Thermoelectric generator in endoreversible approximation: The effect of heat-transfer law under finite physical dimensions constraint

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A heat exchanger is an important device that facilitates the exchange of heat between the working medium and the heat reservoirs. These devices find applications in many engineering systems, such as power plants, refrigeration, and air conditioning systems, automobile radiators, waste-heat recovery units. The real-world energy convertors perform under finite-size and finite-time constraints on the resources. Finite physical dimensions thermodynamics (FPDT) is an approach which considers the physical size of a heat exchanger to study irreversible processes in actual devices.

In this presentation, we focus on a steady-state energy convertor working on the principle of thermoelectricity which is a paradigmatic model to study the effect on performance due to different sources of irreversibility. Here, in addition to optimizing the power output with respect to electric current, we also optimize with respect to the fractional area of a heat exchanger. With this step, it will be shown that the maximum power output should be at a proper selection of the area of the heat exchangers, in addition to an optimal value of the electric current. This selection is an important step in thermal optimization as finiteness of the total heat transfer area is a relevant constraint in the overall design of the energy converter.

Another objective of this paper is to examine the effect of heat transfer law between the working substance and reservoirs on the performance of thermoelectric generator. In particular, we investigate the endo-reversible model based on linear-irreversible law of heat transfer. The results are compared with the usual results based on Newton's law of heat transfer.

Our approach allows the engineer allocate optimal areas to the heat exchangers, apart from an optimal value of thermoelectric electric current. The approach has been earlier applied to various industrial devices, power plants, and cooling systems. The present application to a thermoelectric device shows the utility of FPDT for this class of energy conversion devices. In particular, our analysis also highlights the comparison between linear-irreversible and Newton's laws in thermoelectric engines and provides a useful toy model to analyze the interplay of different forms of the efficiency in these devices.

References

[1] J. Kaur, R. S. Johal, M. Feidt, Phys. Rev. E 105, 034122 (2022).