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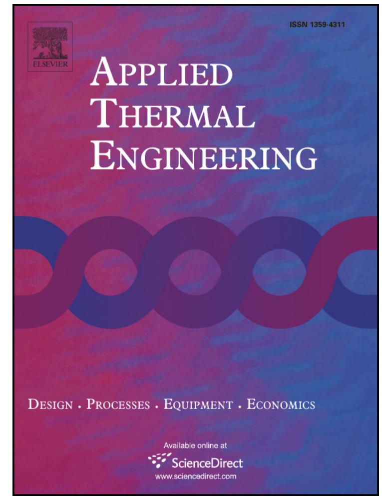

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Design of redundant microvascular cooling networks for blockage tolerance

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Abstract

Microvascular networks can provide host materials with many functions including self-healing and active cooling. However, vascular networks are susceptible to blockage which can dramatically reduce their functional performance. A novel optimization scheme is presented to design networks that provide sufficient cooling capacity even when partially blocked. Microvascular polydimethylsiloxane (PDMS) panels subject to a 2000 $\mathrm{W\,m^{-2}}$ applied heat flux and 28.2 mL $\mathrm{min^{-1}}$ coolant flow rate are simulated using dimensionally reduced thermal and hydraulic models and an interface-enriched generalized finite element method (IGFEM). Channel networks are optimized to minimize panel temperature while the channels are either clear (the O_0 scheme), subject to the single worst-case blockage (O_1), or subject to two worst-case blockages (O_2). Designs are optimized with nodal degree (a measure of redundancy) ranging from 2 – 6. The results show that blockage tolerance is greatly enhanced for panels optimized while considering blockages and for panels with higher nodal degree. For example, the 6-degree O_1 design only has a temperature rise of 7 °C when a single channel is blocked, compared to a 35 °C rise for the 2-degree O_0 design. Thermography experiments on PDMS panels validate the IGFEM solver and the blockage tolerance of optimized panels.

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