International Journal of Research Studies in Science, Engineering and Technology
Volume 5, Issue 5, 2018, PP 19-22
ISSN : 2349-476X

New Homogenization Model to Predict the Micromechanical Behavior of a Multiphase Composite Material Case: Copper and Silica With Barium Titanate

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ABSTRACT

The present work deals with the study of the behavior of the multiphasic piezoelectric composite. The behavior of the multiphasic composite has been studied in terms of prediction, in order to contribute to present a micromechanical approach behavior by means of the homogenization methods namely Mori Tanaka, Eschelby and Vogt and Reuss are used to estimate the macroscopic properties of a heterogeneous material from the properties of the constituent phases and some parameters characterizing their distributions. we used two matrices one consisting of an insulator that is silica (SiO2) and the other is a matrix in the form of a conductor that is copper (Cu). Barium titanate (BaTiO3) was chosen as the intrinsic piezoelectric material used as fiber. The primary objective of this work was to update the model developed in later studies [7], in order to predict the micromechanical behavior of a material. multiphase composite reinforced with fibers that are both insulators or conductors. The second objective was to compare the results found in different scenarios. The results obtained in the simulation using a programming language are compared with those resulting from the analytical modeling of the mechanical behavior of homogenized composites. We have proved that our results are adequate and show that piezoelectricity works very well when using insulators, so a stiffness that is better. In the end, we validated by simulation our model in different cases it is always between two bounds of voigt and Reuss.

Keywords *Piezoelectricity, Composite multiphasic, Behavior, Homogenization, Voigt and Reuss, Eshelby*

INTRODUCTION

Multiphase materials are most often the result of assembling multiple materials. The combination of different materials generally gives the composite new properties that each component can provide alone.

In this work, we will use two matrices one consisting of an insulator that is silica (SiO2) and the other is a matrix in the form of a conductor that is copper (Cu). Barium titanate (BaTiO3) has been chosen as the intrinsic piezoelectric material used as fiber [6].

The methods of homogenization namely Mori Tanaka, Hashin and Strickma, Voigt and Reuss are 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 first objective of this work is to update the model developed in later studies [7], in order to predict the micromechanical behavior of a multiphase matrix composite material reinforced by fibers that are both insulators and conductors. to make use of the various methods of homogenization mentioned above.

The second objective of this study is to compare the results found in the different cases, namely those found during the simulation of our model for the two types of matrices (silica and copper), the latter were taken separately and together.

MATHEMATICAL FORMULATION [6],[7]

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]

The Self-Consistent Model

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

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

The approximation of Mori Tanaka:

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

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

Where: $Q_r = \left[(C_m - C_r) S^{Esh} - C_m \right]^{-1} (C_r - C_m)$

The Influence of the Orientation of the Inclusions on the Behavior

By introducing the transition matrix (3 Euler angles)

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

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 cas of composite with an elastic inclusion.

Application and Interpretation of Results

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

Table1. Mechanical properties of SiO2 and BaTiO3.

	Young's Modulus (GPa)	Poisson's ratio
Silica (SiO2)	107	0.3
Barium Titanate (BaTiO3)	33	0.33

Table2. Mechanical properties of Cu and BaTiO3.

	Young's Modulus (GPa)	Poisson's ratio
Copper (Cu)	90	0.33
Barium Titanate (BaTiO3)	33	0.33

To begin, we have used the self-consistent model to theoretically develop to obtain the actual Ceff properties of silica composite / barium titanate and copper / barium titanate [4]. The equivalent behavior thus obtained is then considered in the second step, as a new matrix to which the piezoelectric fibers are added. The homogeneous equivalent elastic behavior (triphasic composite) is then obtained using the method of Tanaka, Mori and Hashin and Strickman. Subsequently the Voigt and Reuss terminals were served for the validation of the model.

Figure 1 shows the result found during simulation of Copper as matrix and Barium Titanate as fiber while remaining in the case of a triphasic composite. This result was displayed in the three cases Mori Tanaka, Voigt and Reuss and Hashin and Strickman.

After analyzing these results, we found that our model gives better results when using a multiphasic composite instead of a biphasic composite and this has been demonstrated in the study cited in references [7].

Second observation, we have proved that our results are similar to those found in the study carried out beforehand [6], the latter show that piezoelectricity works very well when using insulators which shows the last figure, so a rigidity that is better.

In the end, we validated by simulation our model in different cases it is always between the two terminals Voigt and Reuss.

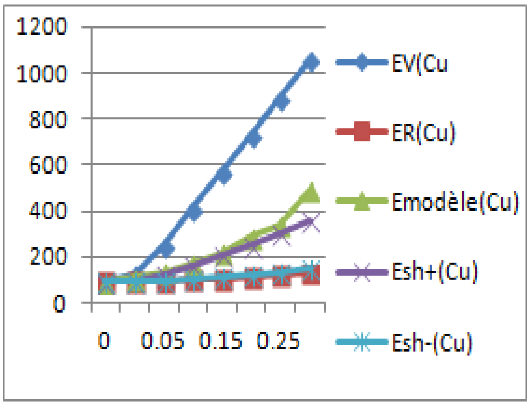

Figure1. *The result found during simulation of Copper as matrix and Barium Titanate as fiber*

The following figure shows the result found when simulating Silica (matrix) and Barium Titanate as fiber, our composite is considered triphasic. This result was displayed in the three cases Mori Tanaka, Voigt and Reuss and Hashin and Strickman.

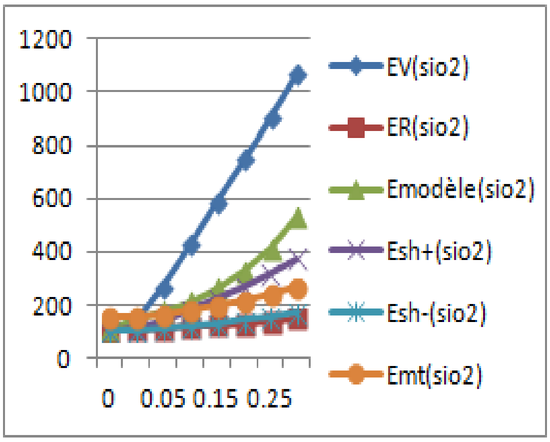

Figure2. T*he result found during simulation of Silica as matrix and Barium Titanate as fiber*

In order to be able to compare our result in the case of copper and silica as a matrix, we have superimposed the different results found in the two cases, which shows the following figure [3]

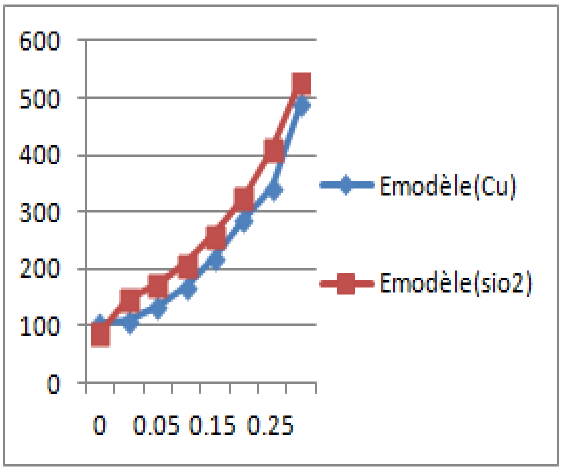

Figure3. *Comparative Results Between Silica And Copper As A Matrix*

Conclusion

In this work, we used two matrices one consisting of an insulator that is silica (SiO_2) and the other is a matrix in the form of a conductor that is copper (Cu). Barium titanate ($BaTiO_3$) has been chosen as the intrinsic piezoelectric material used as fiber [6]. The homogenization methods namely Mori Tanaka, Eschelby and Vogt and Reuss are 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 first objective of this work was to update the model developed in later studies [7], in order to predict the micromechanical behavior of a fiber-reinforced multiphase matrix composite material that are both insulators or conductors. to make use of the various methods of homogenization mentioned above. The second objective was to compare the results found in the different cases of those found during the simulation of our model for the two types of fibers (Silica and copper) the latter were taken both separately and together.

After analyzing these results, we found that our model gives better results when using a multiphasic composite instead of a biphasic composite which gives a better rigidity what has been demonstrated in later studies [7].

We also proved that our results are similar to those found in the pre-study [6], the latter show that piezoelectricity works very well when using insulators, which shows the last figure, therefore a stiffness that is better.

In the end, we validated by simulation our model in different cases it is always between the two terminals Voigt and Reuss.

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Citation: *Z. Sadoune,I. Elguesse and A. Echchelh (2018). "New Homogenization Model to Predict the Micromechanical Behavior of a Multiphase Composite Material Case: Copper and Silica With Barium Titanate", International Journal of Research Studies in Science, Engineering and Technology, 5(5), pp. 19-22.*