A NEW ANALYSIS OF OVERALL THERMO-ELASTIC PROPERTIES OF RANDOM PARTICULATE NANO-COMPOSITES WITH VARIOUS INTERPHASE MODELS

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In the presentation a new (hierarchical) approach to analysis of thermo-elastic properties of random composites with interphases is outlined and illustrated. It is based on the statistical homogenization method – the method of conditional moments – combined with recently introduced notion of the *energy-equivalent* inhomogeneity which, in this presentation, is extended to include thermal effects. After exposition of the general principles, the approach is applied in the investigation of the effective thermo-elastic properties of a material with randomly distributed nano-particles.

The basic idea of equivalent inhomogeneity is to replace the inhomogeneity and the surrounding it interphase by a single *equivalent* inhomogeneity of constant stiffness tensor and coefficient of thermal expansion, combining thermal and elastic properties of both. The equivalent inhomogeneity is then perfectly bonded to the matrix which allows to analyze composites with interphases using techniques devised for problems without interphases.

From the mechanical viewpoint definition of the equivalent inhomogeneity is based on Hill's energy equivalence principle, applied to the problem consisting only of the original inhomogeneity and its interphase. It is more general than the definitions proposed in the past in that, conceptually and practically, it allows to consider inhomogeneities of various shapes and various models of interphases. This is illustrated considering spherical particles with two models of interphases, Gurtin-Murdoch material surface model and spring layer model. The resulting equivalent inhomogeneities are subsequently used to determine effective thermo-elastic properties of randomly distributed particulate composites. The effective stiffness tensor and coefficient of thermal extension of the material with so defined equivalent inhomogeneities are determined by the method of conditional moments. Closed-form expressions for the effective thermo-elastic parameters of a composite consisting of a matrix and randomly distributed spherical inhomogeneities are derived for the bulk and the shear moduli as well as for the coefficient of thermal expansion. Dependence of the effective parameters on the interphase properties is included in the resulting expressions, exhibiting analytically the nature of the size-effects in nano-materials. As a numerical example, the epoxy matrix with randomly distributed spherical glass particles is investigated. The dependence of the effective bulk and shear moduli, as well as of the effective thermal expansion coefficient on the particle volume fraction (for different radii of nano-particles) and on the radius of nano-particle (for fixed volume fraction of nano-particles) for different interphase models are compared to and discussed in the context of other theoretical predictions. Possible applications of the proposed approach to short-fiber composites with various types of interphases are discussed.

Keywords: effective properties, energy equivalence, Gurtin-Murdoch surface model, interphase, random composites, spherical equivalent inhomogeneity, spring layer model.