

## Master's Thesis: Find an Optimal Geometry for Convective Heat Transfer in Energy-Efficient Thermal Processes

### What's It About?

Energy-intensive thermal processes (heating, preheating, annealing, etc.) can be electrified to reduce fossil fuel consumption. To transfer electricity “from the socket” into the material to be heated (e.g., strips or billets) in the form of heat, electrical resistance heating elements are often used. This thesis will focus on heating elements that are exposed to a process gas and primarily transfer heat convectively to this gas, which then in turn transfers the heat to the material. Typically, heating elements are constructed with conductive wires spirally wound around a ceramic support rod. This design was patented over 100 years ago; your task will be to lay the groundwork for developing a new, optimized design.

A promising approach is the application of topology optimization. As in classical optimization, this method defines an objective function along with constraints. This is then combined with numerical simulations like CFD, where the simulation results satisfy the specified optimization conditions, enabling an optimal geometry or flow path to be identified. Topology optimization is typically used to design lightweight components that use material only where absolutely necessary (see Fig. 1). Here, the goal is to achieve a balance between mechanical strength and material use or weight.

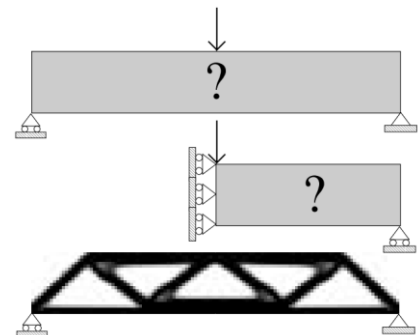


Figure 1: Sigmund 2001 [1]

In the field of resistance heating elements, the goal is to achieve an optimal balance between convective heat transfer, resistive heating, mechanical strength, and pressure loss. Your contribution would involve developing a minimal example with a 2D geometry using topology optimization to maximize convective heat transfer while minimizing pressure loss, ensuring a certain level of mechanical strength is maintained.

### Your Profile:

- Interest in optimization
- Interest in computer-aided research
- Experience with FEM, FVM, CFD, or similar
- Independent working style
- Creativity in overcoming challenges

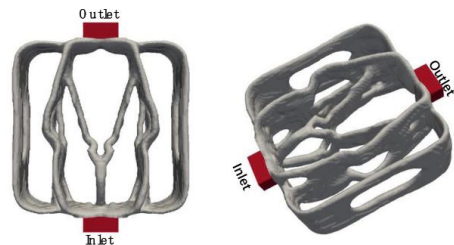


Figure 2: Yu et al. 2020 [2]

I look forward to your application, ideally with a CV and transcript. I would be happy to tell you more about this thesis.

[1]: Sigmund, O.: A 99 line topology optimization code written in Matlab. *Struct Multidisc Optim* **21**, 120–127 (2001). <https://doi.org/10.1007/s001580050176>

[2]: Yu, M., Ruan, S., Gu, J., Ren, M., Li, Z., Wang, X., Shen, C.: Three-dimensional topology optimization of thermal-fluid-structural problems for cooling system design. *Struct Multidisc Optim* **62**, 3347–3366 (2020). <https://doi.org/10.1007/s00158-020-02731-z>

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