STRESS INTENSITY FACTORS OF CRACKS ORIGINATING FROM A HOLE SITUATED BETWEEN WALL REINFORCEMENTS

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The reduction of notch stresses by situating the notch in a groove between wall reinforcements is studied as well as the effect on the stress intensity factor of cracks originating from those notches.

The effect of notches as stress risers is well known. The notch stresses are caused by redirectioning the force flow around the notch. There are many methods to reduce notch stress peaks as for example coldworking of holes and placement of stress relieving notches. These methods are appropriate to increase as well the crack initiation life as the crack propagation life of a component under fatigue loading (1). In this paper the method of situating the notch (circular hole) between wall reinforcements is studied which is also realized at the roots of tree branches (Fig.1). Figure 2 shows the FEM-structure used. The wall reinforcements are axially directed parallel to the externally applied tension and do not fully surround the hole as it is the case for tree branches because only uni-axial force flow is studied here. A second structure (Fig.2) has the thickness of the reinforced plate from Fig.2 including the thickness of the wall reinforcements. The weight function method was applied (2,3) in an approximate way (1,4). As a reference loading case constant internal pressure on the crack faces was studied. For a set of four different crack lengths the crack opening displacement fields were determined and fitted in the function

$$u_r\,(x,a) = \frac{\sigma_0 b}{E} \left\{ \sum_{i=1}^{4} C_i \left(\frac{a}{b}\right)^i \sqrt{1-\frac{x}{a}} + \sum_{j=1}^{4} D_j \left(\frac{a}{b}\right)^j \sqrt{1-\frac{x^2}{a^2}} \right\} \qquad (1)$$

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The constants C_i, D_j have been fitted to FEM-results taken at x=0 and x=a/2. Then the basic equation of the weight function method reads

$$K_{new}(a) = \frac{E}{K_r} \int_0^a \sigma_{new}(x) \frac{\delta u_r}{\delta a} dx \qquad (2)$$

where $K_r(a)$ can be calculated from the self-consistency of the method, i.e. $K_{new} = K_r$ if $\sigma_{new}(x) = \sigma_o$ = const.. The notch stress distributions are the actual loading case of interest. They are calculated from the uncracked structures along the lines A-A', B-B' (Fig.2). Inside the structure the notch stresses of the two structures considered do not differ very much, whilst at the surface the reduction is more significant. Looking on the notch design situated in a groove between wall reinforcements the stresses at the surface where cracks would probably be initiated are reduced to 263 N/mm² (point C) whilst at point B a peak stress of 305 N/mm² is present. This is a stress reduction of about 14% at the surface when both plates are loaded by a tensile stress of $\sigma_{appl.}$ = 100 N/mm². In the internal regions of the cross-section of the plate the stress reduction is smaller.

The normalized stress intensity factors $F = K/\sigma_{appl.}\sqrt{\pi a}$ are shown in Fig.3. Only in the very near surrounding of the hole the reference stress intensity factors for the plate with wall reinforcements are reduced. Far from the hole behind the wall reinforcements the stress intensity factor increases over the value of the thick plate without profile. This may be due to the stiffer behaviour of the thick plate without grooves. The curves with the circular dots are calculated by means of eq.(2), whilst the cross-like points are calculated by use of Rice-integral option in the computer code ABAQUS. Both methods agree well in the range shown. Very near the hole eq.(1) was too rough in the case were wall reinforcements were present. It may be concluded that the notch stresses at a hole situated between wall reinforcements are somewhat smaller than in case of a notched plate with homogeneous thickness. Initiated cracks have at least near the notch a reduced stress intensity factor. This was found for the same external tensile stress applied to both structures.

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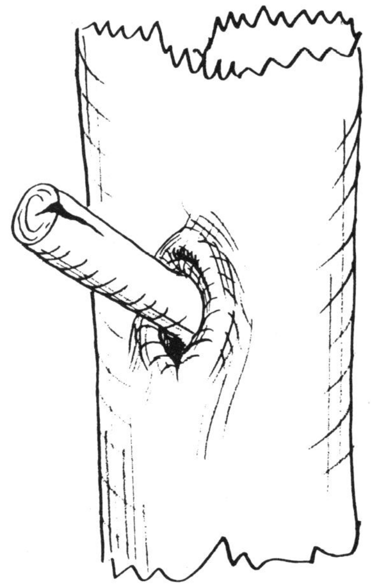

Figure 1 Branch holes surrounded by wall reinforcements at trees

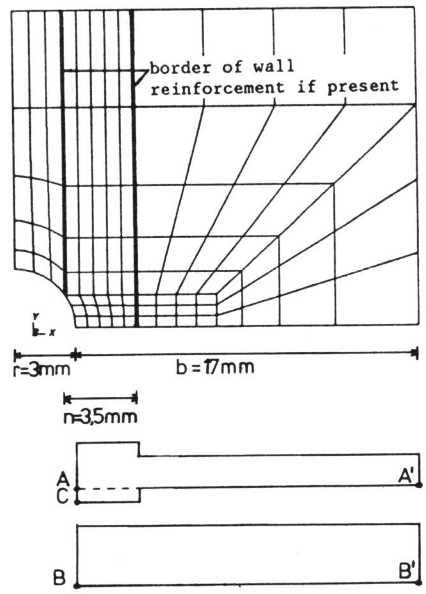

Figure 2 Part of the Finite-Element structures used

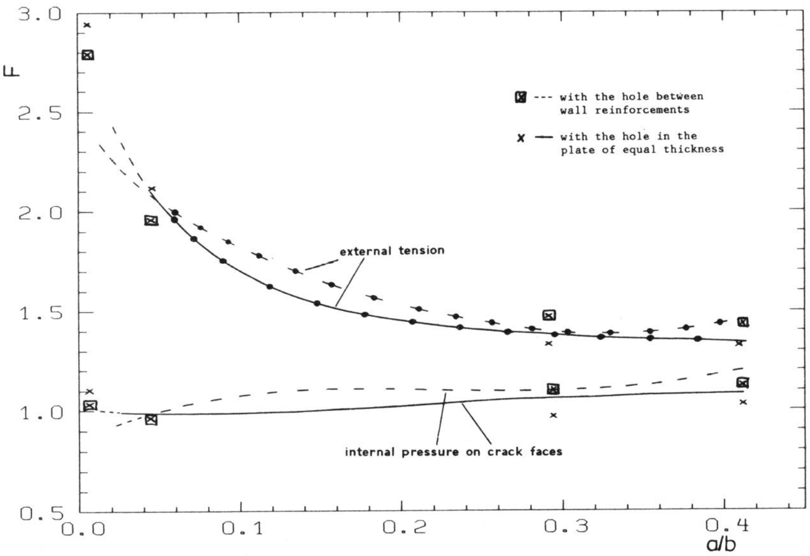

Figure 3 Normalized stress intensity factors $F=K/\sigma_o\sqrt{\pi a}$