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Numerical Modeling of the Effects of Fiber Packing and Reinforcement Volume Ratio on the Transverse Elasticity Modulus of a Unidirectional Composite Material Glass / Epoxy

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ABSTRACT

Composite materials are very widely used in the manufacturing of structures because of their specific mechanical properties. However, they are characterized by heterogeneity and anisotropy and they present great challenges in designing and also in predicting their behavior by using the numerical simulation. The unidirectional composite material has a more relevant property which is the transverse elasticity modulus E_2. The determination of E_2 is still interesting researchers because of the diversity of results obtained by several models and approaches. This study aims to predict the transverse elasticity modulus E_2 of a unidirectional Glass/Epoxy composite material, the effect of the arrangement fibers on the transverse elasticity modulus and predict the values of the reinforcement factorξ used in the Halpin-Tsai model. To do so first we adopted the micromechanical approach, which is accurate but requires much computing, and we used a calculation code based on FEM method and considered two parameters to vary, which are the volume fraction of fibers and the distribution of fibers. The obtained results of numerical modeling were tightly compared to those obtained by the available analytical models and the adopted approach can be used to predict the transverse elasticity modulus E_2 and the reinforcement factor ξ.

1. INTRODUCTION

Today, composite materials are more and more used in the realization of structures in many fields such as transport, automobile, shipbuilding, sports accessories and more particularly aeronautics and aerospace because of their high performance/mass ratio compared to other more conventional materials such as steel or aluminum and also the possibility of obtaining complex shapes by reducing the number of leads, this is due to the use of materials with specific mechanical characteristics such as carbon, glass or Kevlar and the use of the production processes layer by layer with molds and counter molds [1-4].

Unidirectional composites are those that have all fibers aligned in one direction, their mechanical properties vary with the orientations of the fibers therefore these materials are anisotropic. The strength of unidirectional composites in the direction of the fibers is generally dominated by the properties of the fibers while in the transverse direction it is dominated by the properties of the matrix. However, the heterogeneity and anisotropy of composite materials present great challenges to the design of structures, consequently to the numerical simulation of their behavior. In order to respond to these challenges, the current trend is multi-scale modeling because it makes it possible to predict the effective response of heterogeneous materials from their microstructure, and it even gives the possibility of designing new materials with desired or optimized properties. There are two basic approaches are usually considered in the modeling of composites: the macromechanical approach and the micromechanical one.

In the macromechanical approach, the composite is considered as an anisotropic material and the details of the arrangement of the constituent materials are ignored and the micromechanical one aims to develop solutions to be able to predict the effective behavior of a heterogeneous anisotropic material depending on the behavior of the constituent materials and their arrangement [5]. Most theories of homogenization are limited to a few idealized mathematical models of two-phase systems. Many analytical approaches have been developed over the years [6-8], and comprehensive bibliographic studies have been published on the prediction of longitudinal and transverse elastic modulus of unidirectional composites, the estimation of the reinforcement factor ξ and the use of the model of Halpin-Tsai to determine the transverse elasticity modulus E_2 [9-18].

The analytical methods provide a reasonable prediction for relatively simple configurations of the phases for example square or triangular arrangements of the fibers but when it is about complex geometries numerical methods are used for approximate solutions by simplifying hypotheses on microstructures and boundary conditions, as it is the case with finite element method. Numerical methods for calculating the properties of composite materials generally involve the analysis of a representative volume element (RVE).

This work aims mainly to predict the transverse elasticity modulus of a unidirectional Glass/Epoxy composite material with different values of fiber volume fractions, to study the effect of the arrangement randomize of the fibers on the values of the transverse elastic modulus and to predict the values of the reinforcement factor ξ.