

## Article

# Generation of Current in Thermoelectric Generator by Absorption of Heat Using ANSYS Thermal

Farah Javaid<sup>1</sup>, and Said M. El-Sheikh<sup>2</sup>

<sup>1</sup>Department of Physics, Govt. APWA College (W) Lahore, Pakistan

<sup>2</sup>Nanomaterials and Nanotechnology Department Advanced Materials Division Central Metallurgical Research and Development Institute CMRDI, Helwan, Egypt

\*Correspondence: farahjavaid71@gmail.com

**Abstract:** Thermoelectric power generation is a renewable energy conversion process that directly converts heat to electricity. This research proposes a novel fluid-thermal-electric multi-physics numerical model for predicting the performance of a thermoelectric-producing system. On the ANSYS platform, numerical simulations are done along with the exhaust temperature and mass flow rate. The range of hot end temperatures is from 100 to 450 degrees Celsius. Similarly, the cold end temperature can reach a maximum of 25 degrees Celsius and a minimum of 10 degrees Celsius. When the temperature at the generator's hot end rises, it means the temperature at the generator's cold end must fall. It means both have an inverse relation to each other. The maximum heat absorbed at the hot junction is 32.762 W and the minimum heat absorbed at the hot junction is 4.6305 W. Hence the maximum and minimum current values produced in this paper by the thermoelectric generator are 72.156 A & 10.816 A respectively. The hot side heat exchanger's position of the thermoelectric modules has a significant impact on output. Combining the benefits of many models are advised to construct an inclusive thermoelectric generator system for use in real-world applications.

**Keywords:** Thermoelectric generator, Heat absorption, Current density, ANSYS thermal

## Introduction:

Concerns about employing environmentally friendly power generation have grown as a result of pollution problems and global climate changes. There are different ways to generate environment-friendly power, as we are using wind energy. But our concern is about heat which is less used but more exiled to the environment. To put it simply, a thermoelectric generator is a tool for transforming thermal energy into electrical power. Initially, these were made with metal but now with semiconductor elements that are connected in series with metallic conductors [1]. Numerous scientists conducted research to utilize the ability of thermoelectric generators for inducing electric power [2-4]. Thermoelectric generators consist of a thermal module that is inserted between two heat exchangers. When thermoelectric couples are electrically connected in series but thermally coupled in parallel, some of the heat energy that flows between the couples is converted directly into electrical energy [5]. Thermoelectric generators eliminate the need for fossil fuels and lower carbon emissions [6]. Thermoelectric phenomena were discovered in the 18<sup>th</sup> century, at the time it produces a very minor voltage amongst different metallic elements and were used as thermocouples. Thermoelectric (TE) technologies have experienced the fastest development, after the invention of highly-

**Citation:** Javaid, F. ., & M. El-Sheikh, S. Generation of Current in Thermoelectric Generator by Absorption of Heat Using ANSYS Thermal: Absorption of Heat Using ANSYS Thermal. *Pakistan Journal of Emerging Science and Technologies (PJEST)*, 4(4). <https://doi.org/10.58619/pjest.v4i4.157>

Academic Editor: Dr. M. Javaid Afzal

Received date: 05-Nov-2023

Revised date: 23-Dec-2023

Accepted date: 24-Dec-2023

Published date: 30-Dec-2023



Pakistan Journal Emerging Sciences and Technologies (PJEST) in collaboration with [Govt. Islamia College Civil Lines Lahore, Pakistan](#) is licensed under a [Creative Commons Attribution-ShareAlike 4.0 International License](#)

efficient semiconductor device till now. Despite the fact that new materials are being considered. Seebeck effect and Peltier effect are the cornerstones of the fundamental theory underlying thermoelectric technologies (for main refrigeration). Seebeck's effect, states that two joints made of dissimilar metals have different temperatures ( $T$ ) at the joints. The thermo-current and thermo-electromotive force that result from this difference in temperature are present in the joint circuit [7]. Numerous p-type and n-type semiconductor slabs, creating thermocouples, make up thermoelectric generators. These are electrically coupled in series and thermally parallel. The top ceramic plate of TEGs can be heated by a variety of waste heat sources, including those from automotive engine exhaust, industrial and infrastructure-heating activities, geothermal, and others [8]. Due to such importance of thermoelectric generators, a lot of experiments and conducted in field of thermoelectric technology. Amin Nozariasbmarz et al. (2020) studies body heat harvesting system based on thermal electric generator in wearable electronics [9]. Ravi Anant Kishore et el. (2020) studies the generator for field placements. Directly transforming heat into electricity through thermoelectric power generation is a proven energy collecting method [10]. The thermoelectric generator for heat harvesting is investigated by NguyenVan Toan et al. (2020) from the standpoint of material synthesis all the way to device construction. [11]. Theoretical modeling and experimental validation of a thermoelectric generator (TEG) combined with a phase change material (PCM) are investigated by Truong Thi KimTuoi et al. (2020) [12]. Khairul Fadzli Samat et al. (2020) studies the high performance micro-thermoelectric generators (TEGs) based on metal-doped electrochemical deposition [13]. Khairul Fadzli Samat et al. (2020) investigate the dramatic enhancement of thermoelectric characteristics achieved by incorporating porous carbon black nanoparticles into a novel nanocomposite film of bismuth telluride [14]. Nanostructured electrochemical method for micro thermoelectric power sources is investigated by Khairul Fadzli Bin Samat et al. (2020) [15]. High-performance wearable thermoelectric generators with self-healing, recyclable, and Lego-like reconfigurability are the subject of research of Wei Ren et al. (2020) [16]. External variables have a big impact on how well the thermoelectric system works. Temperature swings and humidity levels, for example, can affect a material's characteristics and change its thermal conductivity. Prolonged exposure might cause material deterioration over time, which would reduce the overall effectiveness of the system. It is essential to take these things into account while developing thermoelectric generators that are durable and reliable. Many researchers have used ANSYS and Fuzzy for simulation before fabrication [17-36].

### **ANSYS Simulation:**

For simulation we use ANYSY software. ANSYS is a highest level-simulation program. Basically, it is a design software and gives us to simulator trial of our design for the best results. For example, simulation designed to simulate current and heat absorption. ANSYS Thermal-electric selected from all option from the tool box of ANSYS work bench. The thermal-electric deal with temperature, voltage, current etc. After the selection of thermal-electric, Engineering data were used to assign the custom materials for simulation. The geometry drawn by using different tools sketching and modeling and assigned required material for simulation such as copper as heat absorber and n and p-type substances are shown in fig 1a and 1b. ANSYS Thermal-electric on the ANSYS platform was used in the simulation procedure. The temperature range of 100 to 450

degrees Celsius, mass flow rate, and exhaust temperature were among the specific criteria. Special materials were allocated to our numerical model to ensure transparency and repeatability, including copper for heat absorption.

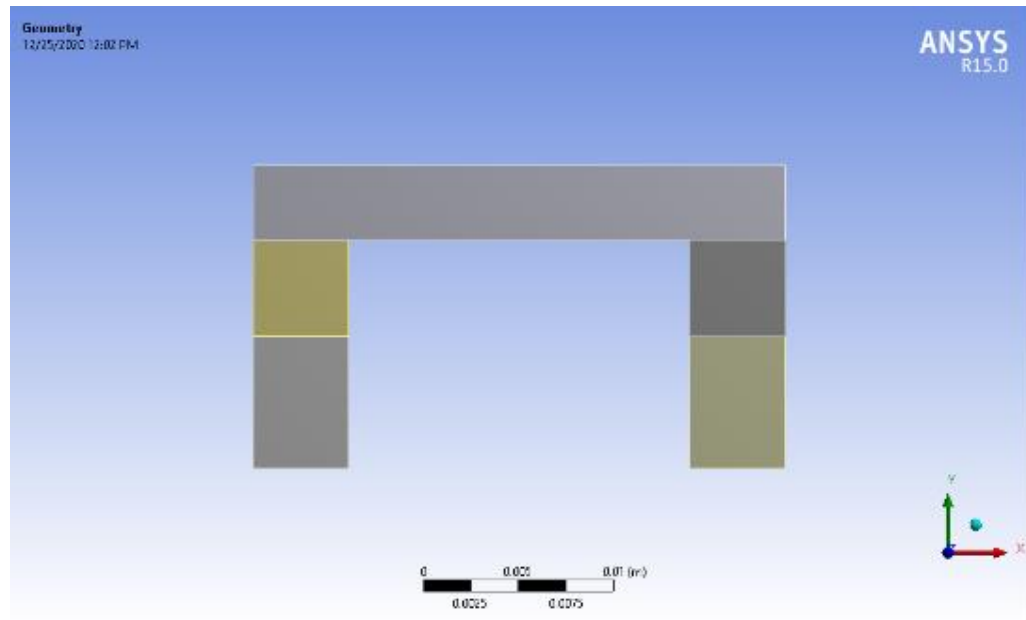


Fig.1(a)

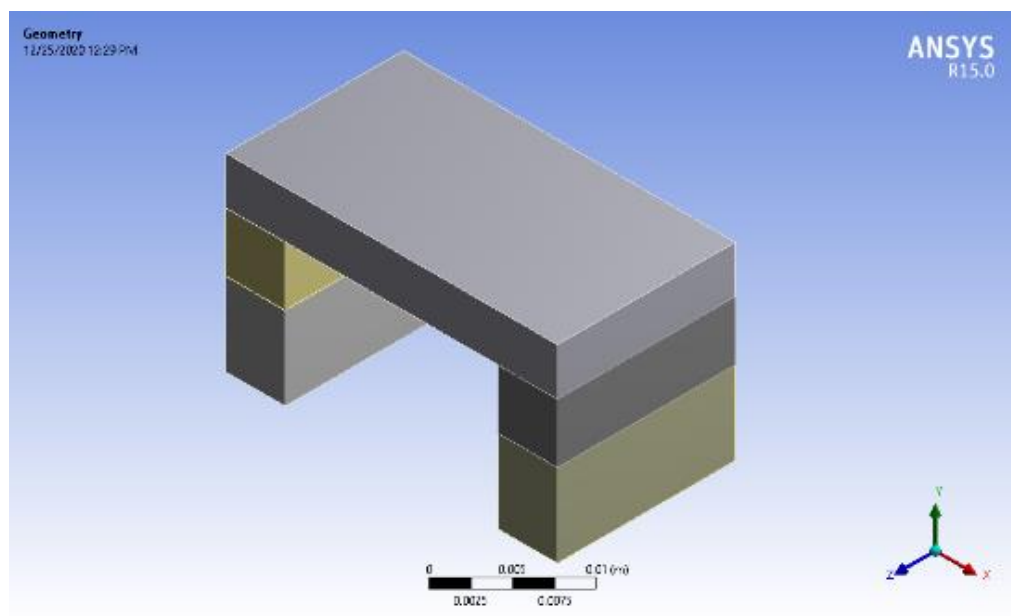


Fig.1(b)

After geometry step, created geometry assign to design modeler for meshing, apply loads and solution of simulation. In design modeler mesh was

used to geometry for better results. the number of nodes 17279 in mesh is and number of elements is 3480.

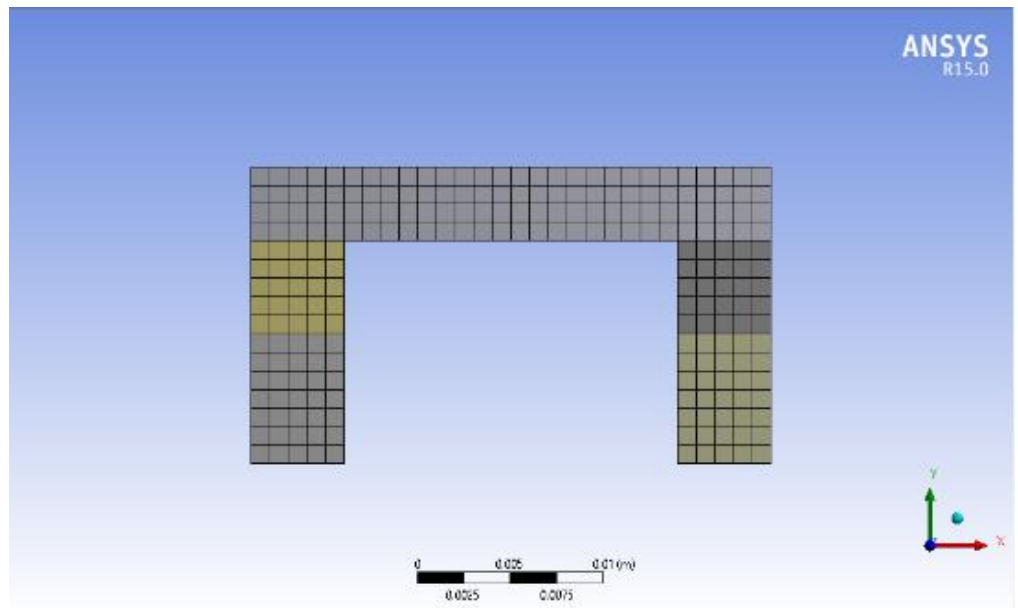


Fig.(a)

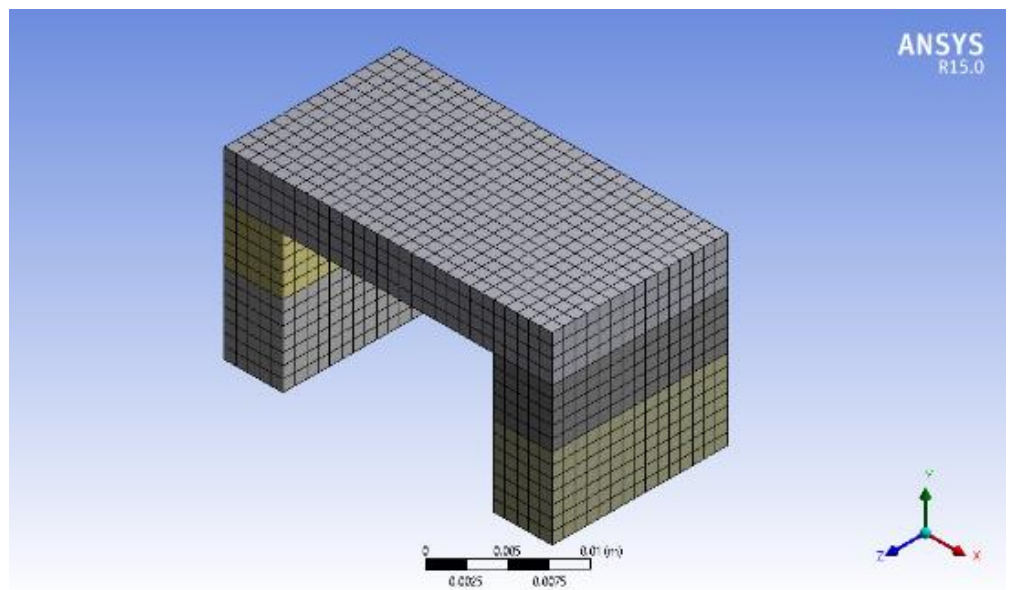


Fig.(b)

Different magnitudes of temperature are applied to geometry at hot junction as well as at cold junction, current and Heat absorbed calculated.

## Results:

At the hot junction, we perform the calculations necessary to determine the values of the generated current and the absorbed heat. The fluid-thermal-electric model we have suggested combines theory and real-world applications. We improve relevance and application by bridging the gap between theoretical understanding and actual thermoelectric generator settings by the integration of exhaust characteristics in ANSYS simulations.

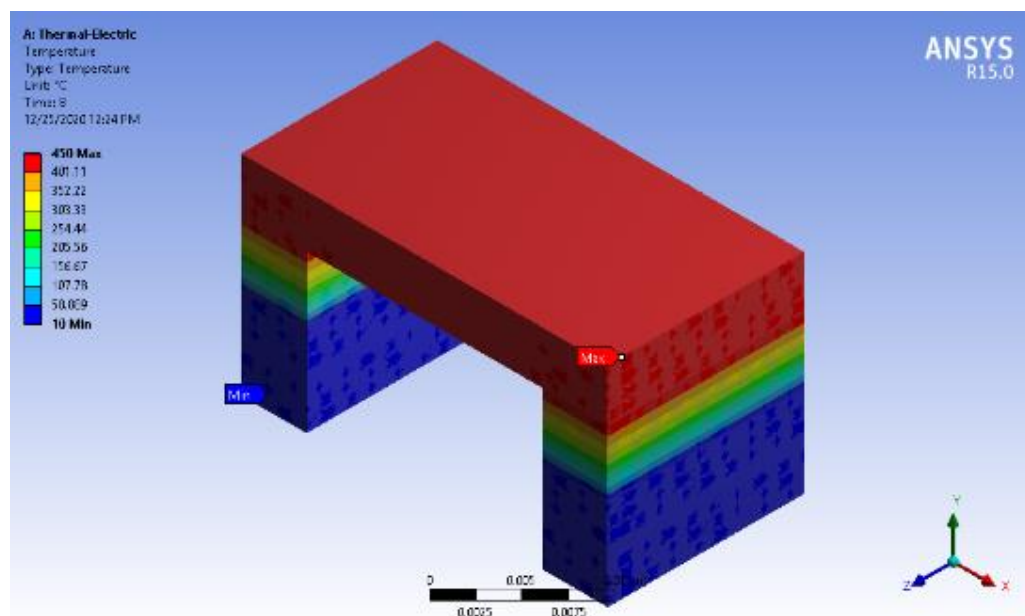
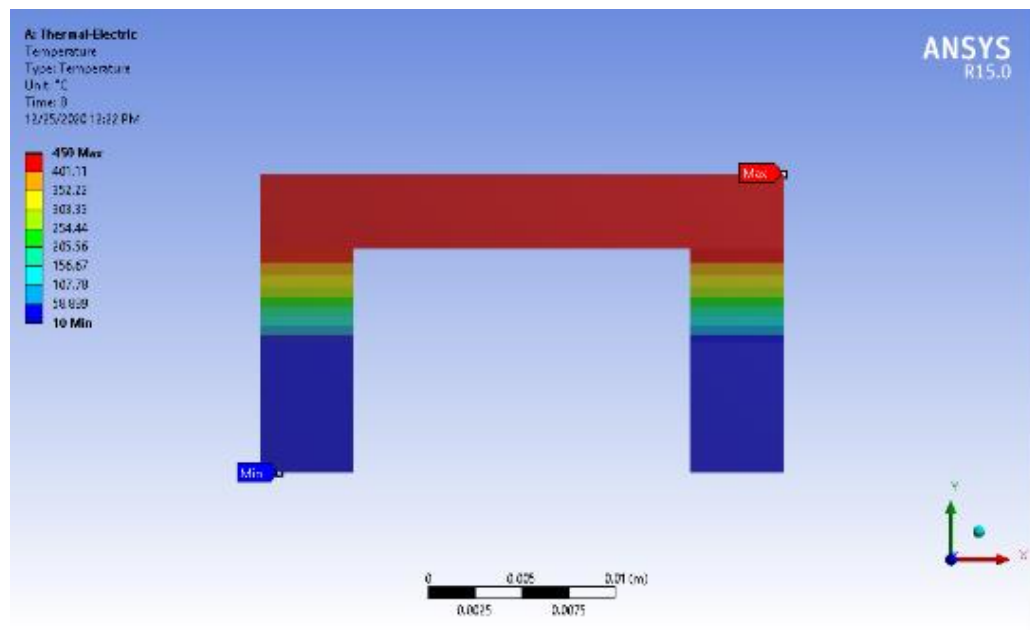


Fig. (a)

Fig. (b)

### Current Density:

Based on the current density, both the current and the amount of heat absorbed at the hot junction have been determined. By putting out a unique fluid-thermal-electric model, this article significantly advances the field of thermoelectric power production. The novel combination of exhaust parameters and numerical simulations improves prediction accuracy and deepens our knowledge of thermoelectric system performance. The optimization of energy conversion processes may be greatly enhanced by this invention.

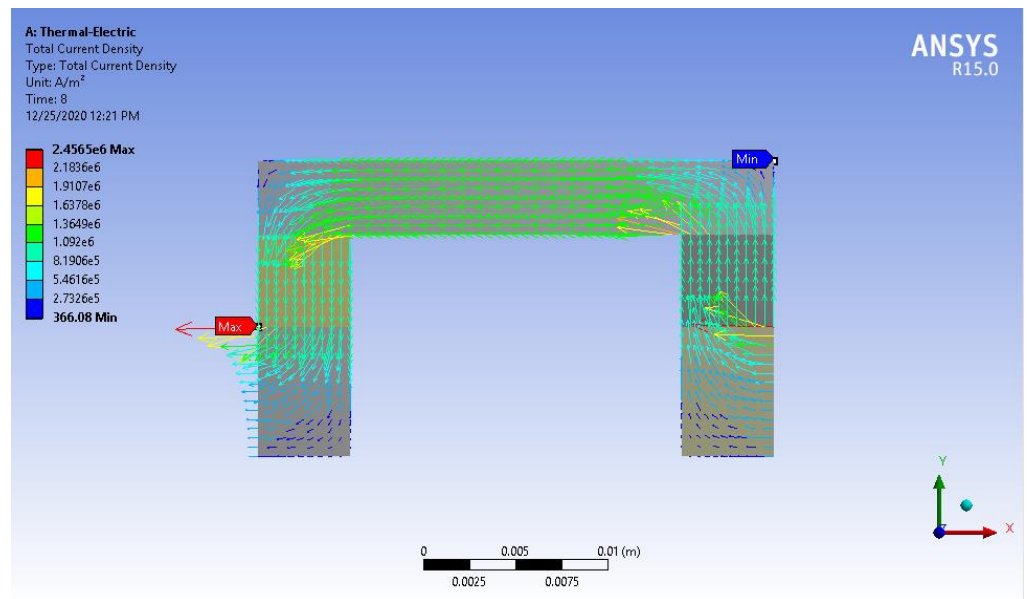


Fig.(a)

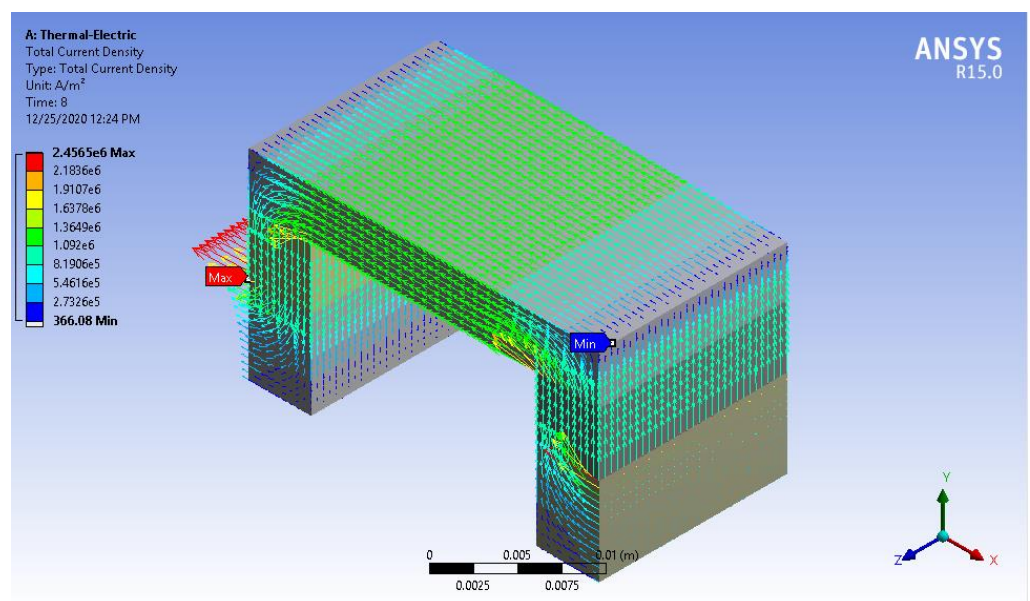


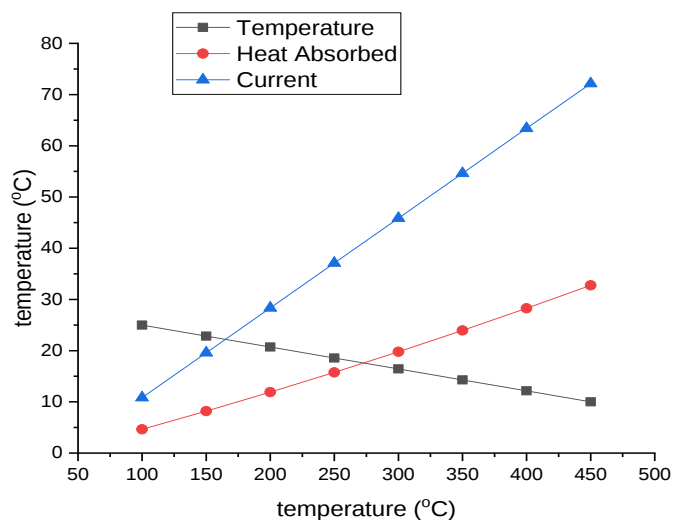
Fig.(b)

### Result Analysis:

The analysis has been shown by the calculated values and graph of generated current and heat absorbed at hot junction of thermoelectric generator. The results of our work have important applications for improving the efficiency of thermoelectric generators (TEGs). The foundation for enhancing TEG performance is laid by our research, which examines current and heat absorption properties. The tendencies that have been found offer important new information that will help thermoelectric generators become more effective. These developments are a step towards sustainable energy solutions and present a viable way to capture waste heat and convert it to electrical power that can be used in a variety of industrial and environmental settings.

| Hot (Junction)<br>End<br>Temperature | Cold (Junction)<br>End Temperature | Heat<br>Absorbed at<br>Hot Junction<br>(Input) | Current |
|--------------------------------------|------------------------------------|------------------------------------------------|---------|
| °C                                   | °C                                 | W                                              | A       |
| 100                                  | 25                                 | 4.6305                                         | 10.816  |
| 150                                  | 22.85                              | 8.1882                                         | 19.585  |
| 200                                  | 20.72                              | 11.896                                         | 28.349  |
| 250                                  | 18.57                              | 15.761                                         | 37.112  |
| 300                                  | 16.43                              | 19.781                                         | 45.867  |
| 350                                  | 14.29                              | 23.956                                         | 54.617  |
| 400                                  | 12.15                              | 28.277                                         | 63.405  |
| 450                                  | 10                                 | 32.762                                         | 72.156  |

### Graphical Analysis:



## Conclusion

A unique fluid-thermal-electric multi-physics numerical model is proposed in this work to forecast the performance of a thermoelectric producing system. Both the exhaust temperature and mass flow rate are input for the ANSYS thermal. The range of hot end temperatures is from 100 to 450 degrees Celsius. Similarly, the cold end temperature can reach a maximum of 25 degrees Celsius and a minimum of 10 degrees Celsius. As the temperature rises at the generator's hot end, it falls at its cold end. It indicates an inverse relationship between the two. The hot junction may absorb up to 32.762 W of power and as little as 4.6305 W. In this study, the thermoelectric generator outputs a maximum of 72.156 A and a minimum of 10.816 A. Location of the thermoelectric modules in the hot side heat exchanger has a major impact on the output. An abundance of theoretical models has been developed in recent years for thermoelectric generators and thermoelectric generator systems with the aim of better forecasting and enhancing performance. It is essential to do sensitivity analyses under various scenarios in order to improve research depth. Evaluating the robustness of results guarantees a thorough comprehension of the model's functionality in a variety of settings, enhancing the overall validity of the research. We then examine the CFD simulations with numerical thermoelectric model which can made the theoretical basis of a thermoelectric producing system. As such, it is suggested that a whole thermoelectric generator system be developed by combining the benefits of multiple types. To increase thermoelectric power generation, future research should investigate novel materials, unique combinations, and enhanced modelling approaches. For the benefit of society, the area will advance and more sustainable and effective energy conversion techniques will be fostered by continuing innovation and collaboration.

**Author's Contribution:** F.J, Conceived the idea; M.E.S, Designed the simulated work or acquisition of data; F.J, executed simulated work, data analysis or analysis and interpretation of data and wrote the basic draft; M.E.S, Did the language and grammatical edits or Critical revision.

**Funding:** The publication of this article was funded by no one.

**Conflicts of Interest:** The authors declare no conflict of interest.

**Acknowledgement:** The authors would like to thank the Chairperson of the Department of Physics Govt. Islamia Graduate College Civil Lines Lahore, for providing all the possible facilities

## References

- [1] K. Witek, A. Skwarek, B. Synkiewicz, P. Guzdek, A. J. I. J. o. M. Arazna, and Optimization, "Technological Aspects of Semiconductor Thermogenerator (TEG) Assembly," vol. 3, no. 5, p. 390, 2013.
- [2] L. Anatychuk, O. Luste, and R. J. J. o. E. m. Kuz, "Theoretical and experimental study of thermoelectric generators for vehicles," vol. 40, no. 5, pp. 1326-1331, 2011.
- [3] S.-K. Kim, B.-C. Won, S.-H. Rhi, S.-H. Kim, J.-H. Yoo, and J.-C. J. J. o. e. m. Jang, "Thermoelectric power generation system for future hybrid vehicles using hot exhaust gas," vol. 40, no. 5, pp. 778-783, 2011.

- [4] Z. Niu, H. Diao, S. Yu, K. Jiao, Q. Du, G. J. E. C. Shu, and Management, "Investigation and design optimization of exhaust-based thermoelectric generator system for internal combustion engine," vol. 85, pp. 85-101, 2014.
- [5] D. J. E. C. Champier and Management, "Thermoelectric generators: A review of applications," vol. 140, pp. 167-181, 2017.
- [6] C.-C. Wang, C.-I. Hung, and W.-H. J. E. Chen, "Design of heat sink for improving the performance of thermoelectric generator using two-stage optimization," vol. 39, no. 1, pp. 236-245, 2012.
- [7] W. He, G. Zhang, X. Zhang, J. Ji, G. Li, and X. J. A. E. Zhao, "Recent development and application of thermoelectric generator and cooler," vol. 143, pp. 1-25, 2015.
- [8] E. Kanimba and Z. J. T. f. P. G. A. L. a. T. i. t. T. Tian, "Modeling of a thermoelectric generator device," pp. 461-479, 2016.
- [9] A. Nozariasbmarz, F. Suarez, J. H. Dycus, M. J. Cabral, J. M. LeBeau, M. C. Öztürk, and D. J. N. E. Vashae, "Thermoelectric generators for wearable body heat harvesting: Material and device concurrent optimization," vol. 67, p. 104265, 2020.
- [10] R. A. Kishore, A. Nozariasbmarz, B. Poudel, S. J. A. a. m. Priya, and interfaces, "High-Performance Thermoelectric Generators for Field Deployments," vol. 12, no. 9, pp. 10389-10401, 2020.
- [11] N. Van Toan, T. T. K. Tuoi, T. J. E. C. Ono, and Management, "Thermoelectric generators for heat harvesting: From material synthesis to device fabrication," vol. 225, p. 113442, 2020.
- [12] T. T. K. Tuoi, N. Van Toan, and T. J. E. R. Ono, "Theoretical and experimental investigation of a thermoelectric generator (TEG) integrated with a phase change material (PCM) for harvesting energy from ambient temperature changes," vol. 6, pp. 2022-2029, 2020.
- [13] N. Van Toan, T. T. K. Tuoi, K. F. Samat, H. Sui, N. Inomata, M. Toda, and T. Ono, "High Performance Micro-Thermoelectric Generator Based on Metal Doped Electrochemical Deposition," in *2020 IEEE 33rd International Conference on Micro Electro Mechanical Systems (MEMS)*, 2020: IEEE, pp. 570-573.
- [14] K. F. Samat, Y. Li, N. Van Toan, and T. Ono, "Carbon Black Nanoparticles Inclusion in Bismuth Telluride Film for Micro Thermoelectric Generator Application," in *2020 IEEE 33rd International Conference on Micro Electro Mechanical Systems (MEMS)*, 2020: IEEE, pp. 562-565.
- [15] T. Ono, N. Van Toan, and K. F. B. Samat, "High Performance Thermoelectric Films with Nanoengineered Electrochemical Process for Micro Thermoelectric Power Generators," in *ECS Meeting Abstracts*, 2020, no. 19: IOP Publishing, p. 1204.
- [16] W. Ren *et al.*, "High-performance wearable thermoelectric generator with self-healing, recycling, and Lego-like reconfiguring capabilities," vol. 7, no. 7, p. eabe0586, 2021.
- [17] M. J. Afzal, M. W. Ashraf, S. Tayyaba, M. K. Hossain, and N. Afzulpurkar, "Sinusoidal microchannel with descending curves for varicose veins implantation," *Micromachines*, vol. 9, no. 2, p. 59, 2018.
- [18] M. J. Afzal, S. Tayyaba, M. W. Ashraf, M. K. Hossain, M. J. Uddin, and N. Afzulpurkar, "Simulation, fabrication and analysis of silver based ascending sinusoidal microchannel (ASMC) for implant of varicose veins," *Micromachines*, vol. 8, no. 9, p. 278, 2017.

- [19] S. Tayyaba, M. W. Ashraf, Z. Ahmad, N. Wang, M. J. Afzal, and N. Afzulpurkar, "Fabrication and analysis of polydimethylsiloxane (PDMS) microchannels for biomedical application," *Processes*, vol. 9, no. 1, p. 57, 2020.
- [20] S. Tayyaba, M. J. Afzal, G. Sarwar, M. W. Ashraf, and N. Afzulpurkar, "Simulation of flow control in straight microchannels using fuzzy logic," in *2016 International Conference on Computing, Electronic and Electrical Engineering (ICE Cube)*, 2016: IEEE, pp. 213-216.
- [21] M. J. Afzal, F. Javaid, S. Tayyaba, M. W. Ashraf, C. Punyasai, and N. Afzulpurkar, "Study of charging the smart phone by human movements by using MATLAB fuzzy technique," in *2018 15th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, 2018: IEEE, pp. 411-414.
- [22] M. J. Afzal, S. Tayyaba, M. W. Ashraf, M. K. Hossain, and N. Afzulpurkar, "Fluidic simulation and analysis of spiral, U-shape and curvilinear nano channels for biomedical application," in *2017 IEEE International Conference on Manipulation, Manufacturing and Measurement on the Nanoscale (3M-NANO)*, 2017: IEEE, pp. 190-194.
- [23] M. J. Afzal, S. Tayyaba, M. W. Ashraf, and G. Sarwar, "Simulation of fuzzy based flow controller in ascending sinusoidal microchannels," in *2016 2nd International Conference on Robotics and Artificial Intelligence (ICRAI)*, 2016: IEEE, pp. 141-146.
- [24] M. Afzal, F. Javaid, S. Tayyaba, A. Sabah, and M. Ashraf, "Fluidic simulation for blood flow in five curved Spiral Microchannel," *Biologia*, vol. 65, no. 1, 2019.
- [25] M. J. Afzal, F. Javaid, S. Tayyaba, M. W. Ashraf, and M. K. Hossain, "Study on the Induced Voltage in Piezoelectric Smart Material (PZT) Using ANSYS Electric & Fuzzy Logic," 2020.
- [26] M. J. Afzal, M. W. Ashraf, S. Tayyaba, A. H. Jalbani, and F. Javaid, "Computer simulation based optimization of aspect ratio for micro and nanochannels," *Mehran University Research Journal Of Engineering & Technology*, vol. 39, no. 4, pp. 779-791, 2020.
- [27] M. Afzal, F. Javaid, S. Tayyaba, M. Ashraf, M. Ashiq, and A. Akhtar, "Simulation of a Nanoneedle for Drug Delivery by Using MATLAB Fuzzy Logic," *Biologia*, vol. 64, no. 1, 2018.
- [28] M. J. Afzal, "Study of constricted blood vessels through ANSYS fluent," *Blood vessels*, vol. 27, pp. 11-2020.
- [29] M. J. Afzal, S. Tayyaba, M. W. Ashraf, M. Khan, F. Javaid, M. K. Basher, and M. K. Hossain, "A Review on Microchannel Fabrication Methods and Applications in Large-Scale and Prospective Industries," 2022.
- [30] M. I. Yasin, M. J. Afzal, S. Tayyaba, M. W. Ashraf, B. Cornel, and M. Balas, "Fuzzy Parametric Estimation of Curvilinear Microchannel for Retinal Vein Occlusion (RVO)," in *Advances in Intelligent Data Analysis and Applications: Proceeding of the Sixth Euro-China Conference on Intelligent Data Analysis and Applications, 15-18 October 2019, Arad, Romania*, 2022: Springer, pp. 355-362.
- [31] M. T. Khan, M. J. Afzal, F. Javaid, S. Tayyaba, M. W. Ashraf, and M. K. Hossain, "Study of tip deflection on a copper-steel bimetallic strip by fuzzy logic and ansys static structural," 2021.
- [32] M. J. Afzal, F. Javaid, S. Tayyaba, and M. W. Ashraf, "J-tip Blood Channel Fluid Dynamics Simulation," 2023.
- [33] N. Ali, M. J. Afzal, F. Javaid, S. Tayyaba, M. W. Ashraf, G. I. Toki, and M. K. Hossain, "Heat Transfer Analysis of Al<sub>2</sub>O<sub>3</sub> Nanoparticles," 2022.

- 
- [34] M. Sufian, M. J. Afzal, F. Javaid, S. Tayyaba, M. W. Ashraf, F. I. Toki, and M. K. Hossain, "Catalytic Converter Simulation for Pressure and Velocity Measurement," 2022.
  - [35] Z. ul Qasmi *et al.*, "ANSYS simulation of Temperature of Cooling System in Li-ion Battery," 2022.
  - [36] M. S. Arif, M. J. Afzal, F. Javaid, S. Tayyaba, M. W. Ashraf, G. I. Toki, and M. K. Hossain, "Laminar Flow Analysis of NACA 4412 Airfoil Through ANSYS Fluent," 2022.