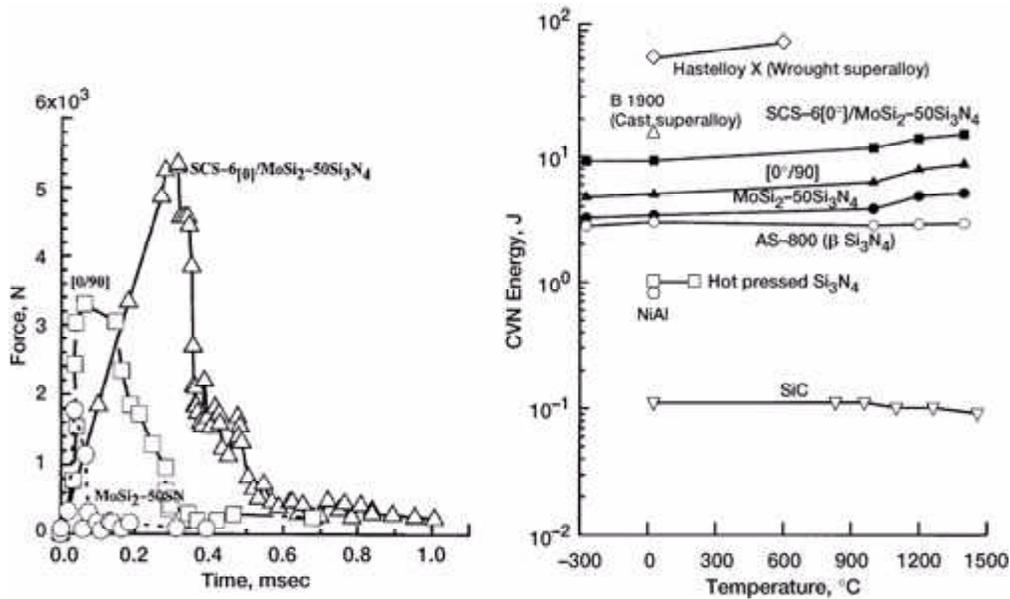


# MoSi<sub>2</sub>-Base Structural Composite Passed Engine Test

The intermetallic compound molybdenum disilicide (MoSi<sub>2</sub>) is an attractive high-temperature structural material for advanced engine applications. It has excellent oxidation resistance, a high melting point, relatively low density, and high thermal conductivity; and it is easily machined. Past research at the NASA Lewis Research Center has resulted in the development of a hybrid composite consisting of a MoSi<sub>2</sub> matrix reinforced with silicon nitride (Si<sub>3</sub>N<sub>4</sub>) particulate and silicon carbide (SiC) fibers. This composite has demonstrated attractive strength, toughness, thermal fatigue, and oxidation resistance, including resistance to "pest" oxidation. These properties attracted the interest of the Office of Naval Research and Pratt & Whitney, and a joint NASA/Navy/Pratt & Whitney effort was developed to continue to mature the MoSi<sub>2</sub> composite technology. A turbine blade outer air seal, which was part of the Integrated High Performance Turbine Engine Technology (IHPTET) program, was chosen as a first component on which to focus.

The first tasks of the materials development effort were to develop improved processing methods to reduce costs and to use fine-diameter fibers that enable the manufacturing of complex shapes. Tape-casting methods were developed to fully infiltrate the fine SiC fibers with matrix powders. The resulting composites were hot pressed to 100-percent density. Composites with cross-ply fiber architectures with 30 vol % Hi-Nicalon SiC fibers (Nippon Carbon Company, Japan) and 30 vol % nitride particles are now made routinely and demonstrate a good balance of properties.

The next task entailed the measurement of a wide variety of mechanical properties to confirm the suitability of this composite in engines. In particular, participants in this effort demonstrated that composites made with Hi-Nicalon fibers had strength and toughness properties equal to or better than those of the composites made with the large-diameter fibers that had been used previously. Another critically important property measured was impact resistance. Aircraft engine components require sufficient toughness to resist manufacturing defects, assembly damage, stress concentrations at notches, and foreign object damage. Engine company designers indicated that impact resistance would have to be measured before they would seriously consider these types of composites. The Charpy V-Notch test was chosen to assess impact resistance, and both monolithic and composite versions of MoSi<sub>2</sub> were tested from 300 to 1400 °C. The results (see the following graphs) show that nitride-particulate-reinforced MoSi<sub>2</sub> exhibited impact resistance higher than that of many monolithic ceramics and intermetallics, and that the fiber-reinforced composites had even higher values, approaching that of cast superalloys.



*Charpy impact properties of MoSi<sub>2</sub> base composites compared with several competitive materials. Left: Force-time curves. Right: Charpy-V-Notch (CVN) energy plot.*

These and other results led to the decision to test the hybrid composite in the aggressive environment of a gas turbine engine. Test coupons were fabricated and tested in Pratt & Whitney's IHPTET XTC/66 demonstrator engine to simulate the thermal cycling conditions of a blade outer air seal. The composite was exposed to thermal cycles to 1200 °C, with a 600 °C gradient through the thickness of the coupon. It survived all 15 engine cycles without any appearance of distress (see the photomicrograph).



*Hybrid composite coupon of MoSi<sub>2</sub>/Si<sub>3</sub>N<sub>4</sub> particulate/Hi-Nicalon SiC fiber after engine testing at Pratt & Whitney.*

These results indicate that MoSi<sub>2</sub>-base composites are still competitive with state-of-the-art ceramic composites as replacements for superalloys in jet engines. Further work on processing, fiber coatings, and mechanical and environmental durability is in progress.

## **Bibliography**

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