

from x rays generated by impacts of energetic electrons. These shields must be thick [typically 2 to 3 ft (about 0.6 to 0.9 m) if made of concrete] and are therefore expensive. They also make it difficult to bring large structures into and out of the curing chambers.

Currently, all major companies that fabricate composite-material spacecraft and aircraft structures form their layups by use of automated tape placement (ATP) machines. In the present improved method, an electron-beam gun is attached to an ATP head and used to irradiate the tape as it is pressed onto the workpiece. The elec-

tron kinetic energy between 200 and 300 keV is sufficient for penetration of the ply being laid plus one or two of the plies underneath it. Provided that the electron-beam gun is properly positioned, it is possible to administer the required electron dose and, at the same time, to protect personnel with less shielding than is needed in the prior method. Adequate shielding can be provided by concrete walls 6 ft ( $\approx 1.8$  m) high and 16 in. ( $\approx 41$  cm) thick, without a ceiling.

The success of the present method depends on the use of a cationic epoxy as the matrix material in the prepreg tape,

heating the prepreg tape to a temperature of 50 °C immediately prior to layup, and exposing the workpiece to an electron-beam dose of  $\approx 2$  Mrad. Experiments have shown that structures fabricated by the present method have the same mechanical properties as those of nominally identical structures fabricated by the prior method with electron beams of 3 to 4 MeV.

*This work was done by Catherine A. Byrne and Alexander Bykanov of Science Research Laboratory, Inc. for Marshall Space Flight Center. Further information is contained in a TSP (see page 1).  
MFS-31837*

## Aluminum-Alloy-Matrix/Alumina-Reinforcement Composites

**Relatively inexpensive, lightweight composite parts could be substitutes for some superalloy parts.**

*Marshall Space Flight Center, Alabama*

Isotropic composites of aluminum-alloy matrices reinforced with particulate alumina have been developed as lightweight, high-specific-strength, less-expensive alternatives to nickel-base and ferrous superalloys. These composites feature a specific gravity of about 3.45 g/cm<sup>3</sup> and specific strengths of about 200 MPa/(g/cm<sup>3</sup>). The room-temperature tensile strength is 100 ksi (689 MPa) and stiffness is 30 Msi (206 GPa). At 500 °F (260 °C), these composites have shown 80 percent retention in strength and 95 percent retention in stiffness. These materials also have excellent fatigue tolerance and tribological properties. They can be fabricated in net (or nearly net) sizes and shapes to make housings, pistons, valves, and ducts in turbomachinery, and to make structural

components of such diverse systems as diesel engines, automotive brake systems, and power-generation, mining, and oil-drilling equipment. Separately, incorporation of these metal matrix composites within aluminum gravity castings for localized reinforcement has been demonstrated.

A composite part of this type can be fabricated in a pressure infiltration casting process. The process begins with the placement of a mold with alumina particulate preform of net or nearly net size and shape in a crucible in a vacuum furnace. A charge of the alloy is placed in the crucible with the preform. The interior of the furnace is evacuated, then the furnace heaters are turned on to heat the alloy above its liquidus temperature. Next, the interior of the furnace is filled

with argon gas at a pressure about 900 psi ( $\approx 6.2$  MPa) to force the molten alloy to infiltrate the preform. Once infiltrated, the entire contents of the crucible can be allowed to cool in place, and the composite part recovered from the mold.

*This work was done by Uday Kashalikar and Boris Rozenoyer of Foster-Miller, Inc., for Marshall Space Flight Center.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Foster-Miller, Inc.*

*350 Second Avenue*

*Waltham, MA 02451*

*Telephone No.: (781) 684-4000*

*Refer to MFS-31784, volume and number of this NASA Tech Briefs issue, and the page number.*

## Fibrous-Ceramic/Aerogel Composite Insulating Tiles

**The best features of aerogels and fibrous ceramics are exploited.**

*Ames Research Center, Moffett Field, California*

Fibrous-ceramic/aerogel composite tiles have been invented to afford combinations of thermal-insulation and mechanical properties superior to those attainable by making tiles of fibrous ceramics alone or aerogels alone. These lightweight tiles can be tailored to a variety of applications that range from insulating cryogenic tanks to protecting spacecraft against re-entry heating.

The advantages and disadvantages of fibrous ceramics and aerogels can be summarized as follows:

- Tiles made of ceramic fibers are known for mechanical strength, toughness, and machinability. Fibrous ceramic tiles are highly effective as thermal insulators in a vacuum. However, undesirably, the porosity of these materials makes them permeable by

gases, so that in the presence of air or other gases, convection and gas-phase conduction contribute to the effective thermal conductivity of the tiles.

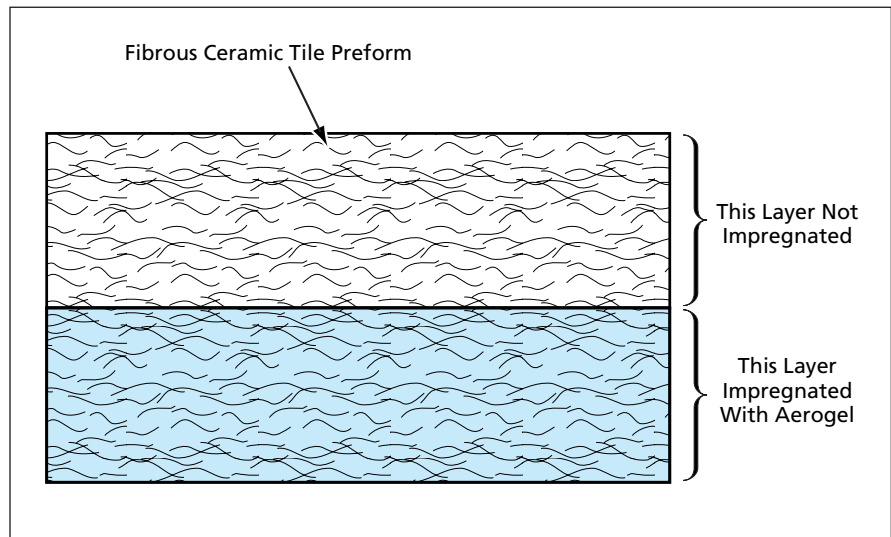
- Other disadvantages of the porosity and permeability of fibrous ceramic tiles arise because gases (e.g., water vapor or cryogenic gases) can condense in pores. This condensation contributes to weight, and in the case

of cryogenic systems, the heat of condensation undesirably adds to the heat flowing to the objects that one seeks to keep cold. Moreover, there is a risk of explosion associated with vaporization of previously condensed gas upon reheating.

- Aerogels offer low permeability, low density, and low thermal conductivity, but are mechanically fragile.

The basic idea of the present invention is to exploit the best features of fibrous ceramic tiles and aerogels. In a composite tile according to the invention, the fibrous ceramic serves as a matrix that mechanically supports the aerogel, while the aerogel serves as a low-conductivity, low-permeability filling that closes what would otherwise be the open pores of the fibrous ceramic. Because the aerogel eliminates or at least suppresses permeation by gas, gas-phase conduction, and convection, the thermal conductivity of such a composite — even at normal atmospheric pressure — is not much greater than that of the fibrous ceramic alone in a vacuum.

In a typical application, a composite tile according to the invention is made from an open-pore rigid ceramic-fiber tile preform by impregnating the preform with an aerogel part way through its thickness (see figure). The details of the impregnation process depend on the specific ceramic and aerogel materi-



A Fibrous Ceramic Tile Preform Is Impregnated with an aerogel part way through its thickness. The invention is not restricted to a single aerogel-impregnated layer as shown here: alternatively, there can be multiple layers impregnated by the same aerogel and/or different aerogels.

als, the desired thickness of the aerogel-impregnated layer, and the desired density of the aerogel. In general, one prepares an aerogel-precursor solution by mixing two component solutions. The preform is partially infiltrated with the precursor solution. The gelation reaction occurs spontaneously between the components of the solution at room temperature. To complete the process, the aerogel is dried in one or more subprocesses that can include fluid extraction at supercritical temperature and

pressure, heating to a temperature above ambient but below the sintering temperature of the aerogel, venting, and/or purging with dry air.

*This work was done by Susan M. White and Daniel J. Rasky of Ames Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-12070.*

## Urethane/Silicone Adhesives for Bonding Flexing Metal Parts

**These adhesives make strong, flexible bonds.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Adhesives that are blends of commercially available urethane and silicone adhesives have been found to be useful for bonding metal parts that flex somewhat during use. These urethane/silicone adhesives are formulated for the specific metal parts to be bonded. The bonds formed by these adhesives have peel and shear strengths greater than those of bonds formed by double-sided tapes and by other adhesives, including epoxies and neat silicones. In addition, unlike the bonds formed by epoxies, the bonds formed by these adhesives retain flexibility.

In the initial application for which the urethane/silicone adhesives were de-

vised, there was a need to bond spring rings, which provide longitudinal rigidity for inflatable satellite booms, with the blades that provide the booms' axial strength. The problem was to make the bonds withstand the stresses, associated with differences in curvature between the bonded parts, that arose when the booms were deflated and the springs were compressed. In experiments using single adhesives (that is, not the urethane/silicone blends), the bonds were broken and, in each experiment, it was found that the adhesive bonded well with either the ring or with the blade, but not both. After numerous experiments, the adhesive that bonded best

with the rings and the adhesive that bonded best with the blades were identified. These adhesives were then blended and, as expected, the blend bonded well with both the rings and the blades.

The two adhesives are Kalex (or equivalent) high-shear-strength urethane and Dow Corning 732 (or equivalent) silicone. The nominal mixture ratio is 5 volume parts of the urethane per 1 volume part of the silicone. Increasing the proportion of silicone makes the bond weaker but more flexible, and decreasing the proportion of silicone makes the bond stronger but more brittle.

The urethane/silicone blend must be prepared and used quickly because