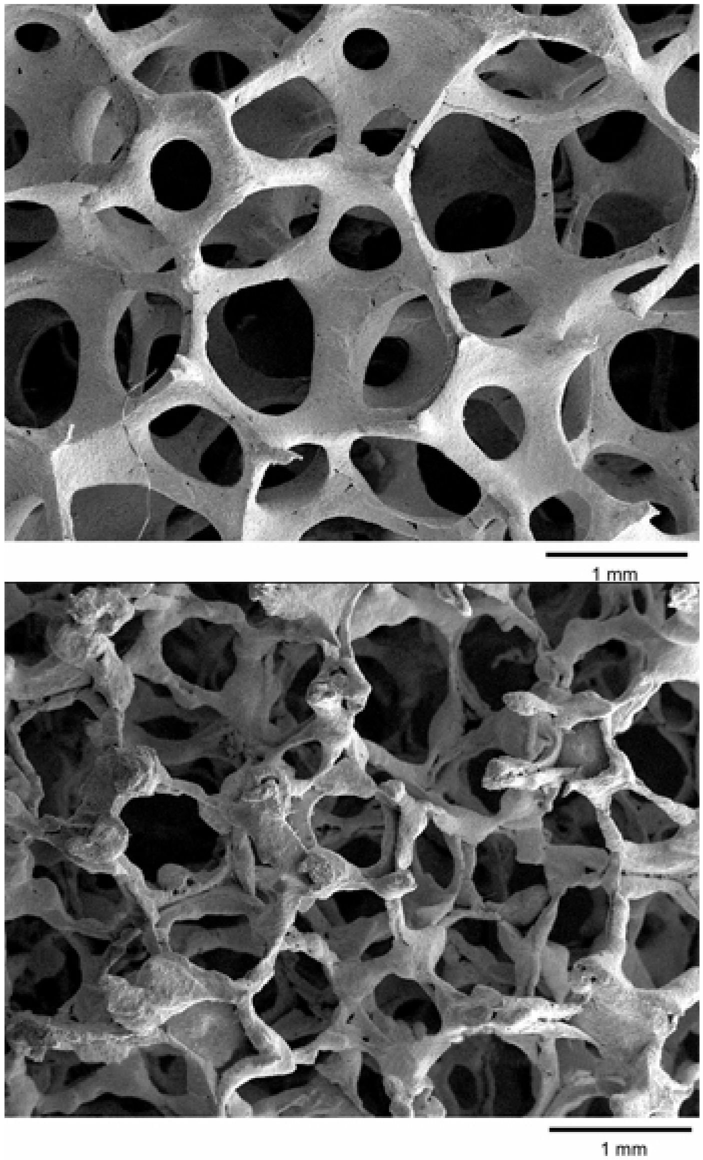
Stainless-Steel-Foam Structures Evaluated for Fan and Rotor Blades

The goal of this project is to use a sandwich structure design, consisting of two stainless-steel face sheets and a stainless-steel-foam core, to fabricate engine fan and propeller blades. Current fan blades are constructed either of polymer matrix composites (PMCs) or hollow titanium alloys. The PMC blades are expensive and have poor impact resistance on their leading edges, thereby requiring a metallic leading edge to satisfy the Federal Aviation Administration's impact requirements relating to bird strikes. Hollow titanium blades cost more to fabricate because of the intrinsically difficult fabrication issues associated with titanium alloys. However, both these current concepts produce acceptable lightweight fan blades.

The NASA Glenn Research Center is studying a possible low-cost alternative to the current technologies: a stainless-steel sandwich structure encasing a stainless-steel-foam core. The face sheets provide structural strength and resistance for the blade, whereas the foam core decreases the overall density, increases vibrational and acoustic damping, maintains face sheet separation, and enhances stiffness (ref. 1). The use of a commercially available aerospace stainless steel and commercial manufacturing methods is expected to produce fan, propeller, and rotor blades that can be manufactured at low cost yet have mechanical properties and densities equivalent to those of currently used designs. Thus, the new design approach could yield a new generation of low-cost, low-density fan blades with performance equal to or better than that of blades produced by conventional manufacturing processes.

Recent work at Glenn has focused on aerospace grade 17-4 PH stainless-steel sandwich panels for these applications. This material is corrosion resistant; possesses excellent impact, high strength, and fatigue properties; and is commercially available, inexpensive, and easy to fabricate. Sandwich foam panels were produced by a commercial vendor using a proprietary powder-metallurgy process. The panels were evaluated nondestructively, then shear and bend tests were conducted. The foam cores were tested in compression. It was observed that the mechanical properties of the foam core were not as good as the predicted values. This was attributed to shrinkage porosity in the ligaments of the foam core formed during the manufacturing process. Foam cores with better integrity were fabricated with further optimization of the manufacturing process. These improvements are depicted in the scanning electron microscope (SEM) photographs, showing a superior quality foam core (left photograph) and a poor-quality foam core (right photograph). The compressive strength of the good-quality foam core was observed to be nearly 3 times that of the poor-quality foam core. Another critical issue for these structures is the quality of the brazed joint between the face sheets and the foam. The brazed joint was studied in detail using destructive and nondestructive methods (ref. 2). Improvement of the brazed joint greatly increased the shear strength of the sandwiched panel.



Structures of 17–4 PH foams. Left: Good structure with clean, smooth ligaments. Right: Poor structure with broken, knobby ligaments.

With the recently improved properties, a series of experimental and theoretical optimization studies can be performed to investigate foam characteristics, such as the number of cells per unit length, the density (i.e., the thickness of the ligaments on the cell edges), and the face-sheet thickness. A range of material requirements will ultimately be defined that will allow the sandwich structure to be utilized in a fan-blade application. Finally, a contoured fan blade will be manufactured to demonstrate the viability of the manufacturing process.

References

1. Min, James B., et al.: Analysis of Stainless Steel Sandwich Panels With a Metal Foam Core for Lightweight Fan Blade Design, AIAA-2004-1836, 2004.

2. Cosgriff, Laura M., et al.: Ultrasonic Spectroscopy of Stainless Steel Sandwich Panels. Presented at the 35th International SAMPE Conference, Dayton, OH, Dec. 2003.

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Glenn contacts: Dr. Bradley A. Lerch, 216-433-5522, Bradley.A.Lerch@nasa.gov; and Dr. Sai V. Raj, 216-433-8195, Sai.V.Raj@nasa.gov
Authors: Dr. Bradley A. Lerch, Dr. Sai V. Raj, Dr. Louis J. Ghosn, Dr. Mohan G. Hebsur, Laura M. Cosgriff, Dr. James B. Min, and Frederic A. Holland, Jr.
Headquarters program office: OAT
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