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The Method of Solving Problems of Strength and Fracture Toughness in CAE-System Using Modified "Birth and Death" Functions

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Abstract

In this paper, we consider the method of solving the problems of strength and fracture toughness with CAx, in particular CAE-system. The relevance of the topic is based on the following factors: the lack of Russian Instruments CAE-system to solve the problems of strength and fracture toughness; high costs of production in the field of testing. Such problems as strength and fracture toughness are considered from the standpoint of the resistance of materials and linear elastic fracture mechanics (LEFM). We use a modified "Birth and Death" function in conjunction with the finite element method (FEM). Finally, the verification task is given that confirms the method of performance.

Keywords: fracture mechanics; strength; fracture toughness; CAE; CAx; FEM; Birth and Death.

1. Introduction

In this paper, to develop a method for solving problems of strength and fracture toughness, is used the region of materials science resistance and linear elastic fracture mechanics (LEFM). LEFM valid for quasi-brittle solids (plasticity zone at the crack tip does not exceed 20% of the size of the crack) [1,2].

Relevance of the topic due to:

- Lack of Russian Instruments CAE-system to solve the problems of strength and fracture toughness;
- High costs of production in the field of testing.

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CAE-system using a numerical method - finite element method (FEM) [3,4].To simulate the processes of initiation and propagation of cracks using the function of "Birth and Death" [5,6].

The novelty of this paper is to use the modified method and to calculate the parameter in LEFM for the energy release rate G_I (which I is crack of the 1st type). Moreover, instead of the traditional functions of the "Birth and Death" for the condition of the critical stress in FE [5], will be used modified variant with the use of the parameter G_I.

2. Theoretical

2.1. Tools resistance of materials

Tools resistance of materials is used to analyze the strength of the structural elements or parts that do not crack [7-9].

$$S_{solve} \geq S_{critical} \tag{1}$$

where S_{solve} is the stress received by the 2nd theory of strength (MPa), $S_{critical}$ is the critical stress equal to the tensile strength of the material at strains (MPa):

$$S_{solve} \equiv S_1 - \mu(S_2 + S_3) \tag{2}$$

where S_1, S_2, S_3 are principal stresses (MPa), μ is Poisson's ratio.

2.2. Tools of fracture mechanics

According to this paper, LEFM operates the following main parameters [1,2]: stress intensity factor (SIF) K_I, energy release rate G_I (which I is crack of the 1st type).

In LEFM there are such things as critical fracture mechanics parameters [1,2], which are responsible for the further propagation of the crack. For K_I and G_I parameters are referred to as K_{IC} and G_{IC}, respectively. If the conditions:

$$K_I \geq K_{IC} \tag{3}$$

$$G_I \geq G_{IC} \tag{4}$$

are satisfied, then there is a further crack propagation, and possibility of the full failure of the construction element or detail. To calculate the critical value SIF K_{IC} used an analytical approach presented in [10]. Critical SIF found analytically referred to as $K_{ICsolve}$:

$$K_{ICsolve} \cong 0.65\sigma_{yield}\sqrt{\pi\sqrt{area}} \tag{5}$$

where σ_{yield} is yield point (MPa), *area* is cracked surface in the plane x - y (mm^2).

The critical energy release rate $G_{ICsolve}$ for a plane-strain condition (PSC) [1,2] determined through $K_{ICsolve}$ follows:

$$G_{ICsolve} = \frac{K_{ICsolve}(1-\mu^2)}{E} \tag{6}$$