Materials

Improving Heat Flux Performance of Flat Surface in Spray-Cooling Systems

Goddard Space Flight Center, Greenbelt, Maryland

A method has been developed for improving heat flux performance relative to flat surfaces in spray-cooling systems. Similar enhancement techniques have been used for convective heat transfer, but, to the best knowledge at the time of this reporting, never spray cooling of foam. Previous studies have shown that spray-cooling heat flux enhancements may be attained using enhanced surfaces. However, most enhanced surface spray-cooling studies have been limited to extended and/or embedded surface structures. This study investigates the effect of foam on spraycooling heat flux.

The foam used was graphite Poco Foam. The foam piece was attached to a copper block with a cross-sectional area of 2 cm^2 using high-thermal-conductivity epoxy as the thermal interface material. Measurements were also obtained on a heater block with a flat surface for purposes of baseline comparison. A 2×2 nozzle array was used with PF-5060 as the working fluid. Thermal performance data was obtained under nominally degassed conditions, with a chamber pressure of 41.4 kPa.

Results show that the highest heat flux attained was 113 W/cm^2 using the graphite Poco Foam. The use of the foam does not require a significant amount of time dedicated to machining the heat exchange surface, and thus is a time-efficient enhancement technique. In addition, with foam, the thermally controlled surface does not experience abrupt catastrophic failure.

This work was done by Eric A. Silk of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15553-1

Treating Fibrous Insulation To Reduce Thermal Conductivity

Lyndon B. Johnson Space Center, Houston, Texas

A chemical treatment reduces the convective and radiative contributions to the effective thermal conductivity of porous fibrous thermal-insulation tile. The net effect of the treatment is to coat the surfaces of fibers with a mixture of transition-metal oxides (TMOs) without filling the pores. The TMO coats reduce the cross-sectional areas available for convection while absorbing and scattering thermal radiation in the pores, thereby rendering the tile largely opaque to thermal radiation.

The treatment involves a sol-gel process: A solution containing a mixture of transition-metal-oxide-precursor salts plus a gelling agent (e.g., tetraethylorthosilicate) is partially cured, then, before it visibly gels, is used to impregnate the tile. The solution in the tile is gelled, then dried, and then the tile is fired to convert the precursor salts to the desired mixed TMO phases. The amounts of the various TMOs ultimately incorporated into the tile can be tailored via the concentrations of salts in the solution, and the impregnation depth can be tailored via the viscosity of the solution and/or the volume of the solution relative to that of the tile. The amounts of the TMOs determine the absorption and scattering spectra.

This work was done by Alfred Zinn and Ryan Tarkanian of The Boeing Co. for Johnson Space Center. Further information is contained in a TSP (see page 1).

Title to this invention, covered by U.S. Patent No. 7,198,839 B2, has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457 (f)}. Inquiries concerning licenses for its commercial development should be addressed to:

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Refer to MSC-23394-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Silica-Aerogel Composites Opacified With $La_{0.7}Sr_{0.3}MnO_3$

Sizes of $La_{0.7}Sr_{0.3}MnO_3$ particles affect their effectiveness as opacifiers.

Marshall Space Flight Center, Alabama

As part of an effort to develop improved lightweight thermal-insulation tiles to withstand temperatures up to 1,000 °C, silica aerogel/fused-quartz-fiber composite materials containing $La_{0.7}Sr_{0.3}MnO_3$ particles as opacifiers have been investigated as potentially offering thermal conductivities lower than those of the otherwise equivalent silica-aerogel composite materials not containing $La_{0.7}Sr_{0.3}MnO_3$ particles. The basic idea of incorporating opacifying particles into silica-aerogels composite to reduce infrared radiative contributions to thermal conductivities at high temperatures is not new: it has been reported in a number of previous *NASA Tech Briefs* articles. What is new here is the selection of $La_{0.7}Sr_{0.3}MnO_3$ particles as candidate opacifiers that, in comparison with some prior opacifiers (carbon black and metal nanoparticles), are more thermally stable.

The preparation of a composite material of the present type includes synthesis of the silica-aerogel component in a sol-gel process. The $La_{0.7}Sr_{0.3}MnO_3$ particles, made previously in a separate process, are mixed into the sol, which is then cast onto fused-quartz-fiber batting. Then the aerogel-casting solution is poured into the mold, where it permeates the silica fiber felt. After the sol has gelled, the casting is aged and then subjected to supercritical drying to convert the gel to the final aerogel form.

The separate process for making the $La_{0.7}Sr_{0.3}MnO_3$ particles begins with the slow addition of corresponding proportions of $La(CH_3COOH)_3$, $Mn(CH_3COOH)_3$, and $Sr(NO_3)_2$ to a solution of H_2O_2 in H_2O. The solution is then peptized by drop-wise addition of NH_4OH to obtain a sol. Next, the sol is dried in an oven at a temperature of 120 °C to obtain a glassy solid. The solid is calcined at 700 °C to convert it to $La_{0.7}Sr_{0.3}MnO_3$. Then $La_{0.7}Sr_{0.3}MnO_3$ particles are made by ball-milling the calcined solid.

The effectiveness of $La_{0.7}Sr_{0.3}MnO_3$ particles as opacifiers and thermal-conductivity reducers depends on the statistical distribution of particle sizes as well as the relative proportions of $La_{0.7}Sr_{0.3}MnO_3$ and aerogel. For experiments performed thus far, samples of aerogel/fiber composites were formulated to have, variously, silica target density of 0.07 or 0.14 g/cm^3 and to contain 30 percent of $La_{0.7}Sr_{0.3}MnO_3$ in average particle size of 0.3 or 3 μm. The thermal conductivities of the samples containing the 3-μm $La_{0.7}Sr_{0.3}MnO_3$ particles were found to be lower than those of the samples containing the 0.3-μm $La_{0.7}Sr_{0.3}MnO_3$ particles. The optimum particle size is believed to be between 1 and 5 μm.

This work was done by Wendell Rhine, Andrew Polli, and Kiranmayi Deshpande of Aspen Aerogels, Inc. for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32587-1.

Cyclic Oxidation Behavior of CuCrAl Cold-Sprayed Coatings for Reusable Launch Vehicles

John H. Glenn Research Center, Cleveland, Ohio

The next generation of reusable launch vehicles is likely to use GRCop-84 [Cu-8(at.%)Cr-4%Nb] copper alloy combustion liners. The application of protective coatings on GRCop-84 liners can minimize or eliminate many of the environmental problems experienced by uncoated liners and significantly extend their operational lives and lower operational cost. A newly developed Cu-23 (wt.%) Cr-5% Al (CuCrAl) coating, shown to resist hydrogen attack and oxidation in an as-cast form, is currently being considered as a protective coating for GRCop-84. The coating was deposited on GRCop-84 substrates by the cold spray deposition technique, where the CuCrAl was procured as gas-atomized powders. Cyclic oxidation tests were conducted between 773 and 1,073 K to characterize the coated substrates.

The coating proved to be effective in preventing the cyclic oxidation of the substrate for up to 1,000 cycles. The coated substrates showed no significant weight loss in comparison to uncoated specimens, which lost between 60 to 80 percent of its original weight with much lower lives. The coating was adherent to the substrate at all temperatures, whereas the uncoated GRCop-84 showed excessive spallation of the oxide scale. It is anticipated that the use of this alloy can extend the operational life of the liner, which translates to increased component reliability, shorter depot maintenance turnaround time, and lower operational cost. Additionally, engines using CuCrAl-coated GRCop-84 combustion liners could operate at higher temperatures, thereby resulting in its increased thermal efficiency.

This work was done by Sai Raj of Glenn Research Center and J. Karthikeyan of ASB Industries. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18330-1.

Ceramic Fiber Structures for Cryogenic Load-Bearing Applications

Woven or braided fibers resist embrittlement under cryogenic conditions, enabling ultralow-temperature applications.

John H. Glenn Research Center, Cleveland, Ohio

This invention is intended for use as a load-bearing device under cryogenic temperatures and/or abrasive conditions (i.e., during missions to the Moon). The innovation consists of small-diameter, ceramic fibers that are woven or braided into devices like ropes, belts, tracks, or cables. The fibers can be formed from a variety of ceramic materials like silicon carbide, carbon, aluminosilicate, or aluminum oxide. The fiber architecture of the weave or braid is determined by both the fiber properties and the mechanical requirements of the application. A variety of weave or braid