Development of a High-Temperature Silicon Carbide Microchannel Heat Exchanger

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Ceramic microchannel devices have applications that include high-temperature heat exchangers, catalytic reactors, electronics cooling, processing of corrosive streams, and pharmaceuticals, where the benefits of ceramic materials are desired. These benefits include high-temperature mechanical and corrosion properties and material properties that can be tailored, such as thermal expansion and electrical and thermal conductivity.

The efficiency and emissions of thermally activated processes can be improved by incorporating high-temperature ceramic heat exchangers. In cooperation with the Department of Energy and Pacific Northwest National Laboratory, SiC-based microchannel heat exchanger concepts are being developed and tested. The development of these heat exchangers is multifaceted. This paper focuses on the design optimization of a layered microchannel heat exchanger, its performance testing, numerical modeling, and fabrication development through rapid prototyping techniques.

The performance benefits of a high-temperature microchannel heat exchanger are realized from the improved thermal efficiency of the high-temperature cycles and the improved effectiveness of microchannel heat and mass transfer. In designing these structures, the heat and mass transfer within the microchannels are being analyzed with heat transfer models (TOPAZ3D) and computational fluid dynamics models (Star-CD) and validated with experimental results. These results provide the basis for heat exchanger scaling and process modeling. As an example, a typical microturbine cycle was modified and modeled to incorporate this ceramic heat exchanger. It was found that the overall thermal efficiency of the microturbine could be improved from about 27% to over 40%.