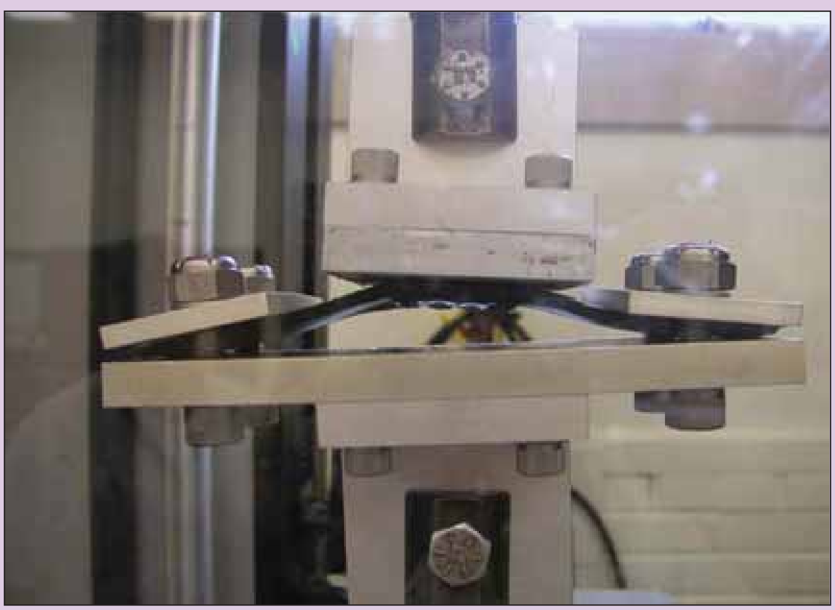
Improved Joining of Metal Components to Composite Structures

Uncured composite material is intertwined with metal studs, then cured.

Marshall Space Flight Center, Alabama

Systems requirements for complex spacecraft drive design requirements that lead to structures, components, and/or enclosures of a multi-material and multifunctional design. The varying physical properties of aluminum, tungsten, Invar, or other high-grade aerospace metals when utilized in conjunction with lightweight composites multiply system level solutions. These multi-material designs are largely dependent upon effective joining techniques, which create a "monolithic," well-integrated and seamlessly functional structure.

UNCURED COMPOSITE PLATE JOINED TO ALUMINUM PLATE WITH SCREWS



CURED COMPOSITE/ALUMINUM STRUCTURE IN TENSILE TESTING MACHINE AT END OF TEST

A **Composite/Metal Joint** of the type described in the text was fabricated, then subjected to a tensile/bending test.

An improved method of joining metal components to matrix/fiber composite-material structures has been invented. The method is particularly applicable to equipping such thin-wall polymer-matrix composite (PMC) structures as tanks with flanges, ceramic matrix composite (CMC) liners for high heat engine nozzles, and other metallic-to-composite attachments. The method is oriented toward new architectures and distributing mechanical loads as widely as possible in the vicinities of attachment locations to prevent excessive concentrations of stresses that could give rise to delaminations, debonds, leaks, and other failures.

The method in its most basic form can be summarized as follows: A metal component is to be joined to a designated attachment area on a composite-material structure. In preparation for joining, the metal component is fabricated to include multiple "studs" projecting from the aforementioned face. Also in preparation for joining, holes just wide enough to accept the studs are molded into, drilled, or otherwise formed in the corresponding locations in the designated attachment area of the uncured ("wet") composite structure. The metal component is brought together with the uncured composite structure so that the studs become firmly seated in the holes, thereby causing the composite material to become intertwined with the metal component in the joining area. Alternately, it is proposed to utilize other mechanical attachment schemes whereby the uncured composite and metallic parts are joined with "z-direction" fasteners. The resulting "wet" assembly is then subjected to the composite-curing heat treatment, becoming a unitary structure. It should be noted that this new art will require different techniques for CMC's versus PMC's, but the final architecture and companion curing philosophy is the same. For instance, a chemical vapor infiltration (CVI) fabrication technique may require special integration of the pre-form and metallic part, as well as, high-temperature metals or transitional molten metals to achieve the desired architecture.

The method accommodates numerous variations. For example, in a demonstration of the method, an aluminum plate having dimensions of 4 by 3 by 0.50 in. (about 10.2 by 7.6 by 1.3 cm) was joined with a 2-by-8-by-0.25-in. (about 5.1-by-20.3-by-0.6-cm) plate made of composite of carbon fibers in an epoxy (thermoset) matrix toughened with a thermoplastic material. The composite plate was prepared in uncured form, and 16 holes were predrilled in the aluminum plate to accept thread-tapping screws intended to serve as substitutes for studs. The array of these holes was used as a template to drill 16 corresponding holes in the uncured composite plate. The screws were inserted through the holes in the uncured composite plate and tightened into the holes in the aluminum plate (see upper part of figure). The resulting assembly was placed in an autoclave, where it was heated to a temperature of 350 °F (≈177 °C) to cure the epoxy. Then the assembly was cooled very slowly [between 10 and 15 °F (between about 5.6 and 8.3 °C) per hour] so that the difference between the coefficients of thermal expansion of the aluminum and the composite would not induce excessive stress.

The resulting unitary structure was subjected to a tensile/bending test as shown in the lower part of the figure. When the test was terminated at a load of 4,683 lb (≈20.8 kN), the composite panel was bent significantly, but no sign of failure of the joint was visible. [The screws were rated to withstand a load of 10,240 lb (≈45.5 kN).]

This work was done by Edmund Semmes of Marshall Space Flight Center.

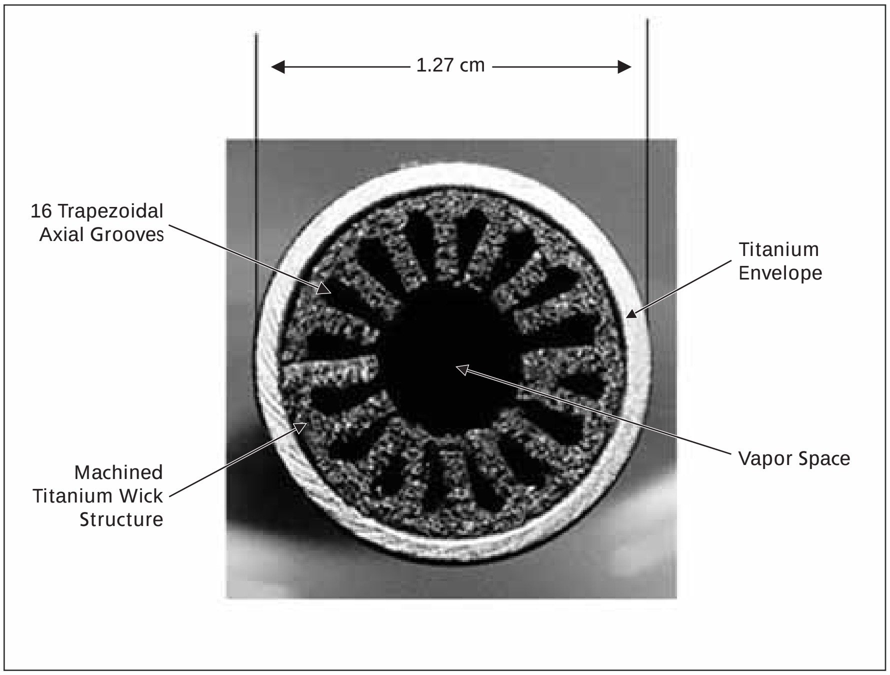
This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31813-1.

Machined Titanium Heat-Pipe Wick Structure

Wicks are fabricated separately, then inserted in tubes.

John H. Glenn Research Center, Cleveland, Ohio

Wick structures fabricated by machining of titanium porous material are essential components of lightweight titanium/water heat pipes of a type now being developed for operation at temperatures up to 530 K in high-radiation environments. In the fabrication of some prior heat pipes, wicks have been made by extruding axial grooves into aluminum — unfortunately, titanium cannot be extruded. In the fabrication of some other prior heat pipes, wicks have been made by *in-situ* sintering of metal powders shaped by the use of forming mandrels that are subsequently removed, but in the specific application that gave rise to the present fabrication method, the required dimensions and shapes of the heat-pipe structures would make it very difficult if not impossible to remove the mandrels due to the length and the small diameter.



Machined Titanium Heat Pipe Wick Structure is shown in cross section.

In the present method, a wick is made from one or more sections that are fabricated separately and assembled outside the tube that constitutes the outer heat-pipe wall. The starting wick material is a slab of porous titanium material. This material is machined in its original flat configuration to form axial grooves. In addition, interlocking features are machined at the mating ends of short wick sections that are to be assembled to make a full-length continuous wick structure. Once the sections have been thus assembled, the resulting full-length flat wick structure is rolled into a cylindrical shape and inserted in the heat-pipe tube (see figure).

This wick-structure fabrication method is not limited to titanium/water heat pipes: It could be extended to other heat pipe materials and working fluids in which the wicks could be made from materials that could be pre-formed into porous slabs.

This work was done by John H. Rosenfeld, Kenneth G. Minnerly, and Nelson J. Gernert of Thermacore Inc. for Glenn Research Center.

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-18206-1.