INTERFACE CRACK GROWTH CONTROL BY MEANS OF A NEW FIBER DESIGN

J. Heitzer*, C. Mattheck**

A new fiber design (Figure 1) characterized by periodically arranged regions of locally increased fiber diameter is presented which is able to stop or deflect interface cracks. Finite-element calculations show the new fiber to exhibit no notch stress concentration if it is subjected to uniaxial stress. The effectiveness of the new fiber design is demonstrated in a comparison of the calculated stress intensity factors for a typical crack configuration with those of a conventional cylindrical fiber.

INTRODUCTION

Uncontrollable growth of interface cracks in laminates and long fiber reinforced materials is one of the major difficulties in using those materials as engineering materials in highly stressed components. The decreased shear strength of the interface, although necessary to intercept dangerous through-crack formation, leads to delamination failure of the material far below the theoretical tensile strength. The authors have shown that it is possible to stop interface cracks at defined locations by appropriately shaping the interface (Heitzer and Mattheck (1)). On the basis of this new crack stop effect a new fiber design was developed and optimized by means of the finite-element method. The new fiber design had to guarantee interface crack stop with the fiber embedded in a piece of matrix, with the additional requirement of constant tangential stress.

* Universität Karlsruhe, Institut für Zuverlässigkeit und Schadenskunde im Maschinenbau, West Germany

** Kernforschungszentrum Karlsruhe, Institut für Material- und Festkörperforschung IV, West Germany

RESULTS

Figures 1 and 2 show the finite-element mesh of the new fiber and the tangential stress distribution on the fiber surface as a function of the angle θ normalized by the maximum tensile stress. The tangential stress on the surface can be kept constant by using the so called "Baud curve" to join the narrow and the wide fiber cross sections.

To obtain an idea about the quantitative effectiveness of the new design, stress intensity factors of a typical crack configuration were calculated by the filter technique separating the stress intensity factors related to mode I and mode II (Mattheck and Moldenhauer (2)). Figure 1 shows the two-dimensional unit cell and the boundary conditions used for these calculations. The K-factors are normalized by the K_I-value of a straight crack extending between two fibers and subjected to the boundary conditions shown in Figure 1. The value of the arc length varies between zero, the point of kinking, and one, the end point of the crack path shown in Figure 1.

Figures 3 and 4 show a striking decrease in both K_I and K_{II} as compared to the cylindrical fiber. In a certain area, K_I equals zero. The finite-element calculation shows that, in this area, nonphysical crack surface penetration occurs. An additional calculation using interface elements showed the existence of a pronounced pressure-stressed area in the interface. This pressure acts as a compressing force and, therefore, closes the crack tip. In this way, the crack is stopped from propagation.

SYMBOLS USED

θ = angle

$\sigma_{\theta\theta}$ = tangential stress

K_I = stress intensity factor for mode I

K_{II} = stress intensity factor for mode II

REFERENCES

(1) Heitzer, J.,and Mattheck, C., "A New Mechanism to Prevent the Growth of Interface Cracks", Fortschrittsberichte der Deutschen Keramischen Gesellschaft, Band 2, Heft 3, 1986, pp. 9 - 17

(2) Mattheck, C., and Moldenhauer, H., "Mode Extraction from Mixed Mode Analysis of Cracks by Special Filter Technique", Int. J. Fract. 34, 1987, pp. 209 - 218

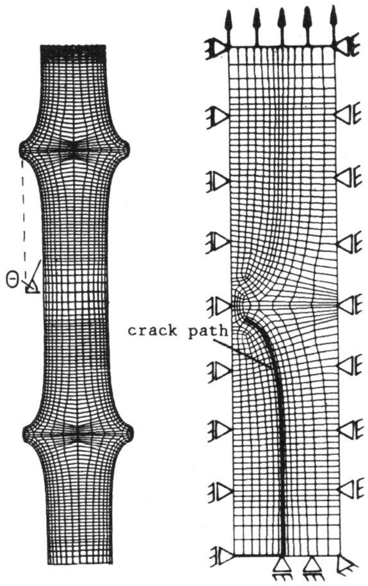

Figure 1 F-E mesh of the new fiber Unit-cell with boundary conditions

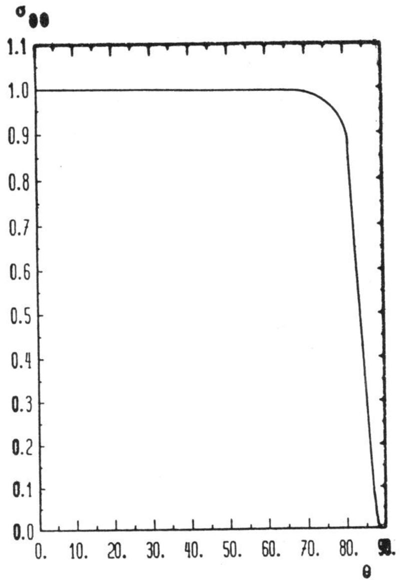

Figure 2 Normalized tangential stress at the surface

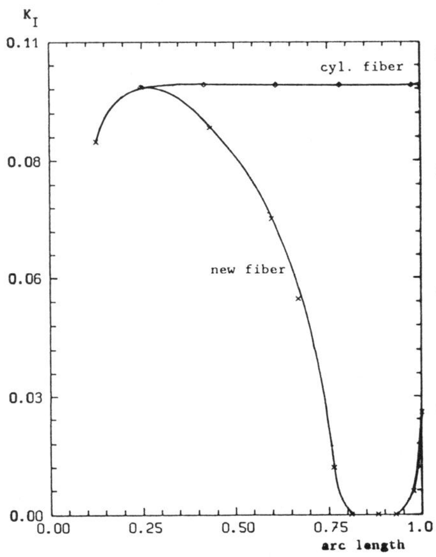

Figure 3 Normalized stress intensity factor K_I

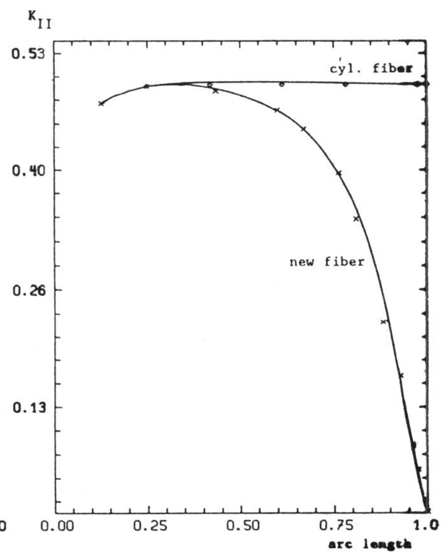

Figure 4 Normalized stress intensity factor K_{II}