Accepted Manuscript

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PII: S0266-3538(18)31341-1

DOI: 10.1016/j.compscitech.2018.09.016

Reference: CSTE 7398

To appear in: *Composites Science and Technology*

Received Date: 4 June 2018

Revised Date: 14 September 2018

Accepted Date: 15 September 2018

Please cite this article as: Sevenois RDB, Garoz D, Verboven E, Spronk SWF, Gilabert FA, Kersemans M, Pyl L, Van Paepegem W, Multiscale approach for identification of transverse isotropic carbon fibre properties and prediction of woven elastic properties using ultrasonic identification, *Composites Science and Technology* (2018), doi: https://doi.org/10.1016/j.compscitech.2018.09.016.

Multiscale Approach for Identification of Transverse Isotropic Carbon Fibre Properties and Prediction of Woven Elastic Properties using Ultrasonic Identification

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Abstract

In this work the possibility to reverse engineer the transverse isotropic carbon fibre properties from the 3D homogenized elastic tensor of the UD ply for the prediction of woven ply properties is explored. Ultrasonic insonification is used to measure the propagation velocity of both the longitudinally and transversally polarized bulk waves at various symmetry planes of a unidirectional (UD) Carbon/Epoxy laminate. These velocities and the samples' dimensions and density are combined to obtain the full 3D orthotropic stiffness tensor of the ply. The properties are subsequently used to reverse engineer the stiffness tensor, assumed to be transversely isotropic, of the carbon fibres. To this end, four micro-scale homogenization methods are explored: 2 analytical models (Mori-Tanaka and Mori-Tanaka-Lielens), 1 semi-empirical (Chamis) and 1 finite-element (FE) homogenization (randomly distributed fibres in a Representative Volume Element). Next, the identified fibre properties are used to predict the elastic parameters of UD plies with multiple fibre volume fractions. These are then used to model the fibre bundles (yarns) in a meso-scale FE model of a plain woven carbon/epoxy material. Finally, the predicted elastic response of the woven carbon/epoxy is compared to the experimentally obtained elastic stiffness tensor. The predicted and measured properties are in good agreement. Some discrepancy exists between the ultrasonically measured value of the Poisson's ratio and the predicted value. Nonetheless, it is shown that virtual identification and prediction of mechanical properties for woven plies is feasible.

Keywords: Multiscale modeling, Constituent Property Identification, Textile composites, UD Composites, Ultrasonic Testing

1. Introduction

Multiscale modelling for fibre reinforced composites promises more accurate prediction of the stiffness and the occurrence of several subcritical damage mechanisms up until final failure of the composite materials. In practice, this is done by modelling the small scale constituents and their interactions as individual entities. For Fibre Reinforced Plastics (FRP), the existing approaches can be categorized according to the length scale on which these entities are

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