Studies in the optimization of power output of steady-state heat engines

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Abstract

With the advancement in technologies, miniaturization of machines, and using waste energy as an input for heat engines or refrigerator is occurring at a tremendous rate. In today's world, a big challenge is to make these machines more efficient, as even small heat leaks could bring a considerable change in its performance. This thesis is dedicated to studying the power optimization of two kinds of heat engines which operate in the steady-state regime, while being in contact with two heat reservoirs at different temperatures:-

(i) TEG: Thermoelectric generator (TEG) is basically a heat engine that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect. Generally, TEGs are quite inefficient and expensive, but considerably less bulky than heat engines. In recent time a lot of research is going on optimizing its power as it could be used in power plants in order to convert waste heat into additional electrical power and in automobiles as automotive thermoelectric generators (ATGs) to increase fuel efficiency. Another application is radioisotope thermoelectric generators which are used in space probes, which has the same mechanism but use radioisotopes to generate the required heat difference. In this report we are trying to optimize the power of a thermoelectric generator (TEG) under a particular model, considering internal and external irreversibilities. Then we find efficiency at maximum power (EMP) and try to infer the series expansion of efficiency around Carnot efficiency.

(ii) Brownian heat engines: In recent times, Brownian microscopic heat engines have drawn much attention for the utilization of energy resource available at the microscopic scale for nanomachines. Brownian heat engines are spatially asymmetric but periodic structures connected to the reservoirs at different temperatures. The microscopic description of these machines could be given using the Langevin equation. However, for our purposes, we only need a macroscopic description of the system. Our work includes power optimization of the model considering irreversible heat flow due to kinetic energy exchange and infers its behavior near equilibrium. Further, we would like to get a bound in efficiency and investigate conditions where it could achive well-known efficiencies such as Carnot or Curzon-Ahlborn (C.A) efficiency. It may not be important for a practical purpose but it would certainly give insight to the theoretical aspects.