CRACK HEALING IN ANISOTROPIC ELASTIC-PLASTIC PLATE UNDER TENSILE LOAD

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Crack propagation in composite materials exhibits several unique characteristics. One notable aspect is the development of large pre-fracture zones near the crack tips. These zones consist of unbroken fibers from the reinforcing material and a sufficiently plastic matrix. To calculate the critical load for such materials, nonlinear fracture mechanics is employed, specifically the use of the δ_c-criterion, which focuses on the critical opening or shear displacement of the crack edges.

In engineering applications, particularly within the construction industry, injection technologies are commonly used to restore the strength of structural elements compromised by cracks [1-3]. These methods involve injecting liquid polymers into defect zones, where, after hardening, the polymers prevent further displacement of the crack surfaces. This process reinforces the structure, allowing it to withstand operational loads.

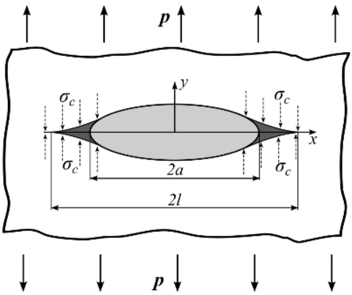

Fig. 1. Tensile schematic of a plate with a filled crack

We consider an elastic-plastic body containing a crack under the tensile load (Fig. 1). The crack is filled with injection material. In the framework of nonlinear fracture mechanics, we reduce the problem to solving an integro-differential equation, using the model of an elastic Winkler-type layer

$$Re\left(\frac{1}{\pi i}\cdot\frac{\mu_2-\mu_1}{q_1\mu_2-q_2\mu_1}\right)\int_{-l}^{l}\frac{g'(x)dx}{x-t}-\frac{g(t)}{h(t)}E+ \\ +p-pa_{22}E-\sigma_c=0, |t|\le l, \tag{1}$$

where $g(x)$ is the displacement of the crack edges; μ_1, μ_2 – the roots of a certain characteristic equation; q_1, q_2 – parameters of anisotropy; $\varepsilon = a_{22}E$.

The analytical solution of equation (1) can be obtained if the crack surface is elliptic with semi-axes a, b, $h(x)=\beta^{-1}\sqrt{a^2-x^2}, \beta = a/b, a \gg b$, and the stress state in the elliptical layer changes little with the formation of plastic zones and is homogeneous, as is the case with the elastic body model [4].

Based on the dependencies above, the following expression of function $g(x)$ can be obtained:

$$g(t) = \frac{\sigma_c - p(\varepsilon - E\beta A)}{\pi Re\left((\mu_2 - \mu_1)/(i(q_1\mu_2 - q_2\mu_1))\right)^*} \times$$

$$\times\left[(t-a)\Gamma(l,t,a) - (t+a)\Gamma(l,t,-a)\right], \qquad (2)$$

$$A = \frac{1-\varepsilon}{Re\left((\mu_2 - \mu_1)/(i(q_1\mu_2 - q_2\mu_1))\right) + E\beta}.$$

To calculate the ultimate load, we will apply the criterion of critical crack surface shear $2g(a) = \sigma_{Ic}$. As a result, we obtain an equation to establish the strength reserve for tensile shear in an anisotropic elastic-plastic body with a healed crack

$$-\frac{8a(\sigma_c - p_*(\epsilon + E\beta A))}{\pi Re\left[(\mu_2 - \mu_1)/(i(q_1\mu_2 - q_2\mu_1))\right]} \ln\cos\frac{\pi p_*(1 - \varepsilon - E\beta A)}{2(\delta_c - p_*(\varepsilon + E\beta A))} = \delta_{Ic} \qquad (3)$$

Our findings indicate that the success of restoring the strength of a cracked body using injection reinforcement technology is influenced by the defect's geometric parameters and the elastic properties of the materials. Additionally, we identify the defect sizes at which linear fracture mechanics can be applied.

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