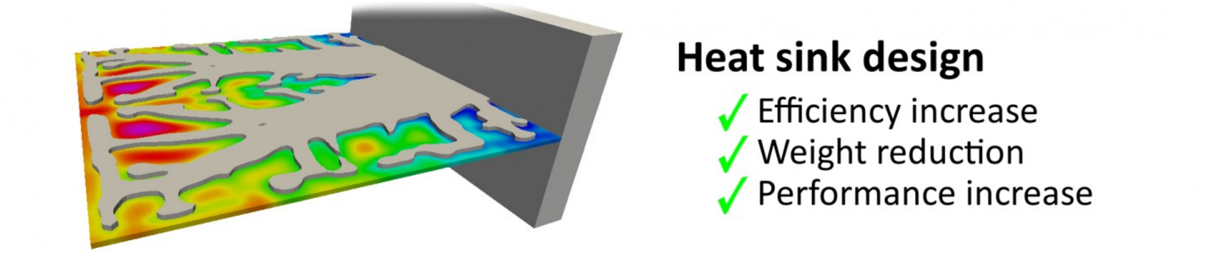
Topology optimization of a heat conduction problem

Diabatix is a young company focusing on high-performant cooling component designs. Cooling components are used on lasers, electronics, engines etc. in order to limit the operating temperature. The performance of a cooling component is context-dependent, but is mostly achieved by having a uniform temperature on a surface (which increases product lifetime) or the most compact design possible. Diabatix achieves the design of cooling components using a state-of-the-art numerical optimization procedure.

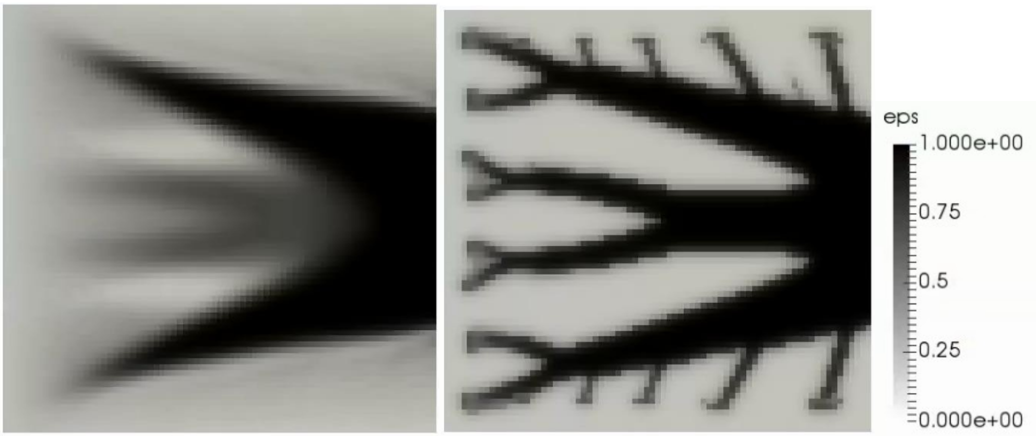
A heat spreader is a device that conducts heat from a heat source to an outlet. The heat spreader is physically put on top of the heat source. The heat spreader itself is made of high conductivity metal embedded in low conductivity plastic. The following figure is from Diabatix' website.



In the assignment, we will design a heat spreader based on a simple heat conductivity problem on a rectangular domain. The heat source is uniformly distributed over the domain. The outlet of the heat spreader is situated on the right side of the domain where a given temperature is imposed. The design question now is to minimize the difference in temperature on the device with the temperature of the outlet, or, in other words: where should metal be put on the domain to maximize heat transport towards the outlet, with a given maximum amount of metal to be used.

This is a discrete optimization problem, where, after discretization, is decided on which cells of the mesh metal is put or not. Solving such problem requires a very large amount of simulations, and therefore, the presence of metal is not represented by a Boolean but a real variable. This allows the use of numerical optimization.

In the optimization procedure, the design is made by distributing material. The distribution of metallic (black) and plastic (white) material is the desired optimization result. The figures below show design iterations of the optimization procedure. The left figure shows an intermediate result, whereas the right figure shows the final design. Note that a black and white design is achieved by the use of 'continuation', i.e. making it more expensive for the design to use intermediate epsilon, detailed in [2]. In order to obtain a clear black-white design, many iterations are necessary.

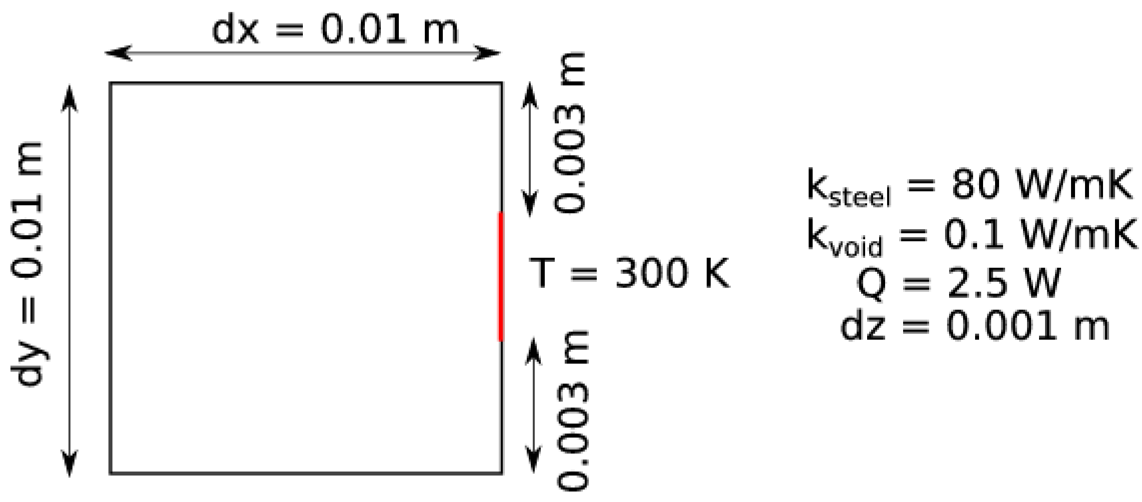


Key problems in this assignment

In this assignment students are required to formulate the optimization problem just described and to implement an algorithm for its solution.

Hints for the representation of the presence of metal using a real variable can be found in [2]. For a given distribution of metal, the temperature can be computed by solving a corresponding heat equation with appropriate boundary conditions. Students can either implement their own software, or can combine existing software packages (some are listed in [1]).

The relevant physical details are detailed on the sketch below. Q is the internal heat source. All walls are insulated except the wall with the fixed temperature. The maximum relative volume of metal in the domain is limited to 40%.



References

[1] , M. M. Gregersen, A. Evgrafov, and M. P. Sørensen, *Topology optimization of heat conduction problems,* Workshop on industrial design optimization for fluid flow 23, September 2010, 2010. See http://flowhead.sems.qmul.ac.uk/events/workshop2010/downloads/workshop-pres/DTU-varna-ws-2010.pdf

[2] C.F. Hvejsel and E. Lund, *Material interpolation schemes for unified topology and multi-material optimization,* Struct Multidisc Optim, 2011.