Development of a finite element strategy for the modeling of thermo-elastic nano-reinforced materials

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Abstract – For nanoreinforced materials, the inclusion surface/ matrix volume ratio is important. Therefore, matrix/reinforcement interface behavior has a major influence on the local and effective material behaviour. Focusing on thermo-elasticity, a numerical approach based on the finite element method is developed for nanomaterials with imperfect coherent interface modeling. For the numerical analysis, a convergence study is performed for multiple homogenization schemes with different boundary conditions.

Keywords: Nanocomposites, imperfect interface, thermo-elastic, numerical modeling, homogenization.

I. Introduction

A nano-composite material can be defined as a composite material where at least one of its constituents' sizes is at the nanoscale. Nanocomposites offer better material physical properties than the classical composites [1] even for small volume fractions of reinforcements. These good properties can be explained by the increase of the interface inclusion/matrix ratio. This phenomenon is known as the size effect, since this ratio increases as the size of the reinforcements decreases. This particularity of nanocomposites can be exploited to design smart materials, which is an explored way for the development of lightweight structures that integrate a maximum of functions. With the increasing use of nanocomposites, numerical and analytical tools are needed to understand and predict their multiphysical behaviour.

II. Interface modeling for nanocomposites

The nanocomposite models have to take account the size effect. In the case of elastic materials, the interface can be considered as a thin elastic layer connecting the matrix and the inclusions. Using asymptotic expansion in these thin regions [2], a stress-strain relationship of the matrix-inclusion interface can be introduced. Thanks to the generalized Young-Laplace equation governing the matrix-inclusion interface equilibrium allows the introduction of size effect in micromechanical models.

III. Numerical strategy

Focusing on homogenization, the analytical solutions of the effective material parameters require simple inclusions geometry (spherical, cylindrical) and are often limited to elastic behaviors. To overcome such limitations, numerical approaches have been proposed in the literature to handle more complex inclusion geometries and non-linear behaviors. To the best of our knowledge, only few studies have been carried out in the scope of thermo-elastic materials with imperfect interfaces. In this work, the finite element method using interface elements [3,4] is considered without additional degrees of freedom to study the influence of imperfect (coherent) interface on the effective moduli for a thermo-elastic material. For the numerical analysis, a convergence study is carried out for multiple homogenization schemes with different boundary conditions.

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