New Approach to Predict the Micromechanical Behavior of a Multiphase Composite Material

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Abstract

The present work focuses on the study of the behavior of composite multiphasic. In this work, the behavior of composite multiphasic has been studied in terms of prediction, in order to contribute to present a micromechanical approach behaviors using the homogenization methods. The first step is to know the behavior of the composite material, and the second step to consider consite injected fibers in the first matrix behavior considered, ie two-stage homogenization for the equivalent behavior. The Mori Tanaka Model has been used to predict the mechanical behavior. The use of this model is based on its compatibility with the composites at high fiber volume content. The results obtained in the simulation using a programming language are compared with those from analytical modeling of the mechanical behavior of composite homogenized.

Keyword: Composite, composite multiphasic, Behavior, Homogenization.

1. Introduction

Multiphase materials most often the result of the assembly of two materials. The combination of different materials usually also gives the composite new properties that each component can provide alone.
In this work the insulator matrix Silica (SiO2) has been studied. The Barium Titanate (BaTiO3) has been selected as intrinsic piezoelectric material used as fillers[4]. The Methods of homogenization used to estimate the macroscopic properties of a heterogeneous material from the properties of the constituent phases and some parameters characterizing their spatial distributions. The objective of this work is to develop a model to predict the micromechanics behavior of a matrix composite reinforced by particles. This model is based on the description of the processing across the grain and scale transition technique of Mori-Tanaka, the fillers orientation is also used in this model.

2. Mathematical formulation

The composite is examined assumed a compound matrix, denoted by the index m and inclusions denoted by the index ‘r’. These inclusions can be aligned or randomly oriented in the matrix.[1]

2.1 The self-consistent model

All reinforcements are assumed embedded in a homogeneous medium called equivalent, having the effective properties $C_{eff}$. [5]

$$C_{eff} = C_m + \sum_{r=1}^{n} f_r (C_r - C_m) \left[ I + S^{Eh}_{eff} C_{eff}^{-1} (C_r - C_{eff}) \right]^{-1}$$

2.2 The approximation of Mori Tanaka:

This model assumes that the reinforcement is embedded in an infinite medium having the properties of the matrix:

$$C_{eff} = C_m \left[ I + \left( \sum_{r=1}^{n} Q_r \right) \left[ I + \sum_{r=1}^{n} f_r (S^{Eh}_{r} - I) Q_r \right]^{-1} \right]^{-1}$$

where: $Q_r = \left( C_m - C_r \right) S^{Eh}_{r} - C_m \left( C_r - C_m \right)$

2.3 The influence of the orientation of the inclusions on the behavior

2.4

By introducing the transition matrix (3 Euler angles)

$$C_{eff} = C_m \left[ I + \left( \sum_{r=1}^{n} f_r P_r Q_r P_r' \right) \left[ I + \sum_{r=1}^{n} f_r P_r (S^{Eh}_r - I) Q_r P_r' \right]^{-1} \right]^{-1}$$

Where: $P_r$, orientation matrix where transition matrix.[5]

In this part of mathematical modeling, a method of homogenization of piezoelectric composite (Mori Tanaka) was developed in our previous work. We recall the main equation obtained by the method of Mori Tanaka in the case of composite with an elastic inclusion.
3. Application and interpretation of results

In this section, we implemented the equations in the MATLAB software programming, and we have taken as an application, the piezoelectric composite: Silicon Dioxide/Barium Titanate (SiO2/BaTiO3).[3]

Table 1 summarized the mechanical properties of the matrix and the filler.

<table>
<thead>
<tr>
<th></th>
<th>Young’s Modulus (GPa)</th>
<th>Poisson’s ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO2)</td>
<td>107</td>
<td>0.3</td>
</tr>
<tr>
<td>Barium Titanate</td>
<td>33</td>
<td>0.33</td>
</tr>
</tbody>
</table>

*Table 1: Mechanical properties of SiO2 and BaTiO3.*

In the first step, the self-consistent model is used to obtain the $C_{eff}$ actual properties of the composite Silica and barium titanate.[4] The $C_1$ equivalent behavior thus obtained is then considered in the second stage, as a new matrix to which are added the piezoelectric fibers. The elastic behavior equivalent homogeneous $C_2$ (composite tri-phasic) is then obtained using the method of Tanaka, Mori.

To validate our model, we simulated our program with the method of terminal models mentioned above “Voigt and Reuss”, while retaining the data previously used in the case of an insulator (silica).

Three-phase piezoelectric composite gives significant results compared with a biphasic composite. Is therefore observed that our model is almost between the lower terminal of Reuss and Voigt superior terminal, which has been predicted theoretically, it can only confirm the efficacy of our model.[3]
4. Conclusion

Here we introduced the following homogenization methods, simulation elastic behavior of composites consist of at least three phases: step 1: get lespropritétés actual $C_1$ of the composite Silica and barium titanate. $C_2$. The equivalent behavior thus obtained is then considered in the second stage, as a new matrix which are added piezoelectric fibers. The effect of fiber on the elastic behavior is important. In this work we presented a study of piezoelectric fiber composites, based on the homogenization model Mori Tanaka, it was developed in the case of a material that contains a high quantity of inclusions. The results offer information on the behavior of piezoelectric composites.

It appears clearly, that a relatively large increase of the volume fraction of inclusions and the orientation of the inclusions has an effect on material composite.

So we can conclude that:
- The rigidity of the material increases and depends on the volume fraction (more volume fraction increases mor deformation also increases).
- three-phase piezoelectric composite gives significant results compared with a biphasic composite.

The method models terminal “lower bound of voigt and upper bound of Reuss” allowed us to test and validate our model.

References


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