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BIEM/BEM SIMULATION OF DYNAMIC INTERACTION BETWEEN A SUB-INTERFACE CRACK AND AN INTERFACE IN 3-D ELASTIC BIMATERIAL

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ABSTRACT

The requirements of a deeper insight into the fracture mechanisms of advanced composites under dynamic loading conditions demand the development of efficient numerical methods for the solution of the corresponding boundary-value or initial boundary-value problems. Boundary integral equation method (BIEM) or boundary element method (BEM) is ideally suited for this purpose due to its possibilities to treat boundary conditions of different types, namely displacement discontinuities or crack-opening-displacements (CODs) on the crack-surfaces and contact conditions at the interface. In this paper, an advanced BIEM/BEM is presented for three-dimensional (3-D) dynamic problems in linear elastic composites consisting of two perfectly bonded elastic half-spaces and a penny-shaped crack arbitrarily embedded in one of the half-spaces. Both impact and time-harmonic loadings are considered. The corresponding 2-D dynamic problem for a bimaterial with a non-interface crack was solved in [1]. An improvement of the classical BIEM/BEM is achieved by introducing modified dynamic Green's functions, which satisfy the displacement and the traction continuity conditions on the interface. For prescribed dynamic loading on the crack-surfaces, the problem is reduced to a system of boundary integral equations (BIEs) for the unknown CODs. As a result, only a discretization of the crack-surface is needed, which reduces the computational efforts. Also the local behavior of the CODs near the crack-front is taken into account implicitly, which allows for a direct and accurate computation of the fracture parameters such as the dynamic stress intensity factors (DSIFs).

When a crack is perpendicular to the interface and subjected to an arbitrary in time t crack-surface loading normal to the crack-plane, then we have a single BIE of the form

$$\iint_S \Delta u^*(\xi,\omega)\left[R(\mathbf{x},\xi,\omega)-\bar{R}(\mathbf{x},\xi,\omega)\right]dS_\xi = N^*(\mathbf{x},\omega), \qquad \mathbf{x}\in S\,.$$

Here S is the crack-surface, asterisks denote the Fourier-transforms over the time or the amplitudes of the normal COD Δu and the crack-surface loading N, ω is the transform parameter or the frequency, the hypersingular kernel R is the same as for a crack in an infinite homogeneous solid [2], the regular kernel $\overline{R}$ describes the additional term due to the bimaterial structure and it contains the shear modulus G^D, Poisson's ratio ν^D and the mass density ρ^D $(D = A, B)$ of the half-spaces A and B.

Approximating the unknown COD by $\Delta u^*(\mathbf{x},\omega) = \sqrt{L(\mathbf{x})} \cdot \alpha^*(\mathbf{x},\omega)$ $(L(\mathbf{x}) = 0$ means the crack-front) and using the regularization and the discretization schemes of [3] results in a system of linear algebraic equations for the discrete α^*-values. After the solution of the BIE the mode-I DSIF K_1 can be computed by using the numerical values of α^* [2].

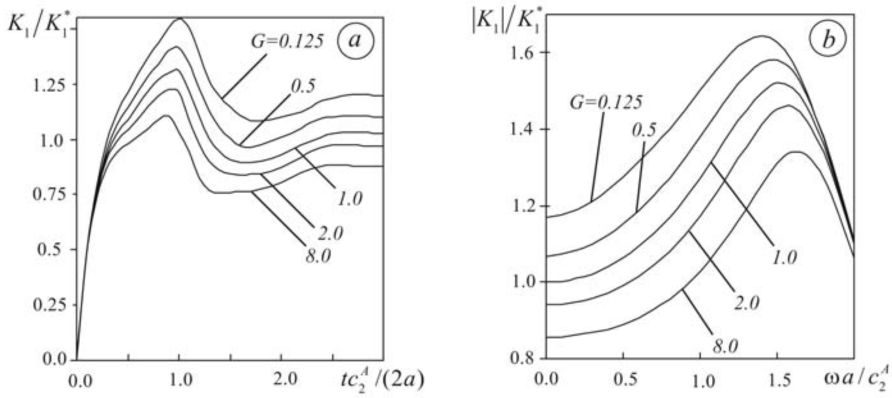

Figure 1: Normalized mode-I DSIF: (a) Impact loading; (b) Time-harmonic loading

For a penny-shaped crack of radius a in the half-space A, Figure 1 presents the normalized mode-I DSIF K_1 at the point on the crack-front nearest to the interface with a distance $0.1a$, where K_1^* is the corresponding static value. Both impact loading $N(\mathbf{x},t) = N_0 H(t)$ and time-harmonic loading $N(\mathbf{x},t) = N_0 \exp(-i\omega t)$ are considered. Here $N_0 = \text{const}$, $H(t)$ is the Heaviside function and $c_2^A = \sqrt{G^A/\rho^A}$. In the numerical calculations, the following material parameters have been selected: $G = G^B/G^A$; $\rho^A = \rho^B$; $\nu^A = \nu^B = 0.3$. For different material combinations, distinct shielding and amplification effects of the interface on the mode-I DSIF are observed in Fig. 1.

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REFERENCES

[1] J. Lei, Y.-S. Wang and D. Gross, "Dynamic interaction between a sub-interface crack and the interface in a bi-material: time-domain BEM analysis", *Arch. Appl. Mech.*, Vol. **73**, pp. 225-240, (2003).

[2] Ch. Zhang and D. Gross, *Wave Propagation in Elastic Solids with Cracks*, Computational Mechanics Publications, 1997.

[3] V.V. Mykhas'kiv, Ch. Zhang, J. Sladek and V. Sladek, "A frequency-domain BEM for 3D non-synchronous crack interaction analysis in elastic solids", *Engng. Anal. Bound. Elem.*, Vol. **30**, pp. 167-175, (2006).