis of Thermoelectric Generator Device based on Electrodeposited Nanocomposites Through Fluid Flow Simulation which conducted in software Ansys. A brief summary on the background of the study is given, followed by the problem statement, objectives, scope, and importance of study. At the end of this chapter, an organization of report and summary is shown to provide a glance through the whole report.

1.1 Study Background

Energy crisis has become a serious issue for worldwide in 21st century. Due to this fact, scientist, and researcher were working hard on finding a new recyclable, renewable and resources that has no pollution when generating power. According to US Energy Information Administration (EIA), the organization states that in the mid-2014 the consumption and production of fossil fuel is about 94millions barrel per day, and it has been significantly increased to 100millions barrels per day in the mid-2014. It results in a huge number of pollutions and resource consumption in worldwide. To reduce the pollution and fossil fuel consumption, a new renewable green energy is needed to be find. Thermoelectric Generator (TEG) device is one of the device that able to generate power from harvested temperature without polluting the environment.

Thermoelectric generator also knows as seebeck generator. According to Prem Kumar D S, Ishan Vardhan Mahajan, Anbalagan R and Ramesh Chandra Mallik in 2014, the working principle behind the TEG device is called as Seebeck effect (Prem Ds, Ishan Vardhan Mahajan, Ramakrishnan Anbalagan and Ramesh Chandra Mallik, 2014). Thermoelectric generator is a solid state device that covert the temperature difference which is the heat flux exist on the device into electrical energy by using the Seebeck effect. Thermoelectric generator has several advantages which are environment friendly energy, high scalability which it can be applied to different size of heat source, lower production cost, able to recycle wasted heat energy and reliable source of energy. However, in today's technology thermoelectric generator has a generally low energy conversion efficiency rate. Also, lack of industry education on the topic of thermoelectric generator and it has adverse thermal characteristics is one of its limitations too.

In 2021, there are more than 50% of research papers focus on the performance of several thermoelectric material which are bismuth telluride (Bi_2Te_3), plumbum telluride (PbTe) and silicon germanide (SiGe). In overall, bismuth telluride Bi_2Te_3 is having a better performance in term of generating power in TEG. However, there are not much research study on the electrodeposited nanocomposite on TEG device.

1.2 Problem Statement

Currently there is lack of research on the nanocomposite material that embedded in the TEG device. A general states that the best thermoelectric device have only around 5 – 20% of efficiency (Enescu, 2019). However, the heat engine efficiency could have an efficiency of around 30 – 50%. This shows that the efficiency of TEG devices are relatively low compared to the other heat engine.

According to Dinesh K. Aswal, Ranita Basu and Ajay Singh in 2016, the article states that for the past two decades there is a lot of new materials able to exhibit a high thermoelectric performance over a wide range of temperature. However, the high thermoelectric performance materials come along with the complexity involved in the preparation of high quality thermal and electrical interfaces (Dinesh K.Aswal, Ranita Basu and Ajay Singh, 2016).

1.3 Objectives

The objectives of this study are:

i) To design a complete fluid flow simulation for Thermoelectric Generator (TEG) device analysis with fluid velocity of 0.01m/s and 1m/s.

ii) To generate the temperature different in fluent simulation when the Thermoelectric Generator (TEG) device is embedded with the investigated bismuth telluride nanocomposite materials.

iii) To investigate the calculated power generated by the applied nanocomposites in TEG device compared to the value with pure material.

1.4 Scope of the study

This study was carried out in the Ansys software by conducting fluent simulation to investigate the estimation of power generated by the TEG device embedded with the different nanocomposite material. In this study, only several types of nanocomposite material is used to compared and conduct in the Ansys fluent simulation. Not only for that, the only manipulating variable in this study is the type of nanocomposite material use in the fluent simulation of TEG device. The synthesis method for the film is not considered in this study.

Before conducting the fluent simulation in software, the 3D model of TEG device was designed and fabricated with the help of Solidworks software. In this project, the 3D model of the TEG device was designed by referring to the previous study. The 3D TEG model is having a 28 pairs of thermoelectric module (Khairul Fadzli Bin Samat, 2020).

Then, predict the temperature different when the TEG device is embedded with the investigated nanocomposite materials. The temperature difference in the TEG device could result in a different thermoelectric performance due to the Peltier and Seebeck effect. After that, an investigation is conducted in this study to calculate the power generated by the modelled applied nanocomposites in TEG device and compare the value with the pure material that use in the TEG device.

1.5 Significant of study

There are some potential outcome can be gained after the completion of this study. The material that get a better thermoelectric performance material will be selected among the others materials after getting the fluent simulation and the calculated of power generated in the TEG device. Then, the nanocomposite materials performance gained in the TEG device will be compared to the pure materials use in the TEG device. In the end, the best materials will be selected, and it will be carried on to the next progress of research study in the TEG device. This study will help in increasing the efficiency of power generated in TEG device. Thus, get to help in improving the TEG device performance, help in reducing the pollution due to others non-environmentally friendly resources and reduce the nonrenewable energy consumption.

1.6 Organization of Report

The organization of the thesis is as follows:

a) Chapter 1 : Introduction

For this first chapter will be begin with the study background to provide an insight to the current situation of the TEG device in the market. From the problem statement and objectives of the study were defined within a set of study scope. Then, the significant of study is stated. Finally, the organization of report and a short summary are provided in the end of chapter 1 as an overview of the study.

b) Chapter 2 : Literature review

In this chapter, the basic theories regarding the research study topic and the previous studies from journal, article, book, and internet will be provided. The current situation of TEG device performance will be listed.

c) Chapter 3 : Methodology

Methodology of the study will be described here in details. This include provide a flow a flow chart to indicate a clear overview of the process, and the detailed explanation on all methods involved during the study will be revealed.

d) Chapter 4 : Results and Discussion

This chapter will be focus on the results of the calculated power generated and discuss on the obtained results. This chapter will provide explanations to various decision made throughout the course of this study.

e) Chapter 5 : Conclusion

In this final chapter, a conclusion will be made for the entire study, then some improvement will be recommended in this section so that the project can be improve.

1.7 Summary

To summarize up, the Chapter 1 covers the introduction of the study, includes the background study, problem statement, objectives, scopes, significant of the study and organization of this report. This study intended to analyze the performance of thermoelectric for different type of nanocomposite material use in TEG device. By analyzing the different type of nanocomposite material in TEG device with the help of Ansys software, this study may bring some significant improvement to the research study. Hence, it able to improve the TEG device performance and efficiency in the future.

1.8 Project activities

Table 1.1: Gantt Chart FYP 1

Project activities	Time scale (Week)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tittle approval	■	■												
Introduction		■												
Problem statement and objective discussion			■	■	■									
FYP 1 report writing				■	■	■	■	■	■	■	■	■	■	
Journal finding				■	■	■	■							
Journal discussion					■	■	■	■						
3D model development								■	■	■				
Methodology discussion									■	■	■	■		
Simulation setup										■	■	■		
Logbook submission											■	■		
FYP 1 presentation													■	
FYP 1 report submission														■

Table 1.2: Gantt Chart FYP 2

Project activities	Time scale (Week)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ansys simulation setup	■	■	■	■	■	■											
Journal/Article finding on data for simulation							■	■	■	■							
Obtain temperature different results										■	■	■	■	■			
Output power calculation & Comparison of results										■	■	■	■	■			
Validation of results										■	■	■	■	■			
Data collection										■	■	■	■	■			
Report writing										■	■	■	■	■	■	■	■
Logbook submission													■				
FYP 2 slide preparation														■	■		
FYP 2 presentation															■		
FYP 2 Q&A session																■	
FYP 2 report submission																	■