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FRACTURE MECHANICS IN FIBER REINFORCED COMPOSITE MATERIALS, TAKING AS EXAMPLES B/Al AND CFRP

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The validity of linear elastic fracture mechanics and other fracture criteria was investigated with laminates of boron fiber reinforced aluminum (R/Al) and of carbon fiber reinforced epoxide (CFRP). Cracks are assessed by fracture strength Kc or Kmax (critical or maximum value of the stress intensity factor). The Whitney and Nuismer point stress criterium and average stress criterium often show that Kmax of fiber composite materials increases with increasing crack length; however, for R/Al and CFRP the curve showing fracture strength as a function of crack length is only applicable in a small domain. For R/Al, the reason is clearly the extension of the plastic zone (or the damage zone in the case of CFRP) which cannot be described with a stress intensity factor.
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The use of composite fiber materials is only being accepted gradually. One of the reasons for this is insufficient knowledge about the mechanical behavior. This is also true for fracture mechanics which is supposed to describe the effect of cracks in fiber composite materials. The problem is complex because depending on the design and the load, different kinds of damage can occur. Up to the present time, at the Institute for Materials Research of the DFVLR, primarily the effects of holes and cracks have been investigated which can develop between connection holes. Failure criteria is sample fracture and not crack propagation among individual layers.

The validity of the linear-elastic fracture mechanics laws (LEBM) another fracture criteria has been investigated in laminates of boron fiber reinforced aluminum (B/Al) and carbon fiber reinforced epoxy (CFK). In the LEBM, a crack is evaluated using the stress intensity factor K which reaches a critical value $K_c$ or $K_{\text{max}}$ upon sample fracture.

Using the crack resistance $K_c$ or $K_{\text{max}}$, the cracks which occur in components can be evaluated and one can then determine whether they are permissible or not. In the case of fiber composite materials in the form of thin sheets, often it has been established that the crack resistance $K_{\text{max}}$ increases with increasing crack length (Figure 1, [1-4]).

This is not only specific for fiber composite materials but also occurs in conventional materials. The increase in the crack resistance can be explained in conventional materials using the R curve concept, but not for CFK [3]. In 1974, Whitney and Nuismer [1] introduced the point stress criterion and the average stress criterion (P.S.K, M.S.K), which in the meantime has been accepted widely
because the increasing crack resistance can be described with constant material parameters (d₀ for the P.S.K, a₀ for the M.S.K). Figure 1, however, shows that using the material parameter a₀, the crack resistance can only be covered over a small range. The reason in the case of B/Al apparently is the expansion of the plastic zone (or the damage zone in the case of CFK) which does not have to be described using a stress intensity factor [4].

REFERENCES:


Figure 1. The dependence of crack resistance $K_{\text{max}}$ on crack length for several B/Al and CFK laminates.