CRACK ONSET FROM A CIRCULAR CAVITY UNDER INTERNAL PRESSURE AND REMOTE BIAXIAL LOADING

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Abstract: Crack onset from a circular cavity is a problem occurring in many engineering applications, spanning from mechanical components to geotechnical structures. Herein, this classical problem is reconsidered using as failure criterion the Finite Fracture Mechanics approach, which, differently from Linear Elastic fracture Mechanics, does not need an initial crack to provide a finite failure load. The solution is achieved in an almost analytical fashion. In fact, as long as the radius of the cavity is much smaller than the size of the medium where it is located, Kirsch stress solution holds and Stress Intensity Factor function can be found in Fracture Mechanics Handbooks. Results are provided as a function of the cavity radius for different values of the parameters, i.e. the biaxial load ratio and the ratio of the remote stress to the internal pressure. A comparison with experimental data available in the Literature and ad hoc experiments concludes the paper.

Keywords: Finite Fracture Mechanics, size effect, wellbore, negative geometries

1. Introduction

Under particular combinations of biaxial compressive stresses and internal pressure, tensile hoop stresses can occur at the contour of a circular cavity. These tensile stresses can generate mode I cracks propagating radially (see Fig.1). Aim of the present paper is to determine the stress/pressure level leading to crack onset. The problem is faced resorting to the Finite Fracture Mechanics approach, although other approaches as the Cohesive Crack Model are possible as well [1].

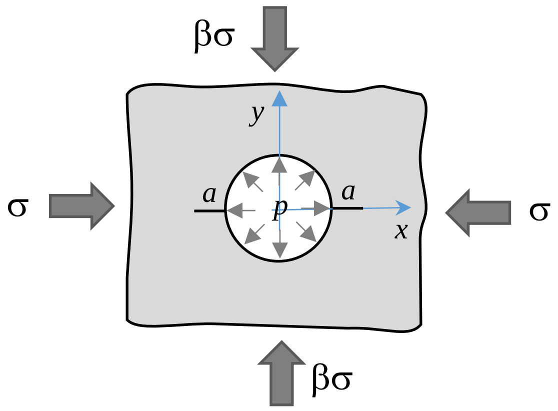

Fig. 1. Circular cavity of radius *R* under remote biaxial compressive stresses and internal pressure with a pair of radial cracks of length *a*.

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2. Finite Fracture Mechanics

Finite Fracture Mechanics (FFM) is a fracture criterion resting on two fundamental assumptions: fracture propagates by finite step (of length Δ) and the (average) stress where finite crack will occur must exceed the tensile strength σ_c of the material. Denoting by K_{Ic} the material fracture toughness, the FFM criterion reads [2]:

$$\begin{cases} \int_0^{\Delta} K_I^2(a)\,\mathrm{d}a \geq K_{Ic}^2 \Delta \\ \int_R^{R+\Delta} \sigma_y(x)\,\mathrm{d}x \geq \sigma_c \Delta \end{cases} \tag{1}$$

The crack onset load is the minimum one fulfilling contemporaneously the two inequalities (1). Depending on geometry, the failure stress σ_f leading to crack onset can be achieved either when (fig. 2a) both inequalities are strictly fulfilled or when (fig. 2b) the failure load satisfying the discrete energy balance is minimum (and the stress requirement is over-fulfilled) [3].

The method allows one to highlight the size effect, i.e. how the strength decreases increasing the size, in this case simply represented by the ratio between the radius R and Irwin's length $l_{ch} = (K_{Ic}/\sigma_c)^2$. In Fig. 2c the size effect on strength is reported for $\beta = 1/6$ and $p = 0$.

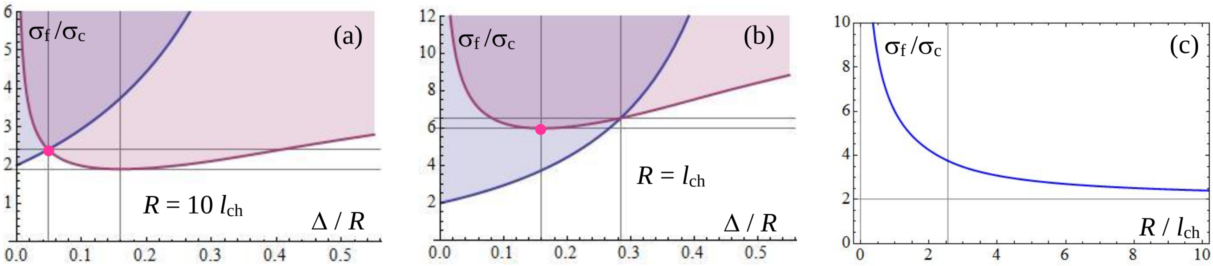

Fig. 2. Failure stress given by the stress requirement (blue lines/regions) and discrete energy balance (magenta lines/regions) for $\beta = 1/6$, $p = 0$: $R = l_{ch}$ (a); $R = l_{ch}$ (b). Magenta dots mark the crack onset load. Failure stress vs. hole radius R for $\beta = 1/6$, $p = 0$ (c).

3. Conclusions

Fracture mechanisms of plates with a circular cavity subjected to remote and internal pressure have been analyzed. The model is almost fully analytical: fracture onset was assessed based on the critical K_{Ic} and σ_c parameters. Theoretical predictions will be compared with data available in the Literature as well as with ad hoc experiments.

References

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