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Flow and Heat Transfer Performance of Porous Heat Exchanger Based on Conformal Geometry Design

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ABSTRACT

As a type of porous material with high porosity and a large surface-area-to-volume ratio, triply periodic minimal surface (TPMS) structures divide space into two non-interconnected parts. This increases the contact area while maintaining full connectivity and smoothness, which helps reduce flow resistance, making it naturally suited for applications in heat exchange designs. The advancement of additive manufacturing (AM) technology has contributed to the development of TPMS-based heat exchangers. However, due to the complexity of fluid heat exchanger designs, developing effective representations, models, and optimization schemes for TPMS structures in multi-fluid heat exchange problems is very challenging. It is important to design heat exchangers with special-shapes that meet the limitations of AM processes to reduce support structures and prevent leaks. This paper proposed a novel conformal filling method to design special-shaped TPMS heat exchangers, which improved fragmentation and leakage by locally altering the cell shape. The study investigated ten different structures based on tubes, Gyroid, Schwarz-D, IWP, and Primitive and each filled in various orientations. The effects of design parameters of TPMS heat exchangers were investigated through numerical and experimental studies. By studying the field synergy angle, flow and heat transfer characteristics, the conformal filling heat exchanger enhanced the balance of the heat transfer area, improving overall heat transfer uniformity. Conformal IWP structure achieved a twice increase in heat transfer efficiency by increasing Nu. Conformal Primitive structure enhanced heat transfer efficiency by three times by reducing f. In experiments, it is verified that conformal structures had faster heat transfer.

KEYWORDS

Porous media; triply periodic minimal surface (TPMS); heat transfer performance; conformal filling method

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