Manufacturing & Prototyping

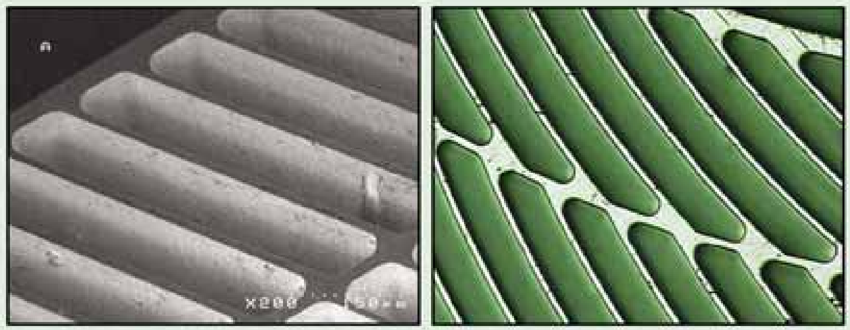
Microfabricated Segmented-Involute-Foil Regenerator for Stirling Engines

Tests show significantly improved performance.

John H. Glenn Research Center, Cleveland, Ohio

An involute-foil regenerator was designed, microfabricated, and tested in an oscillating-flow test rig. The concept consists of stacked involute-foil nickel disks (see figure) microfabricated via a lithographic process. Test results yielded a performance of about twice that of the 90-percent random-fiber currently used in small Stirling converters.

The segmented nature of the involute-foil in both the axial and radial directions increases the strength of the structure relative to wrapped foils. In addition, relative to random-fiber regenerators, the involute-foil has a reduced pressure drop, and is expected to be less susceptible to the release of metal fragments into the working space, thus increasing reliability. The prototype nickel involute-foil regenerator was adequate for testing in an engine with a 650 ºC hot-end temperature. This is lower than that required by larger engines, and high-temperature alloys are not suited for the lithographic microfabrication approach.



Micrographs of Regenerator Disks are shown during the final steps of fabrication: (a) micrograph of features with remaining PMMA removed and (b) picture of nickel ribs after removal from substrate.

This work was done by Mounir Ibrahim and Daniel Danila of Cleveland State University; Terrence Simon, Susan Mantell, and Liyong Sun of the University of Minnesota; David Gedeon of Gedeon Associates; Song-gang Qiu of Infinia Corp.; Gary Wood of Sunpower Inc.; and Kevin Kelly and Jeffrey McLean of International Mezzo Technologies for Glenn 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 NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18431-1.

Reducing Seal Adhesion in Low Impact Docking Systems

Atomic oxygen is used to treat mating silica surfaces to reduce unwanted adhesion during docking/undocking operations.

John H. Glenn Research Center, Cleveland, Ohio

Silicone elastomers, used in seals for airlocks or other sealing surfaces in space, are sticky in their as-received condition. Because of the sticking, a greater force may be needed to separate the mating surfaces. If the adhesion is sufficiently high, a sudden unpredicted movement of the spacecraft during undocking, vibration, or uneven release could pull off the seal, resulting in a damage that would have to be repaired before another docking. The damaged seal can result in significant gas leakage and possibly in a catastrophic mishap impacting the safety of the crew. It is also possible that a compromised seal could result in a delayed but sudden gas leak that could put the crew at unexpected risk. This is especially of concern for androgynous seals, which have identical mating surfaces on both sides for interchangeability and redundancy. Such seals typically have elastomer-on-elastomer sealing surfaces. To reduce sticking, one could use release agents such as powders and lubricants, but these can be easily removed and transferred to other surfaces, causing uneven sealing and contamination. Modification of the elastomer surface to make a more slippery and less sticky surface that is integral with the bulk elastomer would be more desirable.

The analysis of materials retrieved from early space shuttle missions such as the Long Duration Exposure Facility indicated that silicone surfaces were converted to SiO_2 silica glass as a result of the low Earth orbital atomic oxygen exposure. With a controlled atomic oxygen exposure, the converted silica surface is integral with the underlying silicone and is sufficiently thin enough that the elastomers retain their flexibility and sealing properties, yet the silicone does not stick to surfaces because the surface is essentially a thin film of SiO_2 glass.

Silicone seals are mounted on the surface of electrically grounded aluminum exposure plates or suspended such that the interfacing silicone seal surfaces are exposed to a low-pressure atmospheric plasma. The seal surfaces are then exposed to atomic oxygen, until the desired reduction in seal adhesion is achieved. Polyimide Kapton H atomic oxygen fluence witness samples are also placed into the vacuum chamber during air plasma exposure to measure the Kapton effective fluence by weight loss of vacuum dehydrated Kapton H samples.

Functional operation of the seals is such that the atomic oxygen treated surface will then interface during docking with another atomic oxygen treated surface or a metal surface. Thus, the mating is between two opposing silica surfaces on silicone or silica surfaces on smooth metal surfaces.

The atomic oxygen treated silicone seal geometry can be varied as well as the composition of the silicone. Parts of the seal can be treated rather than all of the seal if it is desirable to have adhesion in a specific direction or at a specific interface.

This work was done by Bruce A. Banks and Sharon K. Miller of Glenn 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 NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18572-1.

Optimal Flow Control Design

This design results in a quieter and more environmentally friendly transport aircraft.

Langley Research Center, Hampton, Virginia

In support of the Blended-Wing-Body aircraft concept, a new flow control hybrid vane/jet design has been developed for use in a boundary-layer-ingesting (BLI) offset inlet in transonic flows. This inlet flow control is designed to minimize the engine fan-face distortion levels and the first five Fourier harmonic half amplitudes while maximizing the inlet pressure recovery. This concept represents a potentially enabling technology for quieter and more environmentally friendly transport aircraft.

An optimum vane design was found by minimizing the engine fan-face distortion, DC60, and the first five Fourier harmonic half amplitudes, while maximizing the total pressure recovery. The optimal vane design was then used in a BLI inlet wind tunnel experiment at NASA Langley's 0.3-meter transonic cryogenic tunnel. The experimental results demonstrated an 80-percent decrease in DPCPavg, the reduction in the circumferential distortion levels, at an inlet mass flow rate corresponding to the middle of the operational range at the cruise condition.

Even though the vanes were designed at a single inlet mass flow rate, they performed very well over the entire inlet mass flow range tested in the wind tunnel experiment with the addition of a small amount of jet flow control. While the circumferential distortion was decreased, the radial distortion on the outer rings at the aerodynamic interface plane (AIP) increased. This was a result of the large boundary layer being distributed from the bottom of the AIP in the baseline case to the outer edges of the AIP when using the vortex generator (VG) vane flow control.

Experimental results, as already mentioned, showed an 80-percent reduction of DPCPavg, the circumferential distortion level at the engine fan-face. The hybrid approach leverages strengths of vane and jet flow control devices, increasing inlet performance over a broader operational range with significant reduction in mass flow requirements. Minimal distortion level requirements are met using vanes alone, avoiding engine stall and increasing robustness of this hybrid inlet flow control approach. This design applies to aerospace applications needing flush-mounted boundary-layer-ingesting inlets.

This work was done by Brian Allan and Lewis Owens of Langley Research Center. For further information, contact the Langley Innovative Partnerships Office at (757) 864-8881. LAR-17365-1

Corrosion-Resistant Container for Molten-Material Processing

A combination of materials functions and survives in hot, corrosive environments.

John H. Glenn Research Center, Cleveland, Ohio

In a carbothermal process, gaseous methane is passed over molten regolith, which is heated past its melting point to a temperature in excess of 1,625 °C. At this temperature, materials in contact with the molten regolith (or regolith simulant) corrode and lose their structural properties. As a result, fabricating a crucible to hold the molten material and providing a method of contact heating have been problematic.

Alternative containment approaches use a large crucible and limit the heat zone of the material being processed, which is inefficient because of volume and mass constraints. Alternative heating approaches use non-contact heating, such as by laser or concentrated solar energy, which can be inefficient in transferring heat and thus require higher power heat sources to accomplish processing.

The innovation is a combination of materials, with a substrate material having high structural strength and stiffness and high-temperature capability, and a coating material with a high corrosion resistance and high-temperature capa-