Structural optimization of Energy systems involving Thermodynamic cycles

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Abstract
The goal of the work presented is to improve the efficiency of existing energy systems through topology optimization, such that they can further improve green energy sustainability.

Thermodynamic cycles are essential in many energy systems, and our work is one of the first applications of topology optimization on systems described by a thermodynamic cycle. The work is part of the EnergyShaping project, supported by the Danish Agency for Science, Technology and Innovation, which also includes structural optimization of Solid Oxide Fuel Cells, as presented in another talk by Grigorios Panagakos.

In the present work, we optimize the structure of a simple generic passive regenerator model and show how it relates to improvements of magnetic refrigerator systems. Such systems utilize the magnetocaloric effect to separate an ambient temperature into hot and cold regions through a thermodynamic cycle. (The magnetic Ericsson refrigeration cycle).
The specific numerical model of the magnetic refrigerator is described in the work of T. F. Petersen [1], and relates directly to an existing experimental setup at Risø DTU, Denmark. This model utilizes a small-scale regenerator to support the temperature difference between the hot and cold region, and we first apply the method of topology optimization to improve the overall design, combined then with a subsequent shape optimization to implement a more realistic objective function, and to ensure an easy fabrication of the resulting structures.

In order for the high-level implementation of topology optimization to work [2], the model has to be steady state, and therefore the refrigeration cycle has been reformulated, using harmonically varying fields, into an amplitude model. The amplitude model nicely reproduces the results from direct simulation of the thermodynamic cycle, and initial results from the overall structural optimization are presented.

[1] T. F. Petersen, "Numerical modeling and analysis of a room temperature magnetic refrigeration system", PhD-thesis, DTU Risø, Denmark (2007)
[2] L.H. Olesen, F. Okkels, and H. Bruus, Int. J. Num. Meth. Eng. 65, 975 (2006)