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Contact problem for flat crack under two normally incident tension–compression waves with wave mode-shifting

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ABSTRACT

The frictionless contact interaction of the finite crack edges in an infinite plane is studied for the case of normal incidence of two harmonic tension–compression waves with multiple mode-shifted frequencies. Boundary integral equation method and constrained optimization algorithm are used for the problem solution. Distribution of the forces of contact interaction and displacement discontinuity in space and time are analyzed. Influence of the wave frequencies on the stress intensity factor for different normalized wave numbers is considered here.

1. Introduction

Recent time methods of fracture dynamics have been utilized in engineering design of machines and structures that contain cracks [1]. Fracture mechanics methods and the main trends of their development are presented in encyclopedia [2]. In many situations in structural design that use methods of fracture mechanics, the inertial effects resulting from dynamic load and crack propagation need to be taken into account. These two factors may occur separately or in combination. Examples are stationary cracks under dynamic loading (when the velocity of crack propagation is equal to zero) or propagating cracks under static loading. The main problem of dynamical fracture mechanics is the calculation of the stress intensity factors (SIF) and *J*-integrals for cracked bodies with inertial effects. Methods and problems in fracture dynamics are presented in monograph [3].

Interaction of the elastic waves with plane cracks has been studied in [4,5] and in some books on elastodynamics [6–8]. It is important to point out that besides the above mentioned publications, in many other publications on fracture dynamics, problems have been solved without taking into account the possibility of the contact interaction of opposite crack edges. Analysis of static fracture mechanics problems demonstrates that taking the crack face contact interaction into account may significantly affect the fracture mechanics criteria. In dynamic problems, the effects of the crack edge contact interaction can significantly exceed those in the static case. Moreover, in dynamic problems it is very difficult to find classes of loads which do not cause crack face contact interaction. In the case of harmonic loading, the problem of the crack edge contact interaction is very important. Under the action of a harmonic load, the steady-state condition is usually considered. In this case, the dependence of all functions, which determine the stress–strain state of a body with cracks, is harmonic in time. For example, using such an approach, the problem of the interaction of a tension–compression harmonic wave with a crack of finite length in a plane has been solved in [4,5]. In these and other publications, it has been mentioned that such an approach to this problem is not correct, as it does not take into account the crack edge contact interaction that always occurs during the action of the compressive wave. The assumption that the crack has an initial opening equal to the amplitude value of the crack opening does not remedy the situation, since even in this case there always exists an area in the vicinity of the apex of crack, where the crack face contact interaction takes place.

The mathematical formulation and solution of the elastodynamic problem for a cracked body, which takes into account the possibility of crack edge contact interaction and the formation of areas with close contact, adhesion and sliding, were presented in numerous of our publications (see reviews papers for Refs. [9–12]). In our publications, it was shown that harmonic loading results in a steady-state periodic process, but not a harmonic one, if crack face contact interaction is taken into account. Also influence of the crack faces contact interaction subjected to the harmonic waves on fracture mechanics criteria was investigated. Recent results on study influence of the crack edges contact interaction subjected to harmonic waves are presented in [13–19].

Algorithms for the solution of the problem considering crack edges contact interaction have been developed in the above

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