FRACTURE OF HIGHLY ELASTIC AND COMPOSITE MATERIALS AT COMPRESSION ALONG NEAR-SURFACE CRACK IN CASE OF SMALL DISTANCE BETWEEN FREE SURFACE AND CRACK

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Abstract

In this paper, the nonclassical problems of fracture mechanics for a near-surface crack in the case of small distances between a free surface and a crack plane was investigated. To solve this problem the numerical analytical procedure was proposed. As an example, numerical research for highly elastic material with Bartenev-Khazanovich potential, and composite material was conducted. Also, the applicability of the «beam approximation» for these materials was investigated.

1. Introduction

Investigation of materials under compressive loads directed along the cracks is one of the nonclassical problems of fracture mechanics. For such loading schemes, the stress-intensity factors are equal to zero and the classical fracture criteria of the Griffith-Irwin type are inapplicable. There are two approaches to solving this class of problems. The first approach, called "beam approximation", is based on the various applied theories of stability of thin-walled systems. The second approach is based on the basic relationships and methods of the three-dimensional linearized theory of stability of deformable bodies for finite and small subcritical strains. In this paper, a semiinfinite solid containing a penny-shaped crack of radius a which is situated in the upper halfspace $x3 \geq -h$, in the plane $x3 = 0$ with center on the Ox3-axis in terms of second approach was considered.

2. Results

Within the limits of the second approach for highly elastic and composite materials, the problem is reduced to the solution of the system of integral equations Fredholm.

For searching critical shortening, elongation, and stress the numerical analytical procedure built on a method of Bubnova-Galorkina was proposed. As a system of coordinate functions, the power functions were used. Here the procedure which allows analytical calculate integrals for the chosen system of coordinate functions using a package of symbolic computations was used. It has allowed to achieve the higher exactitude of evaluations at the expense of a numerical integration lapse exclusion. For acceleration of integrals solutions, the recurrence relations were used. After this procedure system of Fredholm integral equations transforms into, the system of linear equations.

As an example, the task for a near-surface penny-shaped crack in a material with Bartenev-Khazanovich potential, and composite material are conducted.

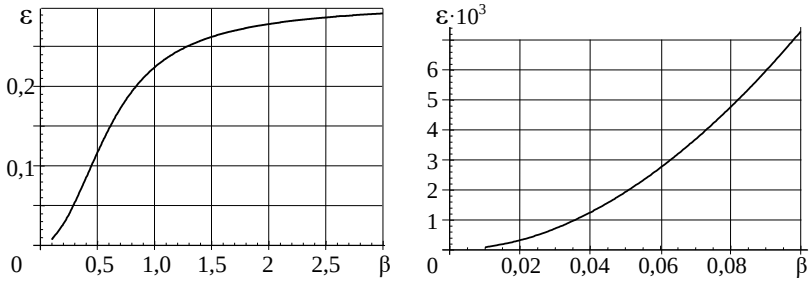

Fig.1 – Dependencies between critical shortening and dimensionless distance between the free surface and the crack surface in highly elastic material with Bartenev-Khazanovich potential.

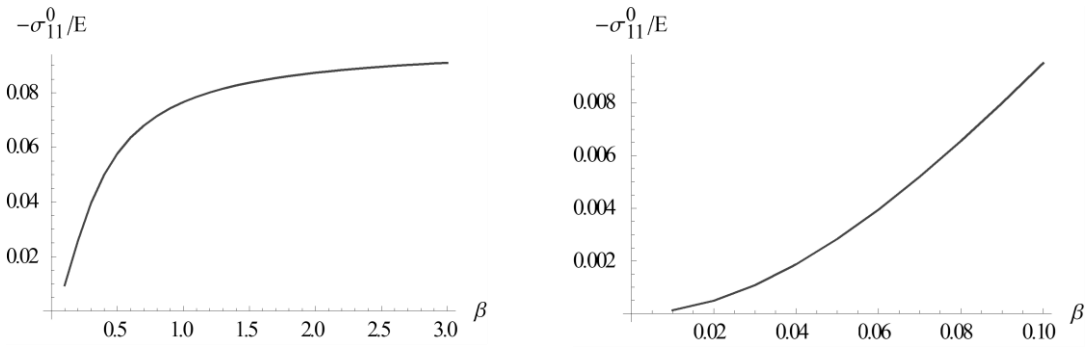

Fig.2 – Dependencies between critical compression and dimensionless distance between the free surface and the crack surface in composite material.

As an example of composite material, we considered a laminate composite with isotropic layers. In macrovolumes such composite may be considered as a transversely-isotropic medium.

On fig. 1 and fig. 2 the dependences of critical shortening and critical compression from a dimensionless distance between the free surface and the crack surface for small and big distances were presented. Analysis of these results allowed us to determine the conditions of applicability of the "beam approximation". For a near-surface penny-shaped crack in "beam approximation" we must use rigid fixing flat disk-shaped plate at compression. Beam approximation good work for a small distance between the crack and the free surface (when $\beta < 0.01$ computing error less than 1%) and bad work in else cases (when $\beta > 0.1$ computing error more than 5%).

3. Conclusions

Using the proposed numerical analytical procedure, the values of critical shortenings and critical stresses for highly elastic material and composite material under compression along a near-surface crack are obtained. Also, the conditions of applicability of the "beam approximation" for this case were determined.