Effective elastic moduli and strength of multiphase composites with randomly located particles

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ABSTRACT

Multiphase materials are generally used due to their beneficial combination of mechanical, physical, and electrical properties compared to their constituent elements. In the past, numerous theoretical approaches have been proposed to predict these properties based on the properties of the constituent elements. Reinforcements could be continuous in the form of fibers, or discontinuous in the form of particles or whiskers. The prediction and estimation of overall mechanical properties of random multiphase composites are of considerable interest to engineers in many science and engineering disciplines. It is the scope of this work to use both analytical and numerical tools to evaluate the effective elastic moduli and strength of these materials, focusing initially in two-phase and three-phase materials containing uniformly and randomly distributed spherical particles.

The analytical work is based on the work of Ju et al. [1-2] and the numerical work on the development of parametric three-dimensional finite element models. The numerical models can evaluate the elastic moduli of every multiphase composite if the mechanical properties of the constituent materials and their volume fractions are known. Three distinct cases are examined with respect to particle distribution, i.e., uniform, random within a unit cell and random within the whole material system. Typical results for a two-phase system are shown in Figure 1 and are compared with experimental data [3]. In this case the matrix has a Young's modulus of 3 GPa and the particles of 76 GPa. Similar good accuracy was achieved for other materials especially for volume fractions up to 30%.

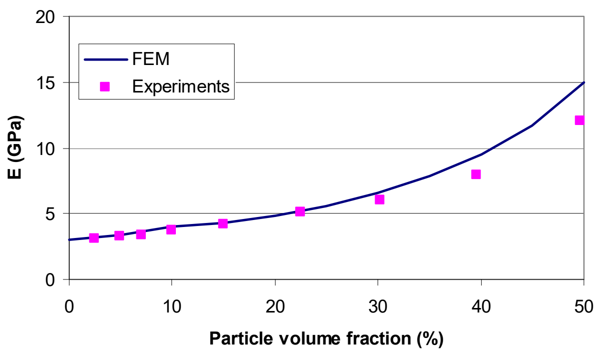

Figure 1: Effective modulus of elasticity

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The work was further extended to account for failure initiation both in the matrix and the matrix/particle interface. In general, the results of this early investigation suggest that randomness has a small effect on elastic moduli but significant effect on strength, both interfacial and matrix failure. Typical results of strength reduction due to the presence of more stiff particles are presented in Figure 2.

Furthermore, for the three-phase materials, an optimization study was carried out in order to design materials with specific stiffness and strength. This is based on the selection of "optimum" materials for the particles and appropriate volume fractions. This study used both analytical expressions and the three-dimensional finite element models. The work is currently extended to account for the prediction of damage evolution using a progressive damage evaluation algorithm.

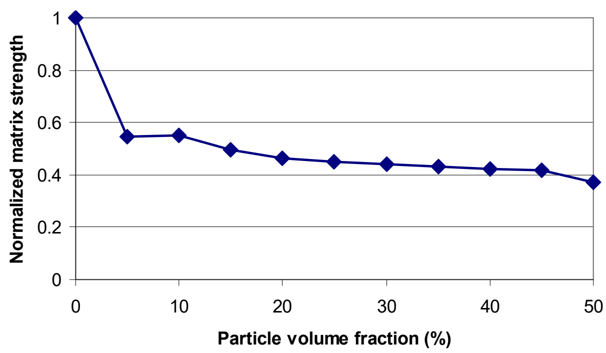

Figure 2: Normalized strength

References

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