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FRACTURE TECHNOLOGY FOR BRITTLE MATERIALS

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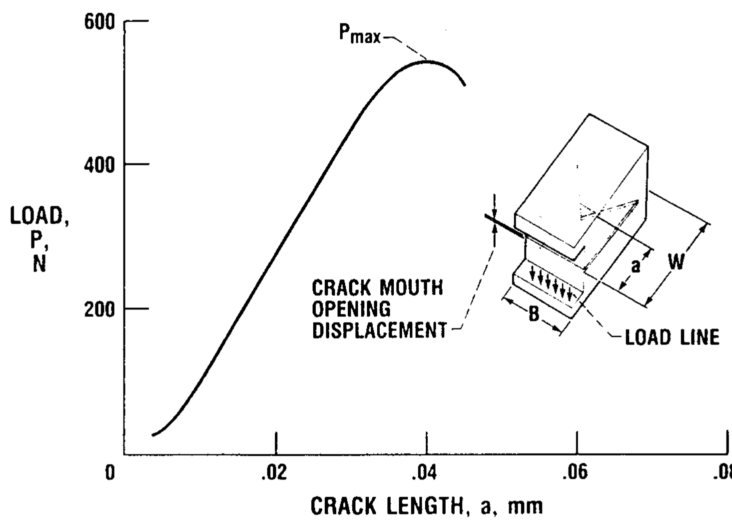
ABSTRACT

Ceramics materials have the potential for use in high-temperature, fuel-efficient engines. However, because these materials are brittle, their fracture characteristics must be well documented prior to their application. Thus Lewis is working to understand the fracture and strength properties of brittle ceramic and ceramic matrix materials. An understanding of fracture properties aids both designers who are attempting to design high-temperature structures and materials scientists who seek to design more temperature-resistant materials. Both analytical and experimental approaches to fracture analysis are being taken (Bubsey et al., 1983). Methods for testing fracture toughness, crack growth resistance, and strength are being developed (Salem and Shannon, 1987; Salem et al., 1988). The failure mechanisms at both room and elevated temperatures are also being investigated (Jenkins et al., 1988). Such investigations aid materials scientists in developing better high-temperature materials. Of concern is the anisotropy of ceramic materials and the experimental verification of ceramic design codes that will allow brittle material behavior to be accurately predicted at high temperature.

OVERVIEW

FRACTURE TOUGHNESS TEST METHOD FOR CERAMICS

Ceramic materials have potential applications in high-temperature, fuel-efficient engines, but these materials are brittle. Thus Lewis has developed a fracture testing methodology for brittle materials (Bubsey et al., 1983). The procedure accurately measures the fracture toughness of brittle, flat, crack-growth-resistant materials (Salem and Shannon, 1987).



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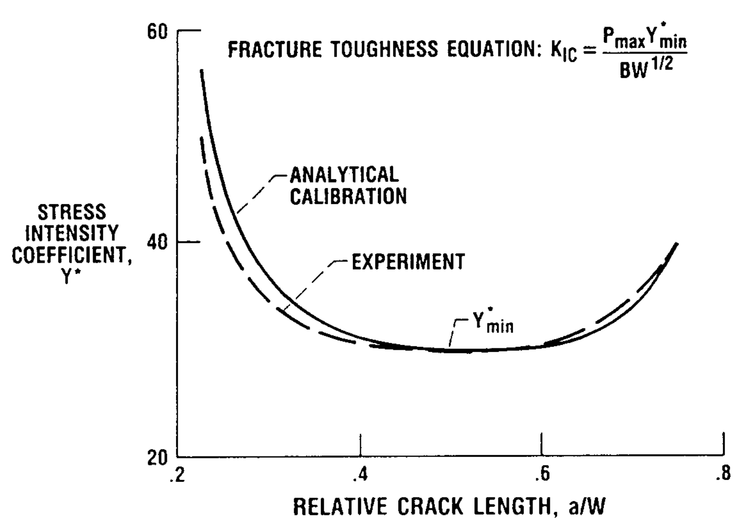

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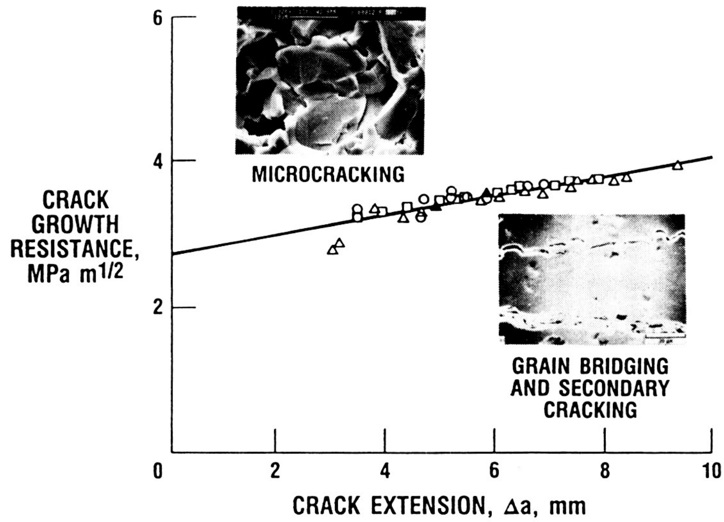
TOUGHENING MECHANISMS IN CERAMICS

The development of more crack-growth-resistant ceramic materials for use in high-temperature structures requires an understanding of energy-dissipative failure mechanisms. If these mechanisms are understood and related to the material's properties, better materials can be manufactured. In contrast to metals, where the energy-dissipative process that produces toughness is deformation accompanied by cracking, ceramics adsorb energy by plastic microcracking, crack surface friction, or both (Jenkins et al., 1988; Salem et al., 1988).



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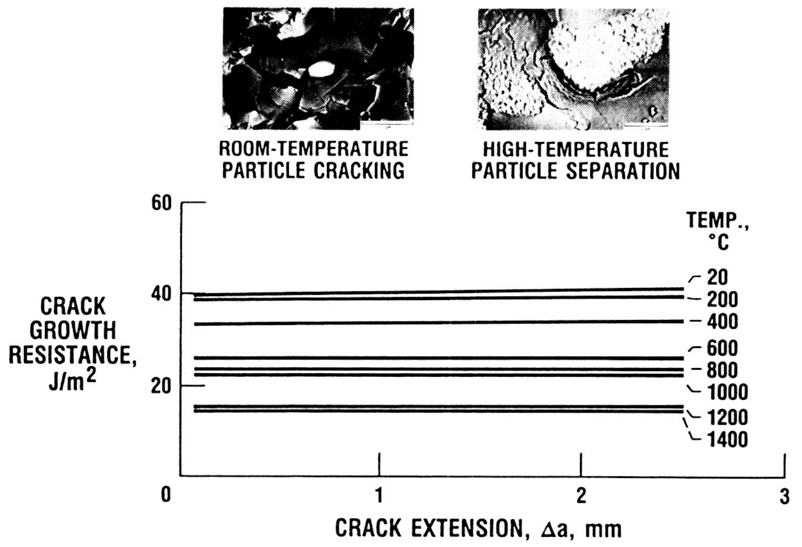

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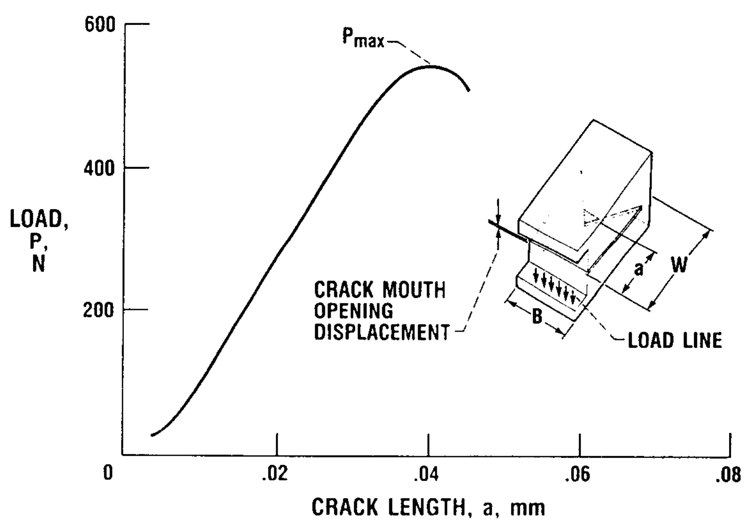
POSTER PRESENTATION

FRACTURE TOUGHNESS TEST METHOD FOR CERAMICS

Ceramic materials have potential applications in high-temperature, fuel-efficient engines, but these materials are brittle. Thus Lewis has developed a fracture testing methodology for such brittle materials (Bubsey et al., 1983; Salem and Shannon, 1987). The test specimen and the experimental load displacement record used to calculate the material's fracture toughness K_{IC} are shown below. The calculation defined in the lower graph involves the use of an experimental or analytical calibration known as a stress intensity coefficient Y* (Munz et al., 1980). The coefficients are dependent on the specimen geometry and the loading configuration. The unique aspect of this method is that it does not require measurement of the crack length, as most test methods do.



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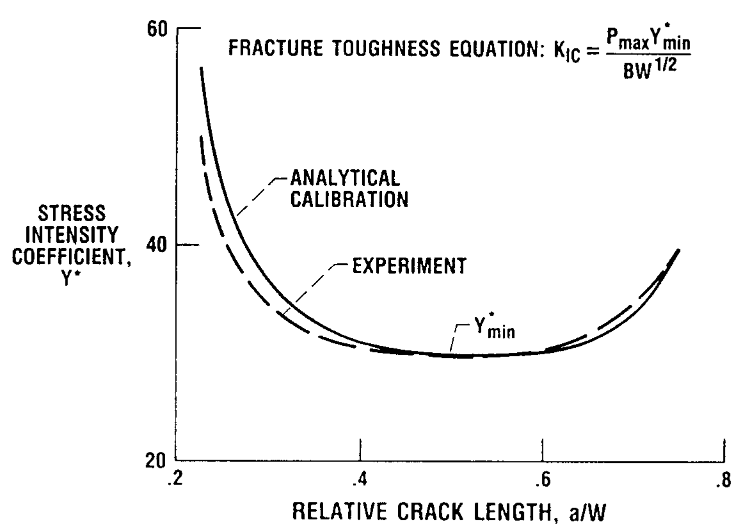

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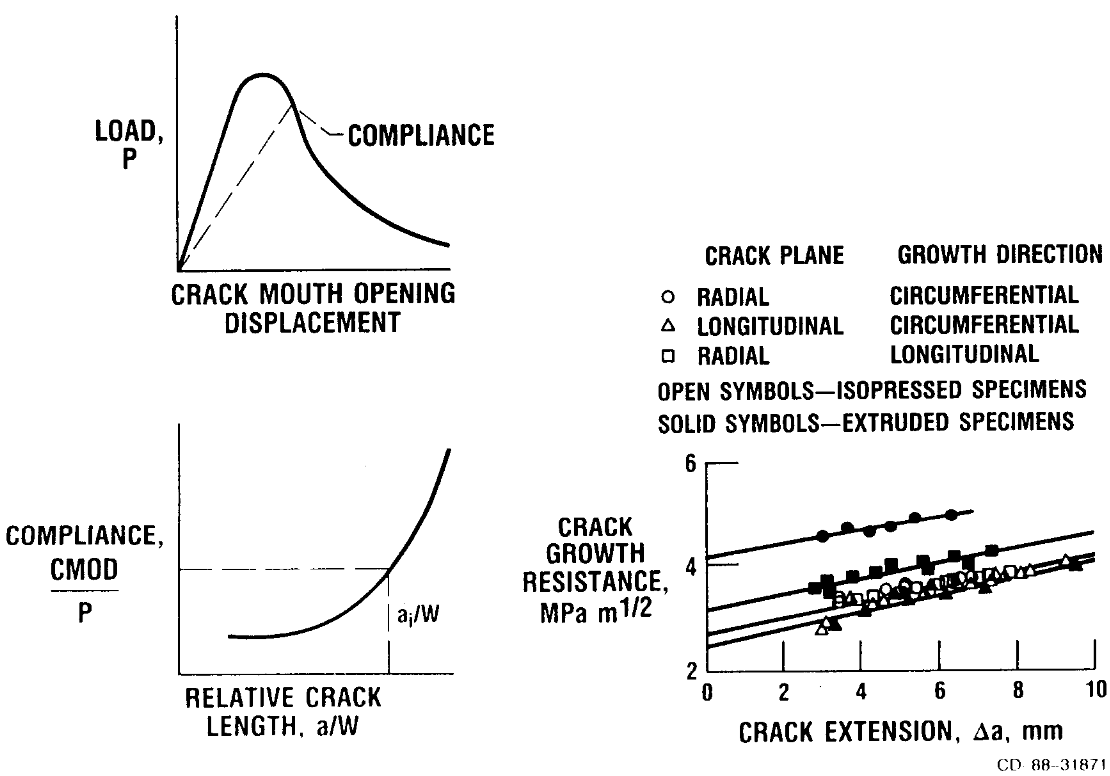
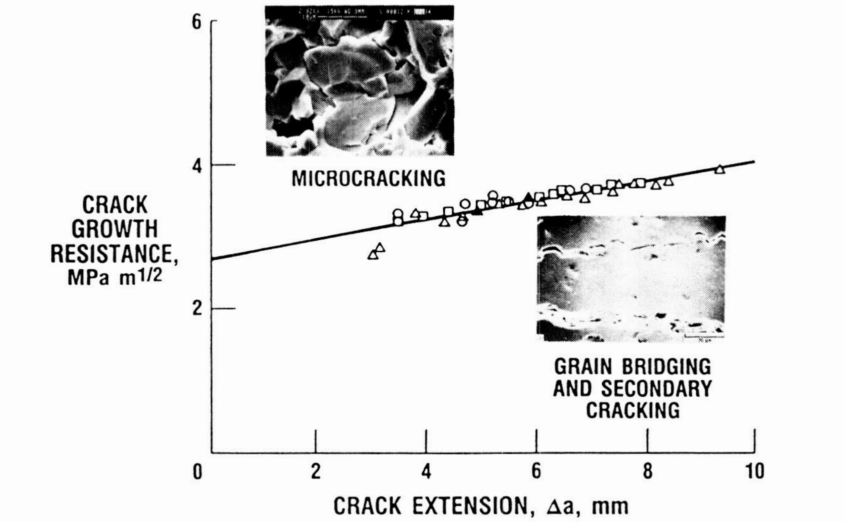
CRACK GROWTH RESISTANCE OF CERAMICS

Brittle ceramic materials must be able to withstand crack-like damage. This ability is often referred to as "crack growth resistance." To determine the level of crack growth resistance in ceramics, Lewis has applied fracture mechanics measurement techniques to ceramics (Salem et al., 1988). The crack mouth opening displacement behavior of a specimen under load, or its compliance, is measured as shown below. The compliance is used with compliance - crack length relations to determine the crack length as shown in the lower left-hand graph. The crack growth resistance of the material can be calculated from the crack length and stress intensity coefficients (previous page). Results for various orientations of an extruded Al_2O_3 ceramic are also illustrated here.



CRACK-GROWTH-RESISTANCE MECHANISMS IN CERAMICS

The development of more crack-growth-resistant ceramic materials for use in high-temperature structures requires an understanding of energy-dissipative failure mechanisms. If these mechanisms are understood and related to the material's properties, better materials can be manufactured. In contrast to metals, where the energy-dissipative process that produces toughness is plastic deformation accompanied by cracking, ceramics adsorb energy by micro-cracking, crack surface friction, or both. The upper graph shows micro-cracking, bridging, and secondary cracking in an alumina ceramic that exhibits rising crack growth resistance (Salem et al., 1988). Although cracking often imparts improved properties, in some cases it does not, as for the SiC/TiB_2 composite shown in the lower graph (Jenkins et al., 1988).



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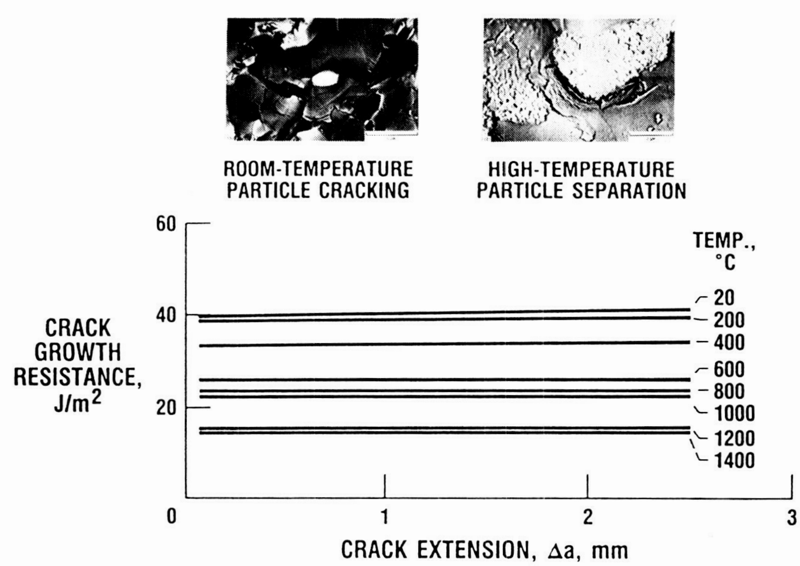

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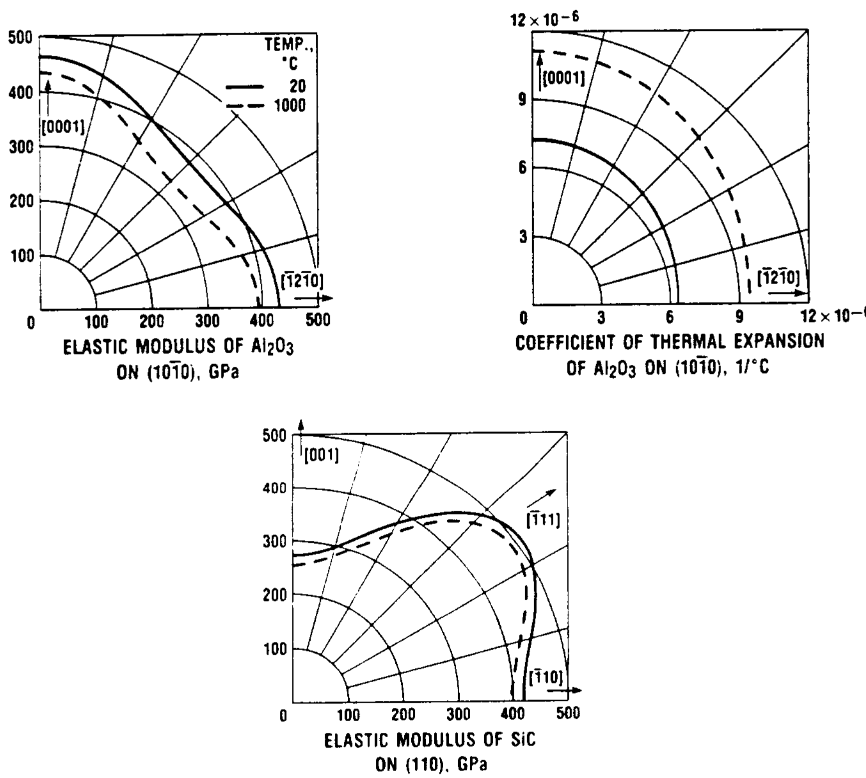
ANISOTROPY OF Al_2O_3 AND SiC WHISKERS FOR COMPOSITES

The introduction of ceramic whiskers into ceramic and metallic materials results in composite materials with unique properties. Single-crystal whiskers exhibit thermal and elastic anisotropy that can be used to tailor composite properties to the needs of designers. Thus an understanding of thermal and elastic properties of whiskers as a function of orientation is necessary in the design of ceramic- and metal-matrix composites. The property variations depend on the crystallographic structure of the material. Whiskers of Al_2O_3 have a hexagonal crystal structure, and both the elastic modulus and the coefficient of thermal expansion vary with crystal orientation, as shown in the upper two plots. SiC is a cubic crystal structure and therefore does not exhibit variation in the coefficient of thermal expansion but does exhibit a large variation in elastic modulus, as shown in the bottom figure (Salem et al., 1986).



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