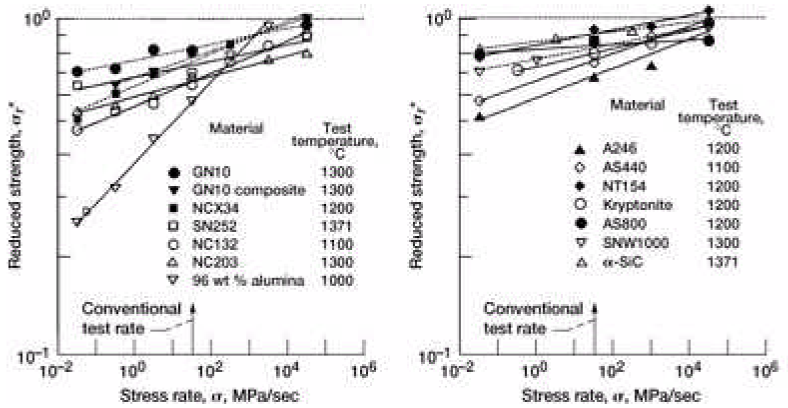
"Ultra"-Fast Fracture Strength of Advanced Structural Ceramic Materials Studied at Elevated Temperatures

The accurate determination of inert strength is important in reliable life prediction of structural ceramic components. At ambient temperature, the inert strength of a brittle material is typically regarded as free of the effects of slow crack growth due to stress corrosion. Therefore, the inert strength can be determined either by eliminating active species, especially moisture, with an appropriate inert medium, or by using a very high test rate.

However, at elevated temperatures, the concept or definition of the inert strength of brittle ceramic materials is not clear, since temperature itself is a degrading environment, resulting in strength degradation through slow crack growth and/or creep. Since the mechanism to control strength is rate-dependent viscous flow, the only conceivable way to determine the inert strength at elevated temperatures is to utilize a very fast test rate that either minimizes the time for or eliminates slow crack growth. Few experimental studies have measured the elevated-temperature, inert (or "ultra"-fast fracture) strength of advanced ceramics. This is, in part, because conventional test frames are incapable of very high rate testing. In addition, data acquisition systems are inadequate, and there are safety concerns. Commonly, a maximum test rate of about 30 MPa/sec has been used to determine the elevated-temperature strength of ceramic materials. The strength that is determined at this test rate has been called the fast-fracture strength, implying that it is the maximum attainable, or ultimate, strength of the material at the temperature.

At the NASA Lewis Research Center, an experimental study was initiated to better understand the "ultra"-fast fracture strength behavior of advanced ceramics at elevated temperatures. Fourteen advanced ceramics--one alumina, eleven silicon nitrides, and two silicon carbides--have been tested to date using constant stress-rate (dynamic fatigue) testing in flexure with a series of stress rates including the "ultra"-fast stress rate of 33 000 MPa/sec with digitally controlled test frames. The experimental results for these 14 advanced ceramics indicate that, notwithstanding possible changes in flaw populations as well as in flaw configurations because of elevated temperatures, the strength at 33 000 MPa/sec approached the room-temperature strength or reached a higher value than that determined at the conventional test rate of 30 MPa/sec. The graphs summarize the test results for the 14 ceramics, where the reduced strength is an elevated-temperature strength normalized with respect to the corresponding room-temperature strength. On the basis of the experimental data, it can be stated that the elevated-temperature, inert strength of an advanced ceramic material can be defined as the strength where no slow crack growth takes place at the temperature. Specifically, the elevated-temperature inert strength is close to its room-temperature counterpart and can be obtained via a series of "ultra"-fast stress rates, including 33 000 MPa/sec in many cases. The strength determined at 33 000 MPa/sec must be used as an inert strength to determine the required life prediction parameters of the material.



Summary of reduced strength as a function of stress rate for 14 advanced ceramics. Left: GN10, GN10 composite, NCX34, SN252 and NC132 silicon nitrides, NC203 silicon carbide, and 96 wt % alumina; Right: A2Y6, AS440, NT154, "Kryptonite" composite, AS800 and SNW1000 silicon nitrides, and a*-silicon carbide.*

Bibliography

Choi, S.R.; and Gyekenyesi, J.P.: Elevated-Temperature, ‘Ultra’-Fast Fracture Strength of Advanced Ceramics: An Approach to Elevated-Temperature Inert Strength. ASME Paper 98-GT-479, 1998.

Choi, S.R.; and Gyekenyesi, J.P.: Elevated Temperature ‘Ultra’-fast Fracture Strength Behavior of Advanced Structural Ceramics. Ceramic Materials and Components for Engines, K. Niihara, et al., eds., Technoplaza Co., Japan, 1998, pp. 689-694.

Choi, S.R.; and Salem, J.A.: ‘Ultra’-Fast Fracture Strength of Advanced Ceramics at Elevated Temperature. Mater. Sci. Eng., A242, 1998, pp. 129-136.

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