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BEM-BASED DETERMINATION OF LOCAL AND GLOBAL DYNAMIC PROPERTIES OF 3D ELASTIC COMPOSITES WITH DISC-SHAPED INCLUSIONS

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It is well-known, that the shapes and rigidities of inclusions play an important role in the mechanical responses of elastic composite materials. In many practical situations, particularly on the nanoscale, the non-classical thin-walled (disc-shaped) rigid inclusions are used in the matrix to achieve the desired high-performance levels and exclusive qualities for novel and innovative technologies. The presence of such particles may have significant influence on the integrity, safety and durability of composite materials, especially in 3D configurations and at the dynamic loading conditions [1-3]. Therefore, a detailed multiscale analysis of 3D elastic materials with interacting thin-walled inclusions under elastic wave propagation is required. A deep insight into their dynamic behaviour is extremely helpful in designing of new generation composites, fracture and damage analysis, and non-destructive material testing by the acoustic emission and ultrasonics.

In the case of infinite matrices, application of the boundary element method (BEM) for the numerical solution of corresponding 3D elastodynamic problems is very attractive, because of the reduction by one of space dimensionality in the resulting equations, the automatic satisfaction of Sommerfeld radiation conditions at infinity, high accuracy, and simple pre- and post-processing for input and output data. Here advanced numerical scheme conjuncting the BEM and the effective medium method is proposed for the micromechanical analysis of time-harmonic elastic wave propagation in an elastic composite consisting 3D infinite matrix and completely bonded massive disk-shaped inclusions. Each inclusion is regarded as a rigid body and is allowed to translate and rotate in the matrix. The location of the micro-inclusions in a composite is assumed to be random, while their orientation can be both aligned and random. In addition, a variable mass of distributed movable inclusions is supposed, what describes the different material properties of particles as well as their geometric aspect ratios. First, 3D wave scattering problem by a single inclusion occupying the domain S is reduced to a system of boundary integral equations for the interfacial stress jumps (ISJs) $\Delta\sigma_i$ across the inclusion surfaces. These equations with Helmholtz-type weakly-singular kernels R_{ji} are written in a schematic form as:

$$\sum_{i=1}^{3}\iint_S \Delta\sigma_i(\xi) R_{ji}(\mathbf{x},\xi)\, dS_\xi = u_j^{in}(\mathbf{x}), \qquad j=1,2,3, \quad \mathbf{x}\in S\,,$$

where u_j^{in} are the displacement components of the incident wave. The regularization and collocation techniques are implemented for solving the boundary integral equations numerically. Far-field scattering amplitudes, and near-field mixed-modes dynamic stress intensity factors in the inclusion vicinity are computed directly on this stage by using the ISJs. After that the solution of single scattering problem is applied to estimate the effective dynamic parameters of the composite materials containing randomly distributed inclusions of dilute concentration by Foldy's dispersion relation and introducing complex wave numbers of corresponding effective medium. Numerical results concern the influences of wave frequency, inclusion mass and direction of the wave incidence on the dynamic stress intensity factors near the inclusions (see Fig. 1). The attenuation coefficients and the effective velocities of longitudinal and transverse waves in 3D elastic composites containing parallel and randomly oriented rigid disk-shaped inclusions with the different mass distributions are also presented and discussed (see Fig. 2).

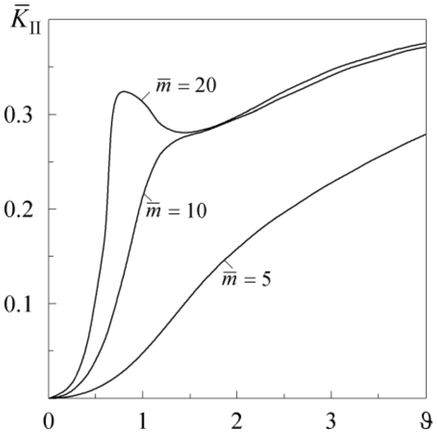

Figure 1. Effects of the inclusion mass $\bar{m}$ on the mode-II dynamic stress intensity factor $\bar{K}_{\mathrm{II}}$ as the function of wave number ϑ for normal incidence of longitudinal wave on the disc-shaped inclusion.

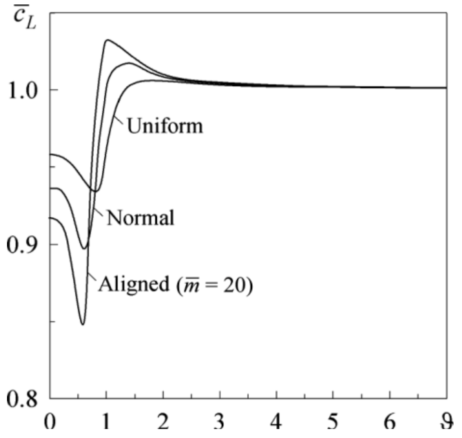

Figure 2. Effects of the inclusion mass distribution on the effective velocity of longitudinal wave $\bar{c}_L$ as the function of wave number ϑ for 3D composite with randomly oriented disc-shaped inclusions.

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