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Design and Development of a Low-Cost, High Temperature Silicon Carbide Micro-Channel Recuperator

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ABSTRACT

Typically, ceramic micro-channel devices are used for high temperature heat exchangers, catalytic reactors, electronics cooling, and processing of corrosive streams where the thermomechanical benefits of ceramic materials are desired. These benefits include: high temperature mechanical and corrosion properties and tailorable material properties such as thermal expansion, electrical conductivity and thermal conductivity. In addition, by utilizing Laminated Object Manufacturing (LOM) methods, inexpensive ceramic materials can be layered, featured and laminated in the green state and co-sintered to form monolithic structures amenable to mass production. In cooperation with the DOE and Pacific Northwest National Labs, silicon carbide (SiC) based micro-channel recuperator concepts are being developed and tested. The performance benefits of a high temperature, micro-channel heat exchanger are realized from the improved thermal efficiency of the high temperature cycles and the improved effectiveness of micro-channels for heat transfer. In designing these structures, the heat and mass transfer within the micro-channels are being analyzed with heat transfer models, computational fluid dynamics models and validated with experimental results. As an example, a typical micro-turbine cycle was modified and modeled to incorporate this ceramic recuperator and it was found

that the overall thermal efficiency of the micro-turbine could be improved from about 27% to over 40%. Process improvements require technical advantages and cost advantages. These LOM methodologies have been based on well-proven industry standard processes where labor, throughput and capital estimates have been tested. Following these cost models and validation at the prototype scale, cost estimates were obtained. For the micro-turbine example, cost estimates indicate that the high-temperature SiC recuperator would cost about \$200 per kWe. The development of these heat exchangers is multi-faceted and this paper focuses on the design optimization of a layered micro-channel heat exchanger, its performance testing, and fabrication development through LOM methodologies.

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