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NASA TECH BRIEF

Lewis Research Center

Advanced Tungsten Fiber-Reinforced Nickel Superalloy

Fiber-reinforced metals have been investigated extensively in recent years. One of the promising composite types being studied is refractory metal fiber-reinforced superalloys. NASA is interested in developing these particular composites for use in gas turbines where turbine blade temperatures may exceed 1366 K (2000°F). A tungsten-hafnium-carbon (W-Hf-C) fiber-reinforced nickel-base superalloy has now been developed which has a 1000-hour rupture strength of 372 MN/m^2 (54,000 psi) at 1366 K (2000°F). This is equivalent to the 100-hour rupture strength of the strongest previously developed composite, and is nine times as strong as commercially available nickel superalloys. The strength-to-density ratio of this composite is also greater than for previous alloys, and therefore this composite can be considered for applications where reduced weight as well as greater strength is desired.

Previous work has shown that the properties of fiber-reinforced materials are greatly affected by the fiber-matrix reaction. The strength of the composite is determined by the retained strength of the fiber; adverse fiber-matrix reaction can substantially reduce fiber strength. Accordingly, one of the efforts being made to improve the strength of composites is to develop stronger fibers. The stronger the fiber, the stronger the composite for a given degree of fiber-matrix reaction. The tungsten alloy fiber, developed for use with the composite described above, contained 0.37 weight percent hafnium and 0.03 weight percent carbon. The fibers are 0.38 mm (0.015 in) in diameter and specially drawn for high strength. Production of these tungsten alloy fibers was previously announced in NASA Tech Brief 73-10003 (see Notes 4 and 5).

Matrix composition, fabrication technique, and fiber diameter were selected to minimize fiber-matrix reaction and preserve composite strength. The matrix composition in weight percent is: nickel 56, tungsten 25, chromium 15, titanium 2, and aluminum 2. The composite is prepared by slipcasting a powdered superalloy-water slurry into an array of fibers. The dried slipcasting is consolidated by pressing and heating. Fiber content can be varied from zero to 80 volume percent to achieve the desired reinforcement. The 70 volume percent unidirectional-oriented fiber composite has a 100-hour rupture strength of 565 MN/m^2 (82,000 psi) at 1366 K (2000°F), and a 1000-hour rupture strength of 372 MN/m^2 (54,000 psi) at 1366 K (2000°F).

Notes:

1. The strongest refractory-alloy-fiber reinforced superalloy developed in the past (announced in NASA Tech Brief 70-10183) used tungsten fibers containing 2 weight percent thorium oxide. This composite has a 100-hour rupture strength of 338 MN/m^2 (49,000 psi) at 1366 K (2000°F) and a 1000-hour rupture strength of 255 MN/m^2 (37,000 psi) at 1366 K (2000°F).
2. These fiber-reinforced composites may be used in place of superalloys where higher strength or greater strength-to-density ratios are advantageous, and will permit higher operating temperatures in particular applications.
3. Further information is available in the following report:

   NASA TN-D-7773 (N74-34939), Stress-Rupture Strength and Microstructural Stability of W-Hf-C Wire Reinforced Superalloy Composites

   Copies may be obtained at cost from:

   Aerospace Research Applications Center
   Indiana University
   400 East Seventh Street
   Bloomington, Indiana 47401
   Telephone: 812-337-7833
   Reference: B74-10248
4. Production of the tungsten alloy fibers was previously announced in NASA Tech Brief 73-10003, "Production of Small Diameter, High-Temperature-Strength Refractory Metal Wires." Further information is available in the following reports:

   NASA TN-D-6881(N72-29561), High-Temperature Strength of Refractory-Metal Wires and Consideration for Composite Application

(continued overleaf)

NASA CR-120925 (N72-26399), Development of Wire Drawing Processes for Refractory Metal Fibers

Copies may be obtained at cost from the Aerospace Research Applications Center (address above).

5. The alloy from which the tungsten fiber was produced was also developed by NASA and is described in NASA Tech Brief 66-10551, " New Tungsten Alloy Has High Strength at Elevated Temperatures."
6. Specific technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B74-10248

Patent Status:

Inquiries concerning rights for the commercial use of this invention should be addressed to:

NASA Patent Counsel
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