# ON THE PATH STABILITY OF STANDARD AND SIDE-GROOVED DCB-SPECIMEN

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## INTRODUCTION

A crack generally propagates in the direction of maximum hoop stress, which is approximately equivalent to the direction of maximum energy release rate. According to this criterion a straight crack on the center-line of a symmetrical system, for example, is supposed to propagate in its original direction. However, it has been shown by several authors (Cotterell (1), Cotterell and Rice (2), Streit and Finnie (3), Schindler and Sayir (4), Levy and Perl (5)) that this is not always true. There are several crack systems, e.g. the DCB-specimen, where the crack deviates from its original direction, thereby destroying the symmetry. This behaviour is called path-instability.

The above mentioned authors agree that path stability is governed by the homogeneous unaxial stress field acting parallel to the crack, i.e. the constant term in Williams (6) stress series. Cotterell (1) and Cotterell and Rice (2) found that the condition for path-stability is

$$T < 0 \tag{1}$$

where T denotes the magnitude of the homogenious stress field (tension positive). Schindler and Sayir (4) noticed, that the path can also be stable for positive T, unless it exceeds some material-dependent critical value $T_c$. The corresponding stability criterion is then

$$T < T_c \tag{2}$$

The order of magnitude of $T_c$ is one third of the ultimate strength. The criterion (2) is applicable to cases, where the initial perturbation, i.e. the initial deviation of the crack-tip lies within the $K_I$- and T-controlled region. For larger initial deviations a more stringent criterion - possibly criterion (1) - has to be applied.

The purpose of the present paper is to show a very simple analysis of path-stability of the DCB-specimen.

## STANDARD DCB-SPECIMEN

In order to clarify the role which the various physical parameters play in path-instability a closed-form solution for T is required.

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Let us imagine that the DCB-specimen is split into a pure bending part and a shear part. A dimensional analysis leads to

$$T = \frac{6 \cdot P \cdot a}{t \cdot h^2} (1 + c_1) / h^2 + P \cdot c_2/(h \cdot t) \qquad (3)$$

P denotes the load, a the crack length and h the half width of the DCB-specimen. $c_1$ and $c_2$ are dimensionless constants, which were determined with numerical T-values given by Leevers and Randon (7) to

$$c_1 = -0.160 \; ; \; c_2 = -1.00 \qquad (4)$$

For quasistatic crack-growth the actual load P is not arbitrary but given by the condition of crack-instability

$$K_I = K_c \qquad (5)$$

With the standard solution

$$K_I = 2 \cdot \sqrt{3} \cdot P \cdot (0.64 + a/h) \, /(t \cdot h^{-0.5}) \qquad (6)$$

and the equations (3) - (5) one obtains

$$T = \frac{\sqrt{3} \, K_c}{\sqrt{h}} \cdot \frac{(0.84 - 0.166 \; h/a)}{(1 + 0.64 \; h/a)} \qquad (7)$$

t denotes the thickness of the specimen. According to eq. (7) and criterion (2) the straight path is more stable, when the material is more brittle, the crack shorter and the width of the specimen bigger. These statements are in agreement with experimental experience. Eq. (7) holds only for cases, where the remaining ligament at the end of the specimen is bigger than about 1.5 h. For smaller ligaments the crack path stabilizes rapidly with increasing cracklength.

## SIDE-GROOVED DCB-SPECIMEN

A well known practice to stabilize the crack-path is to supply the specimen with side-grooves. Their effect on path-stability is twofold: First, the stress-intensity-factor $K_I$ is higher than in the case of the standard specimen. Thus the material behaves more "brittle" in the sense of eq. (7). Second, the resistance of the material against crack-growth becomes higher in the lateral than in the straight direction. This effect can be accounted for by an adequate increase of the right-hand side of Eq. (2). In the following the two effects are roughly quantified.

Whereas eq. (3) and (4) remains approximately valid in the case of side-grooves, eq. (7) has to be adjusted. The generalized stress-intensity factor is now

$$K_I = \sqrt{t/t_o} \cdot 2 \cdot \sqrt{3} \cdot P \cdot (0.64 + a/h) \; / \; (t \cdot h^{-0.5}) \qquad (8)$$

where $t_o$ denotes the thickness of the grooved section.

As mentioned above, the effect of increased resistance against crack growth in lateral direction can be accounted for by modifying eq. (2). Since this criterion is given in terms of stresses, it is reasonable to assume that the critical value $T_c$ increases linearly with the factor $t/t_o$. Combination of these two effects results in the following criterion for path-stability:

$$T = (t/t_o)^{3/2} \; \frac{\sqrt{3} \cdot K_c \cdot (0.84 - 0.166 \; h/a)}{\sqrt{h} \; (1 + 0.64 \; h/a)} < T_c \qquad (9)$$

For example, eq. (9) enables easy determination of the critical stress $T_c$ from a single experiment, where the crack length at path instability is to be measured. Once $T_c$ and $K_c$ are known the geometrical parameters (cracklength, dept of side-grooves, specimen width) required for path-stability can be readily estimated by means of eq. (9). Since the simplyfied analysis presented here is only a very rough approach to a relatively complicated three dimensional problem, it is up to further numerical and experimental work to show its accuracy and limitations.

## R E F E R E N C E S


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