BIAXIAL TENSILE STRENGTH OF BRITTLE SOLIDS

Fenghua Zhou and **Jean-Francois Molinari**

Department of Mechanical Engineering
Johns Hopkins University
Latrobe Hall, 3400 N. Charles Street
Baltimore, Maryland, 21218
fzhou@jhu.edu; molinari@jhu.edu

Brittle solids such as rocks and ceramics contain intrinsic defects. Under tensile loading, these defects may develop into a single or multiple cracks. These materials being brittle, the initiated crack may grow rapidly to cause the catastrophic failure of the structure. There are many cases in which brittle solids, from continental plates to silicon IC chip, fail under multiaxial tension. Nevertheless, due to experimental difficulties, little test data, which compares directly the biaxial strength to the uniaxial strength of brittle materials, is available.

We have developed an explicit dynamic 3D FEM model, which simulates the failure behavior of brittle structures. In the simulations, the structure is considered as a body containing initial defects. These defects are modeled as facets shared by two neighboring ordinary elements. Each facet has a specified strength and fracture energy. When the loading stress on the facet exceeds its strength, the facet is activated as a microcrack that is treated as a cohesive element. The strengths of the facets are scattered following a Weibull distribution. The modeling technique has been successfully applied to analyze the failure of silicon carbide (SiC) under impact compressive loading [1] and impact tensile loading [2].

In this paper, the developed numerical stochastic fracture model is applied to simulate the failure process of SiC under biaxial loading. We found that the tensile strength of a specimen tends to be lower under biaxial loading state than that under uniaxial state (“*biaxiality effect”*). The physical mechanisms explaining this phenomenon are: (a) more microcracks can be initiated under biaxial loading than under uniaxial loading; and (b) the initiated microcracks are easier to grow and coalesce under biaxial loading than under uniaxial loading.

Finally, inspired by the numerical results, a failure theory is proposed based on the “the weakest link” hypothesis. The failure theory includes a biaxial parameter $m_{biaxial}$. This parameter, which differs from the Weibull modulus of the uniaxial strength, determines how significant the biaxiality effect is. We will show, by conducting parametric studies, that the biaxiality effect grows with increasing brittleness of the material. Additionally, we will demonstrate that a more heterogeneous material exhibits a stronger biaxiality effect. The proposed failure theory, fitted with appropriate $m_{biaxial}$ values, reproduces the numerical strength distributions of the specimen (Fig. 1).

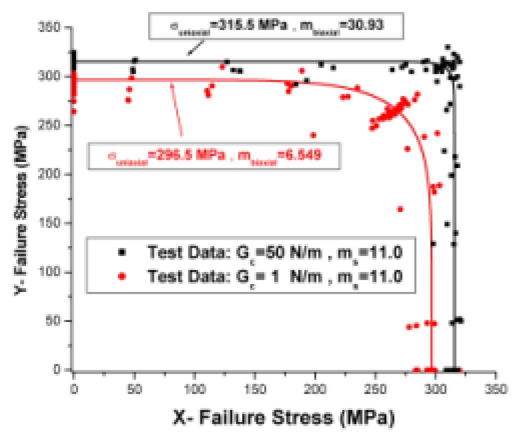

Fig.1 Biaxial failure strength of SiC

References

[1] F. Zhou, and J-F. Molinari, “Numerical Investigation of Dynamic Compressive Loading”, presented on the *27th Annual Cocoa Beach Conference and Exposition* (Jan 26-31, Cocoa Beach, Florida, U.S.A., 2003)
[2] F. Zhou, and J-F. Molinari, “Stochastic Fracture of Ceramics under Dynamic Tensile Loading”, submitted to *Journal of Multiscale Computational Engineering*