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On the non-optimality of tree structures for heat conduction

Suna Yan[1*], Fengwen Wang[2] and Ole Sigmund[3]

[1] State Key Laboratory for Manufacturing Systems Engineering, Xi'an Jiaotong University, 710049 Xi'an, China, sunayan.me@gmail.com[1]

[2] Department of Mechanical Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark, fwan@mek.dtu.dk

[3] Department of Mechanical Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark, sigmund@mek.dtu.dk

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This work revisits topology optimization of heat conduction structures for minimum thermal compliance and minimum maximum temperature, respectively. For both optimization problems, volume-to-line and volume-to-point structures are optimized based on three material interpolation models describing different design spaces regarding the relation between material density and effective conductivity. Specifically, the material models are optimal rank-1 microstructures scheme, penalized density approach and variable thickness sheet model.

In contrast to common understanding, this work shows that lamellar needle structures, rather than commonly seen tree structures, provide the (near-)optimal topologies for heat conduction [1]. This conclusion still holds when a minimum length scale is imposed for both high and low conductive regions. The suboptimal designs obtained by penalized density approaches as well as the majority of the results from the literature, demonstrate how easy it is for standard optimization formulations to get stuck in local minima. Initial guesses projected from the designs of rank-1 laminates [2] help circumvent local minima. Alternatively, one must resort to very slow continuation approaches or an additional local volume constraint. For minimum thermal compliance and min-max temperature problems under single load conditions, optimal designs can be realized by rank-1 laminates. By contrast, the variable thickness sheet model is optimal only for the self-adjoint minimum thermal compliance problem.

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