Comparison between thermomagnetic and thermoelectric generators

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Nowadays, the supply of waste heat is sufficiently abundant to make it a key target for technology development. So far, thermal energy harvesting of low-grade heat has been mainly associated to thermoelectric generator (TEG) technology. However, recent advances on magnetocaloric materials (MCM) aimed to applications in room temperature magnetic refrigeration, could pave the way for a new generation of thermogenerators (TMG). We propose to study the efficiencies and the power density of TMG and TEG at maximum power in the framework of the finite time thermodynamic [1]. The performance will be discussed as a function of the temperature difference between the reservoirs and of the efficiency of the heat exchangers.

Finite time thermodynamic applied on TMG reveals that as long as the adiabatic temperature change reaches half of the temperature difference of the reservoir ΔT_{res}, the TMG reaches the optimum cycle as confirmed in the simulation [2]. However, when this condition is not feasible due to field limitation, the optimum cycle is no longer reached and the efficiency relative to the Carnot efficiency, η_{rel}, decreases (Fig. 1). Our approach based on the work of Curzon and Ahlborn [1] gives a general method to estimate the performance achievable by TMG. Comparisons with the power density measured in some prototypes [3] show a good accordance with our results.

On the other side, TEG have already been well optimized [4] and even if the optimum is far from the Curzon and Ahlborn, its relative efficiency does not strongly decrease when the ΔT_{res} increases like TMG (Fig.2). Even if these primary results need to be confirmed, they show a potential benefit for TMG at low ΔT_{res}. Staging thermodynamic cycles could be seen as a possible improvement of the TMG, but our finite time thermodynamic analysis shows no gain. We, therefore, put our attention on the potential use of TMG in microsystem.
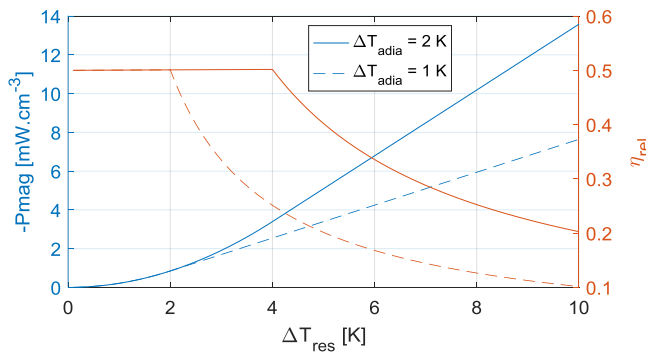

Figure 1. Power – Efficiency of thermogenerator
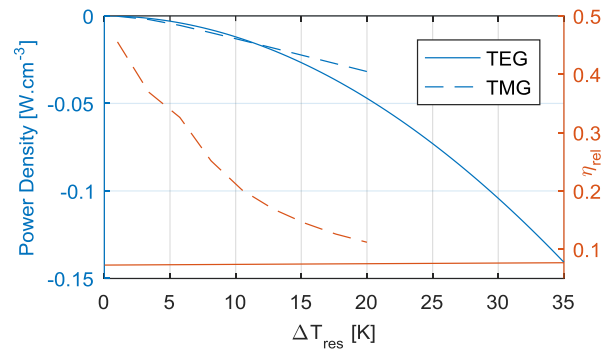

Figure 2. Comparison between TEG and TMG

[1] F. L. Curzon, "Efficiency of a Carnot engine at maximum power output," *Am. J. Phys.*, vol. 43, no. 1, p. 22, 1975.

[2] M. Almanza, A. Pasko, F. Mazaleyrat, and M. LoBue, "Numerical study of thermomagnetic cycle," *J. Magn. Magn. Mater.*, vol. 426, pp. 64–69, Mar. 2017.

[3] M. Gueltig *et al.*, "High Frequency Thermal Energy Harvesting Using Magnetic Shape Memory Films," *Adv. Energy Mater.*, vol. 4, no. 17, p. n/a-n/a, Dec. 2014.

[4] Y. Apertet, H. Ouerdane, O. Glavatskaya, C. Goupil, and P. Lecoeur, "Optimal working conditions for thermoelectric generators with realistic thermal coupling," *EPL Europhys. Lett.*, vol. 97, no. 2, p. 28001, Jan. 2012.