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DISCRETE AND CONTINUOUS SOURCE FUNCTIONS FOR MODELING OF COMPOSITES REINFORCED WITH PARTICLES AND SHORT FIBERS

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ABSTRACT

The numerical model is more efficient the better the approximation functions used to interpolate the field variables satisfy both the governing equations inside corresponding sub-domain and boundary conditions or inter-domain compatibility on its boundary. The numerical methods using functions which satisfy the governing equations in linear problems inside the domain are the Boundary Element Method (BEM), the Method of Fundamental Solutions (MFS), the Hybrid-Trefftz Finite Element Method (HTFEM), the Fast Multi-pole Method (FMM) and some other methods closely related to these. This feature is especially important in modelling the problems with micro-structure, where large gradients arise in the field variables between inter-domain boundaries of the structure with very different physical properties. Classical methods would require millions and billions of equations to simulate the problem in discretized form.

In our formulations triple dipole (source) functions are located into the centres of particles for simulation of materials reinforced by particles with aspect ratios close to one in order to simulate the interaction of particles with matrix as well as mutual simulation of particles in the composite material [1]. The continuity of displacements is satisfied in three pairs of points located on the lines connecting the centre of the particle with the particle boundaries in direction of the main strains (for spherical particles), or in direction of the main axis of the particle (for ellipsoidal particles). Very effective iterative solution with fast convergence is used to solve the problems with large number of particles.

For the interaction with domain boundary and/or with the Control Volume Element (CVE) boundary auxiliary source functions are included outside the simulated domain in order to reduce integration and for obtaining better accuracy of the model.

Recently, very attractive composite materials are materials reinforced by short fibres and with nanotubes. The aspect ratio of such reinforcing elements can be very large, as $10^2 – 10^4$ or even larger. Classical methods are ineffective to simulate the interactions of such materials. For this purpose we developed models using distributed forces and dipoles along the fibre axis [2]. Only 1D distribution of source functions is necessary to receive very good accuracy. The models show how important is to simulate accurately

the interaction. The topology of the fibres influences very strong the transmission of load in such composite and the stresses in the fibre can exceed the stresses in the matrix including the stresses in the interlayer by several orders.

It will be shown that, for simulation of composite material reinforced with curved or imperfect straight fibres, additional distributed couples are necessary to model such material.

The boundary conditions are satisfied in collocation points on the fibre boundaries in the form of differences of displacements in cross sectional direction to the fibre axis and in its longitudinal direction as well. In this way the rigid body motion of the reinforcing particles is also correctly simulated.

Source functions by dipoles are derivatives of the Kelvin solution (force acting in infinite medium) in direction of the acting force. The source function for a couple is the derivative in perpendicular direction to the force direction.

It will be shown that the Fast Multipole formulation has direct meaning with source functions used in the models and no Taylor expansions are necessary to obtain fast solution by our models and authors believe that the reductions of computational models by our method are simpler and even more effective.

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