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## Shape optimization of microvascular composites used in active cooling applications

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### ABSTRACT

Inspired by microchannels networks in biological systems, microvascular composites are being used for various applications including active cooling, autonomic healing, and sensing. The recent development of a manufacturing technique for microvascular composites based on a sacrificial fiber approach has enabled the creation of complex networks of microchannels embedded in composite parts [1]. Motivated by these recent improvements in manufacturing of microvascular composites, we study design of an actively cooled composite plate. We examine the impact of microchannels configuration on the thermal response of the microvascular composite. Here, the composite plate is subjected to a heat flux that causes a high surface temperature in the absence of the active cooling by microchannels. The objective of this study is to determine the optimal configuration of the microchannels to maximize the thermal efficiency of microchannels to keep the domain temperature below a critical temperature value. We present a new gradient-based Isogeometric Interface-enriched Generalized Finite Element Method (IIGFEM) [2–4] optimization scheme that allows for the accurate and efficient extraction of the sensitivity of objective functions and constraints on the design parameters that define the geometry of the microchannels. At the heart of the modeling effort, the IIGFEM allows for the very accurate and efficient capture of the thermal impact of the embedded microchannel network on the thermal field in the composite part. Because the microchannels diameters are typically much smaller than other characteristic dimensions of the problem, we model microchannels as line (or curve) sinks. The IIGFEM solver allows for the capture of curved and branched microchannels over a mesh that does not conform to the geometry of the microchannels. One of the key challenges associated with the conventional finite element-based shape optimization of microvascular composites is the large mesh distortion that often takes place during the optimization process, as the finite element mesh must conform to the evolving microstructural elements. This mesh distortion may affect the accuracy of the optimum solution. Because of the stationary nature of the nonconforming mesh used by the IIGFEM, the issue of mesh distortion disappears. In this study, we adopt an isogeometric IGFEM-based adjoint shape sensitivity approach, which is simplified by the fact that only the enrichment (interface) nodes move, appear or disappear during the shape optimization process. To demonstrate the performance of the method, a set of microstructural shape optimization problems for the design of microvascular composites are presented.