DYNAMIC INTERACTION OF BRANCHED CRACKS

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1. Introduction

Branched cracks in materials exist as a result of technological processes, corrosion, loading conditions, etc. Fast running cracks subjected to high loadings can split into several branches. The stresses at crack tips of branched cracks are characterized by stress intensity factors (SIF). The values of static or dynamic SIF for a general geometry of the body and loading conditions are obtained by numerical methods.

Daux et al. [1] presented the extended finite element method (X-FEM) to analysis of cracks with multiple branches and cracks emanating from holes. A standard displacement approximation was enriched by incorporating additional discontinuous functions. The method allows the modelling of discontinuities independently of the mesh. Raffie et al. [2] investigated bifurcation and trifurcation of fast running cracks under various biaxial loading conditions. Arbitrary curvilinear crack propagations were analyzed by the time-domain BEM. Branching of cracks was controlled by the opening mode SIF and velocity and direction of crack growth by the maximum circumferencial stress at the crack tip. Numerical solutions were compared with experimental results. Fedelinski [3] applied the boundary element method to analysis of statically and dynamically loaded plates with branched and intersecting cracks. The dynamic problem was solved by using the Laplace transform method and the solution in the time domain was computed by the Durbin numerical inversion method. Numerical examples of a branched crack in a rectangular plate and a star-shaped crack in a square plate were presented. The influences of angles between branches of the crack and dimensions of the plate for the star-shaped crack on dynamic SIF were analyzed.

In the present work the boundary element method is applied to analysis of static and dynamic stress intensity factors of branched cracks in infinite plates. The infinite plates are analyzed to study interaction between the cracks and to avoid interaction with external boundaries of plates. The crack problem is solved by the dual BEM which was developed for dynamic loading by Fedelinski et al. [4]. An overview of different BEM approaches in dynamic fracture mechanics was presented by Fedelinski [5]. The present paper is an extension of the previous work [3] published by the author. In this work influence of distance between branched cracks, their orientation and direction of loading on static and dynamic SIF are analyzed.

2. Numerical example – two branched cracks in an infinite plate

Two branched cracks in an infinite plate are subjected to tensile loading, as shown in Fig. 1. The dimension of the crack branches is a=1 cm and the distance between crack centres is $2l$ and l/a=2. The angle between crack branches is $2\alpha=2/3\pi$. The material is isotropic and linear-elastic and the Young modulus is E=200 GPa, the Poisson ratio ν=0.3, mass density ρ=8000 kg/m^3 and the material is in plane strain conditions. The velocity of the longitudinal wave is c_1=5801 m/s and the velocity of the shear wave is c_2=3101 m/s. The tensile loading p with the Heaviside time-dependence is applied in the direction perpendicular to the line connecting crack centres. In order to model the infinite plate and avoid influence of reflection of waves from boundaries the rectangular plate of width $2w$=30 cm and height $2h$=20 cm is considered. The uniformly distributed tractions are applied along horizontal edges of the plate. The plate with the cracks is divided into 320 boundary elements (200 elements for the external boundary and 10 elements for each crack edge). The numerical solution is obtained using 50 Laplace parameters and the time step Δt=0.4 μs. The stress intensity factors are normalized with respect to $K_o = p\sqrt{\pi c}$, where $2c=3/2a$ is the width of the branched crack in the horizontal direction. The results for the static and dynamic loading are compared with the solution for the single crack in the centre of the plate. The normalized static SIF for double and single cracks are given in Table 1. The time dependence of dynamic SIF is presented in Fig. 2.

The static SIF for the interacting cracks are several percent larger than SIF for single cracks. The dynamic SIF are 0 up to about 16 μs when the longitudinal wave propagates from the loaded boundary to the crack tips. For the considered distance between cracks the influence of interaction on dynamic SIF is small.

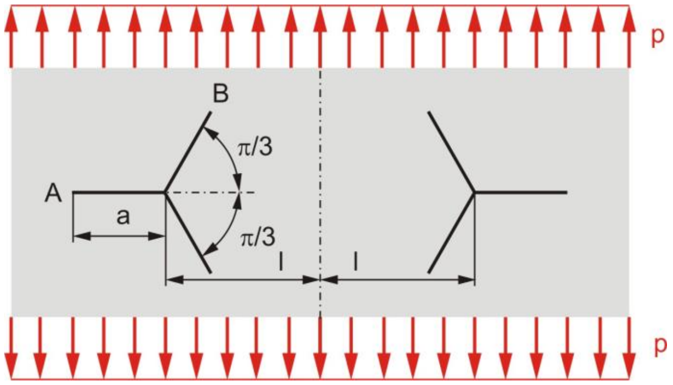

Fig. 1. Two branched cracks in an infinite plate

Branched cracks	$K_I(A)/K_o$	$K_I(B)/K_o$	$K_{II}(B)/K_o$
double	1.700	0.472	0.915
single	1.659	0.434	0.898

Table 1. Normalized static SIF for double and single branched cracks

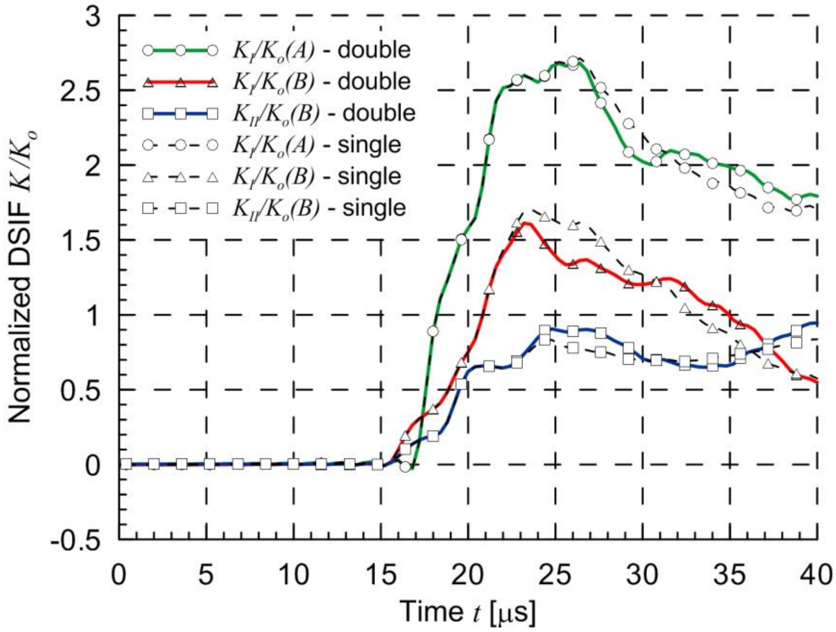

Fig. 2. Normalized dynamic SIF for double and single branched cracks

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