DEVELOPING METHODOLOGY FOR SEARCHING EFFICIENT THERMOELECTRIC MATERIALS AND THEIR UTILIZATION IN DESIGNING THERMOELECTRIC GENERATORS

A THESIS

submitted by

KUMAR GAURAV

for the award of the degree

of

MASTER OF SCIENCE

(by Research)

SCHOOL OF ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY MANDI

FEBRUARY, 2018 (REVISED)

Declaration by the Research Supervisor

This is to certify that the thesis entitled "**DEVELOPING METHODOLOGY FOR SEARCHING EFFICIENT THERMOELECTRIC MATERIALS AND THEIR UTILIZATION IN DESIGNING THERMOELECTRIC GENERATORS**" submitted by **Kumar Gaurav**, to the Indian Institute of Technology Mandi, for the award of the degree of **Master of Science**, is a bonafide record of the research work done by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Place: Mandi
Date: February, 2018

Dr. Sudhir Kumar Pandey
Research Guide

Declaration by the Research Scholar

This is to certify that the thesis entitled "**DEVELOPING METHODOLOGY FOR SEARCHING EFFICIENT THERMOELECTRIC MATERIALS AND THEIR UTILIZATION IN DESIGNING THERMOELECTRIC GENERATORS**", submitted by me, to the Indian Institute of Technology Mandi, for the award of the degree of **Master of Science**, is a bonafide record of the research work done by me under the supervision of Dr. Sudhir Kumar Pandey. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Place: Mandi
Date: February, 2017

Kumar Gaurav
(Enrolment No. : S14005)

ACKNOWLEDGEMENTS

It is my duty to acknowledge people who have helped me directly or indirectly in my work. First of all, I want to thank my thesis supervisor Dr. Sudhir Kumar Pandey for his constant guidance, motivation, and support. I owe my gratitude to my supervisor and lab members, whose constant support, encouragement, and healthy discussions are never forgotten. This helped me to develop self-learning skills.

I am thankful to MHRD for providing fellowship to pursue the course at IIT Mandi. I acknowledge Dr. Viswanath Balakrishnan for taking effort to motivate me and valuable discussions with him. I am thankful to my APC committee members Dr. Rajeev Kumar, Dr. Viswanath Balakrishnan, Dr. Vishal S Chauhan, and Dr. Kaustav Mukherjee for their timely assessment, suggestion, and guidance which were helpful to improve myself.

I would also like to extend my gratitude to the faculty at IIT Mandi for their teachings and guidance. I would like to especially thank Dr. Bindu Radhamany, Dr. Viswanath Balakrishnan, Dr. Atul Dhar, Dr. Kunal Ghosh for having taught me the necessary courses to help me progress with my research.

Much of my efforts would not have been successful without proper help and support from my adorable lab-mates: Ashutosh Patel, Sohan Lal, Saurabh Singh, Shiv Prasad.

I am really grateful to Ajay Bhardwaj, Pawan Kumar, Davinder Singh, Rohit Pathak during this period. You were a source of constant optimism and fun. You were the one who gave me company while I was working in new area of research. Words fail me to describe the support that I received from my family especially my father, the iron man in my life. You have always been a constant source of strength, courage and optimism that kept me moving during these couple of years. I also wish to acknowledge the support of my dearest mother, whom I count as the most important pillar of my family. I wish to acknowledge my dear sister Nisha and brother Aditya for your love.

Special thanks go to Sudhir Sir for offering International Litti Chowkha. I still remember the outings, parties and specifically trekking with friends, which kept me entertained in the busy schedule.

Thank you all.

Kumar Gaurav

ABSTRACT

In this thesis, we discuss the methodology for accurate measurement of efficiency for thermoelectric generator (TEG), which is of great importance for materials research and development. Approximately all the parameters of a thermoelectric material (TEM) are temperature dependent, so we can't directly apply the $\eta_{\max}$ formula for efficiency calculation in the large temperature range. We have calculated the TEG efficiency and studied the suitability of different TEM like Bi_2Te_3, Sb_2Te_3, $PbTe$, $TAGS$, $CeFe_4Sb_{12}$, $SiGe$ and $TiO_{1.1}$ in the estimation of TEG efficiency. The efficiency of TEG made up of Bi_2Te_3 or Sb_2Te_3 gives ∼7% in temperature range of 310 K - 500 K. $PbTe$ or $TAGS$ or $CeFe_4Sb_{12}$ generates ∼6% in temperature range of 500 K - 900 K and $SiGe$ or $TiO_{1.1}$ also have remarkable efficiency in higher temperature range i.e ∼1200 K. The efficiency obtained is close to experimental results. Here, we report the enhancement of efficiency by using the segmented technique for different combinations of above-mentioned materials. To this end, the proposed values of overall efficiency of TEG by segmenting Bi_2Te_3 and $PbTe$; Bi_2Te_3 and $TAGS$; Bi_2Te_3 and $CeFe_4Sb_{12}$ are 12%, 14% and 11.88%, respectively, for the temperature range of 310 K to 900 K. For automobile, the efficiency of TEG having fixed exhaust temperature with varying sink temperature is also discussed. For steel industry and spacecraft application (∼ 1200 K), either segmentation is done by comprising Bi_2Te_3, $PbTe$ and $SiGe$ or Bi_2Te_3 and $TiO_{1.1}$, which shows efficiency of ∼15.2% and ∼17.2%, respectively. The relative change in efficiency by considering loss at interface surface is found out to be 10.5%. In this work, we are developing the theoretical prototype and improving the technique for installing the TEG set up in automobiles. We have used methodology for enhancing the efficiency of TEG and make it economical and user friendly. We have considered a linear curve fit from a zigzag curve of reported mass flow rate and temperature variation at the hot gas inlet. Accordingly the temperature of the coolant is also varied linearly at inlet from 300 K to 320 K and

accordingly the mass flow rate of coolant. Circular fin is installed around each circular layer of TEM after the water jacket. The calculated heat loss through each fin is 24 W. Energy balance was done at each and every TEM and correspondingly calculated the amount of power transferred through each segment of TEG as 32 W. We have calculated the length of TEM sample for attaining the respective temperature range for the hybrid of Bi_2Te_3 and $TiO_{1.1}$. This calculation is done by considering the compatibility factor derived as $s = \frac{\sqrt{1+ZT}-1}{\alpha T}$ which is a function of only intrinsic material properties and temperature and is represented by a ratio of current to conduction heat flux. The length obtained for this particular combination is ~8 mm. To this end, we have reported the efficiency with respect to mass flow rate of hot flue gas from automobile for different layers of TEG for the above mentioned combination. Here, we have explored the possibility of installing a number of different layers TEG module which can be installed throughout the lateral surface area of exhaust chamber. Thermal mismatching criteria is also discussed at the adjoining surface of TEM because of high temperature. To maintain the thermal expansion or contraction of TEM, spring and bolt arrangement is provided, which is fixed over the aluminium oxide ceramic substrate. The proposed methodology and results can be treated as a viable option for engineers, who are looking for fabricating TEG in real life by using the temperature dependent material's parameters like thermal conductivity, electrical conductivity, and Seebeck coefficient on which $z\bar{T}$ depends.

KEYWORDS: Thermoelectric Generator (TEG); Thermoelectric Materials (TEM); Figure of merit $z\bar{T}$; Seebeck coefficient; Thermal conductivity; Electrical Resistivity; Efficiency; Applications; Automobile; Python

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