IMPACT OF ADDITIVE MANUFACTURING ON PERFORMANCE ENHANCEMENT OF HEAT EXCHANGERS: A CASE STUDY ON AN AIR-TO-AIR HEAT EXCHANGER FOR HIGH TEMPERATURE APPLICATIONS

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Abstract

In this paper, we first review the fundamentals and latest progress in applications of additive manufacturing to development of next-generation, high-performance heat exchangers/thermal management systems for diverse applications. Next, we discuss a case study in which additive manufacturing was applied to enhance air-side heat transfer, including application to high temperature heat exchangers. We performed design optimization studies to analyze the impact of additive manufacturing in fabricating a compact, light weight, cross-flow, air-to-air advanced micro heat exchanger with a manifold-microchannel design that would significantly enhance the air-side heat transfer. We compare our results with state-of-the-art traditional manufacturing technologies. The advanced manifold-microchannel heat exchanger design considered in the case study consisted of a manifold that feeds the flow evenly on top of a microchannel surface, where the air flow is distributed into multiple segments within the microchannel surface and travels for a short length (keeping the flow regime in the hydro-dynamically developing stage) in the microchannels before it is guided out. The innovative design characteristics of this heat exchanger result in substantially higher heat transfer coefficients and lower pressure drops compared to state-of-the-art heat transfer augmentation technologies. A numerical optimization study was performed to calculate the maximum effectiveness of the manifold-microchannel heat exchanger manufactured as a single piece by direct metal laser sintering, an additive manufacturing technique, for a specified set of operating conditions. For comparison purposes, similar optimizations were conducted for heat exchangers with the manifold fabricated by 3-D metal printing and the microchannel surface fabricated by competitive manufacturing techniques such as photochemical etching and laser micro machining. As discussed in this paper, the heat exchanger with the additively manufactured manifold and microchannel surface showed improved effectiveness with a smaller volume, compared to heat exchangers fabricated using other advanced manufacturing techniques.