OPTIMIZATION OF THERMOELASTIC TWO-PHASE COMPOSITES USING ANALYTICAL AND NUMERICAL HOMOGENIZATION

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The aim of the presented study is to develop efficient and reliable procedures for finding the optimal microstructures in view of the potential applications of composite materials in structural elements.

Proper estimation of the overall properties of heterogeneous materials using micromechanical analysis is a problem that has been studied for a long time. Nowadays, multiple micromechanical models exist, most of them basing on the Eshelby solution. Eshelby's problem assumes a single ellipsoidal inclusion in an infinite elastic medium, being subject to a homogenous external load located at the infinity. Among mean-field models originating from this fundamental solution, the Mori-Tanaka method is most widely used for composite materials. In this model, the medium material is the matrix material, while the far-field quantities are replaced by the average fields in the matrix phase. Unfortunately, the above mentioned classical models fail to describe properly the scale effects related to the inclusion size as well as their space distribution within the sample. A cluster model proposed by Molinari and El Mouden [1996,2000] for the assessment of elastic and thermal properties was the solution for the problem. In the cluster model an elementary cubic volume containing finite number of N inclusions is created which is then periodically reproduced to fill the desired space This analytical model provides a way for finding optimal microstructures regarding the desired characteristics (like e.g. strength, weight or thermal insulation).

Based on the above mentioned solutions, the presented work aims to create virtual representative unit cells - elementary cubic volumes of materials that allow both regular and random spatial distribution of non-overlapping inclusions in a matrix. Such sample cells are next subject to computational homogenization using the Finite Elements Method software in order to calculate global outcome values. Analyses of series of different samples allow to obtain the overall strain-stress relationship which can be a base for determination of the average macroscale parameters of the entire composite material.

Results from the FEM are then compared with the cluster model predictions for validation purposes. In the future, it is planned to also validate the theoretical results with tests on physical samples created using 3D-printing techniques.

This process may provide a tool for optimization. Different engineering tasks may require balance between different parameters of materials, e.g. high stiffness, low thermal expansion and proper thermal conductivity while staying below weight limits. Efficient procedures for finding the optimal microstructures may help in creating quick and cost-effective design tools.

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