Reducing thermal errors with topology optimization and distributed cooling

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Commented [ML1]: Denk dat het goed is om Fred ook mede-auteur te maken, hij is tenslotte jepromotor!

Abstract

Thermal errors play an important role in the design of high-precision systems and machine tools. With more demanding specifications regarding the precision, the thermal error becomes a significant factor in the total error budget. Therefore, the design's geometry should be chosen carefully to limit the thermal error due to temperature fluctuations during operation. Moreover, the introduction and placement of external cooling becomes critical to provide a proper thermal management for the thermal loads imposed on the structure.

In this work the benefits of topology optimization are investigated to design a structure's shape as well as the placement of the external cooling. Existing research mostly applies topology optimization for either the material distribution or the distribution of cooling. However, by simultaneously performing an optimization of both aspects, the thermo-mechanical behaviour works efficiently together with the available, distributed cooling. The objective of the optimization is to minimize the thermal error (i.e. temperature-induced displacement) of a specific point of interest, while the domain is subjected to thermal and mechanical loads. We present multiple two-dimensional examples to demonstrate the performance of the optimization. The proposed method is able to effectively find designs that minimize the thermal error for various combinations of thermal and mechanical loads, which can serve as inspiration for improved designs. In future work, the investigated problems are extended towards transient analysis with refined modelling of the external cooling by the introduction of cooling channels.

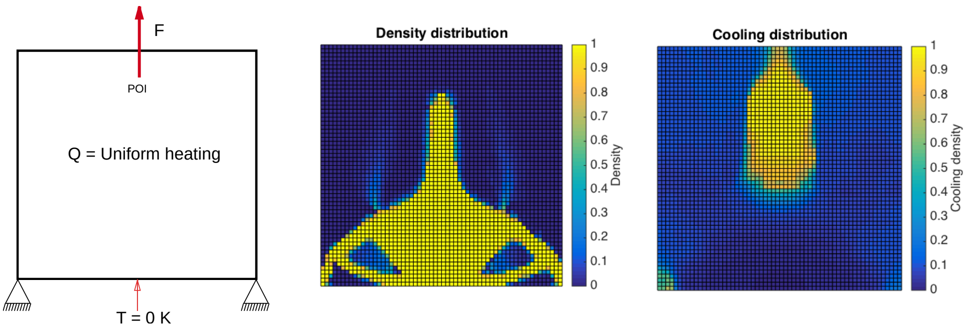

Figure 1: (left): The design domain subjected to a uniform heat load and a vertical force. The domain is fixed at the bottom corners and a heat sink is positioned in the middle of the bottom edge. The other figures present the normalized material density distribution (center) and cooling distribution (right) provided by the optimization routine to minimize the thermal error of the point of interest (POI).