Maximization of Energy and Exergy Efficiencies for a Sustainable Thermoelectric Cooling System by applying Genetic Algorithm

Jitendra Mohan Giri* and Pawan Kumar Singh Nain

School of Mechanical Engineering,
Galgotias University,
Greater Noida, Uttar Pradesh-201312, India
Email: jitendra.giri@galgotiasuniversity.edu.in
Email: pawan.kumar@galgotiasuniversity.edu.in
*Corresponding author

Abstract: The efficient thermal management of thermoelectric cooler (TEC) as a sustainable cooling technology is important. The energy loss, electrical power requirement, and irreversibility of the TEC system need to be minimized. Hence, the loss of energy and energy quality (exergy) are two significant points of concern. Thus, energy and exergy efficiency can be used as the key indicators to optimize TEC's performance. Through this work, authors separately optimized TEC energy efficiency (η_I) and exergy efficiency (η_{II}) considering thermoelectric elements geometry and electric current by using the genetic algorithm (GA). The effects of electrical contact resistance and thermal resistance are considered in the mathematical model of this work. Unlike previously reported works, the authors have used junction temperatures different from surface temperatures at the respective cold and hot sides of TEC. This study reveals that maximum energy and exergy efficiencies are obtainable at the same values of electric current, length, and cross-sectional area of thermoelectric elements. It is significant as these identical optimum design variables assert maximum η_I and η_{II}. At cold surface temperature (T_c) of 20°C, the maximum energy efficiency of 4.11 and the maximum exergy efficiency of 0.0715 are obtained. Exergy efficiency can be used as the basis to choose TEC since it assures better energy quality and connects with sustainable development. The genetic algorithm optimization result is validated through ANSYS® finite-element simulation. This study will help enhance actual TEC performance.

Keywords: thermoelectric cooler; energy efficiency; exergy efficiency; genetic algorithm; optimization; finite-element simulation

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Biographical notes: Jitendra Mohan Giri received his B.E. degree in Mechanical Engineering from Dr. B.R. Ambedkar University, Agra, India, and M.Tech. from the Uttar Pradesh Technical University, Lucknow, India. He is pursuing Ph.D. from the Galgotias University, Greater Noida, India. He is presently working on the performance optimization of thermoelectric coolers.

Pawan Kumar Singh Nain is a Professor in the School of Mechanical