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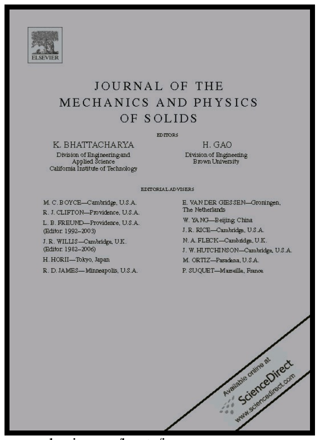

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Engineering the crack path by controlling the microstructure

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Abstract

We explore the possibility of engineering the crack path by controlling a material's microstructure in order to increase its crack growth resistance. Attention is confined to a specific type of microstructure that is encountered in a variety of structural metals and alloys - second phase particles distributed in a ductile matrix. The type of controlled microstructure modeled is characterized by various sinusoidal distributions of particles with fixed mean particle spacing. Three dimensional, finite deformation small scale yielding calculations of mode I crack growth are carried out for such controlled microstructures using an elastic-viscoplastic constitutive relation for a progressively cavitating solid. The results show that appropriately engineered sinusoidal distributions of particles can give fracture toughness values 2 to 3 times greater than a random distribution of particles with the same mean particle spacing. Tearing modulus values can be increased by a factor of 1.5 to 2. The greatest crack growth resistance generally occurs when the amplitude and the wavelength of the sinusoidal distribution are increased together. When the amplitude and the wavelength of the sinusoidal distribution do not increase together the crack can jump from one crest (or trough) to the next crest (or trough) which tends to reduce the crack growth resistance. Fracture surface roughness statistics are also calculated. In contrast to the essentially universal value for random distributions of particles, the value of the computed Hurst exponent is found to depend on the amplitude and the wavelength of the sinusoidal profile. A correlation is found between the computed fracture toughness values and values of characteristic length scales of the fracture surface roughness.

Keywords: Ductile fracture, Fracture surface roughness, Micromechanical modeling, Finite elements, Crack path engineering

1. Introduction

Ductile fracture limits the performance, safety, reliability and manufacturability of a variety of engineering components and structures; for example, the crash worthiness of automobiles, the integrity of pipelines, the blast resistance of ships and airplane cargo holds,

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