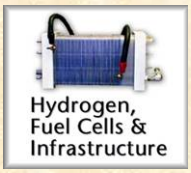


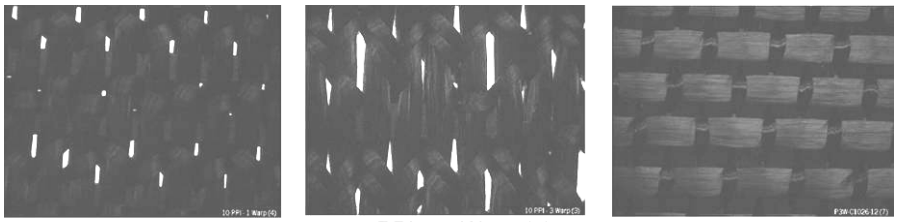
Graphite-based Thermal Management System Components for Fuel Cells

High Efficiency/Lightweight Graphite-woven Heat Exchanger Systems

Background

The efficient operation of vehicles powered by fuel cells requires systems capable of managing heat flow among components that require cooling (e.g., air compressor, water recovery condenser, fuel cell stack), and components that require heating for operation (e.g., water vaporizers). The thermal management systems of fuel cell powered vehicles must also incorporate a heating, ventilation and cooling (HVAC) system for passenger comfort.

The design of thermal management systems poses challenges because of complexity and restrictions imposed by weight, volume and cost. However, the low density and outstanding thermal properties of graphite have prompted efforts to investigate the feasibility of using this material for the fabrication of components, such as heat exchangers, condensers and vaporizers.

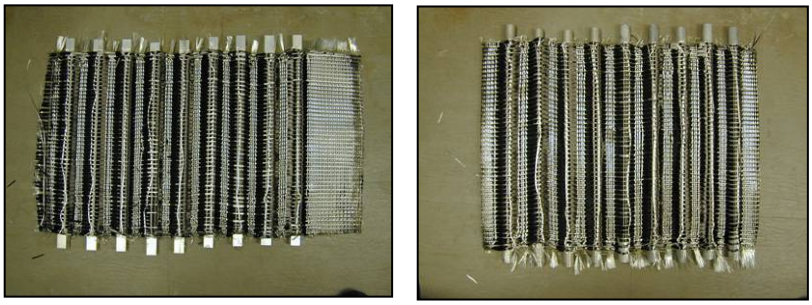


10 PPI – 1 Warp (4) 10 PPI – 3 Warp (3) P3W-C1026-12(7)

3-D graphite fiber weaves with different porosity

Technology

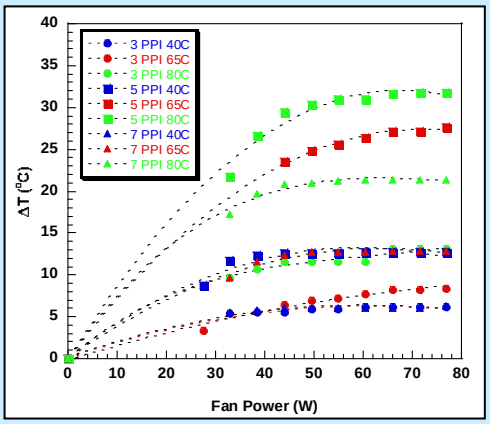
Graphite fibers are ideal candidates for the fabrication of thermal management components because of their low density, high thermal conductivity, outstanding mechanical properties and commercial availability. Furthermore, graphite fibers can be woven to produce lightweight 3-D structures using standard textile technologies. The architecture of woven fiber structures can be designed and optimized through experimental and modeling work. The type of fiber and fiber orientation in the woven structure are selected to maximize heat transfer while minimizing cost. The geometrical features of the woven structure (weaving pattern) and their scale (spacing between fill and warp bundles) can be determined in order to minimize pressure drop.



Woven carbon fabrics incorporating aluminum tubing and utilizing high conductivity graphite fibers in a single direction with glass fibers in the other two directions.

Accomplishments

Fabrics with different architectures were woven by 3-Tex, Inc. at their Rutherfordton, NC facility using their patented 3-Weave™ process. The permeability of 3-D graphite fiber weaves was determined as a function of fiber architecture and porosity.



Water temperature drop as a function of fan power. Results for three woven graphite fiber structures with single tube geometry and different fiber architectures at three different input water temperatures.

A new test rig was designed to measure permeability and pressure drop across woven structures, and to measure heat transfer across carbon fiber weaves containing metal tubing. These results were used to calibrate existing models, and then to design graphite woven structures that optimize heat transfer, cost and pressure drop. Modeling determined that only fibers oriented perpendicular to tubing carried heat, prompting the use of lower cost fibers elsewhere. Testing also has indicated the single metal tubes work as well as the triple tubes used initially, and that larger tubes were needed to increase water flow through the structures to increase heat transfer.

The successful manufacture of heat exchangers and evaporators using woven graphite fibers will lead to efficient, light weight and cost effective thermal management systems for fuel cell powered vehicles.

Test rig to evaluate the thermal and hydraulic performance of 3D woven fiber structures retrofitted with blower assembly.

Future Work

Further evaluation of 3-D graphite fiber weaves around arrays of metallic tubes, and the comparison of the thermal and hydraulic performance of these modified systems to commercial products is needed. The next step is the design and evaluation of prototype thermal management components for fuel cell powered vehicles, in collaboration with industrial partners.

Points of Contact

Edgar Lara-Curzio, 865-574-1749, laracurzioe@ornl.gov
James Hemrick, 865-574-7601, hemrickjg@ornl.gov