COMPUTED-TOMOGRAPHY BASED MODELING OF TEXTILE COMPOSITE MATERIALS

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Summary: The present work focuses on computed-tomography based modelling and simulation of thermo-chemo-mechanical behaviour of carbon/epoxy 2D and 3D textile composites for aircraft applications. Dedicated segmentation procedures were developed to retrieve the real geometry and orientations of the composites and its defects. Then, image based finite element models are built through different meshing strategies at local and global scales.

1. INTRODUCTION

The recent introduction of Organic Matrix Carbon Fibre Reinforced Textile Composites (OMC) in aeronautical structures subjected to long term environmental ageing and fatigue needs robust finite element models to predict their long term durability. Due to the complex heterogeneity of 2D and 3D OMC, those models should be based on volumetric observation and deep understanding of complex phenomena that occur in the different phases of the composite. Micro-computed tomography (CT) allows to observe and characterize the 3D volumetric evolution of OMC geometry, cracks and defects, but the understanding of their interaction needs to simulate the OMC thermo-mechanical response at local scale to take into account small discontinuities. The real architecture, can be obtained by 3D image processing of CT Scans, but specific procedures should be developed, in particular to identify the local orientation of carbon fibres in the different yarns. In this work, a novel approach to segment phases and extract fibres 3D orientations will be presented and then applied to build 3D finite element models of 2D and 3D textile composites.

2. IMAGE BASED MODELISATION METHOD

Laboratory CT is a useful technique to image OMC bulk geometry, however the size of representative specimens can be thousands times the size of carbon fibres (~5 to 6µm). Therefore, as fibres in the yarns are poorly discretised in such specimens, specific segmentation procedures should be developed to retrieve their local orientations from CT scan. In recent works several approaches were employed to retrieve fibres directions: gradient based technique [1-3] or morphological operations [4]. Those techniques need a regularization before derivation, here we propose to use wavelet decomposition [5] to enhance the texture at the optimal scale. Segmentation of the different phases of the composite can be therefore conducted and 3D orientations associated locally to each interweaving tows.
Different strategies can be employed to mesh the 3D geometry of the composite. Voxel based approach [6] is one of the simplest way but this approach leads to a non-efficient description of the geometry. Stairs like boundaries result from cubic shape of the elements and local discontinuities should be idealized to minimize the huge number of elements. Another possibility is to generate conformal mesh of the material interfaces with comparably small number of nodes. Image mesh libraries using Delaunay or Marching Cube family algorithms can be employed, but mesh quality is directly linked to smoothness of the segmented interfaces. In this work we use an approach inspired by different studies in computer graphics (see for ex. [7]). The idea is to extract the smooth interface mesh from multi-materials image with following surface remeshing and volumetric meshing. Moreover, following a previous work [8-9], we propose the implementation and the development of a technique of analysis based on a "global-local" approach. It allows to simulate "hierarchically" (at different scales) the behaviour of critical zones of a tested sample. The strategy is – creating a multi-physic model at 3 different scale levels where result of analysis of higher level will be used as boundary conditions at lower level model (the models are joined using the submodeling technique). Here we titled these models (corresponding to the scale level): ply level, tow level and fibre level (micro-scale) models. At each level we used different image-based meshing approach: voxel mesh – at ply level, smooth

interface reconstruction with following tetrahedral volumetric meshing – tow level and 2D mesh extruding – at fibre level (see ***Figure 1***). Finally, some results of multi-physic simulation using global-local approach will be presented.

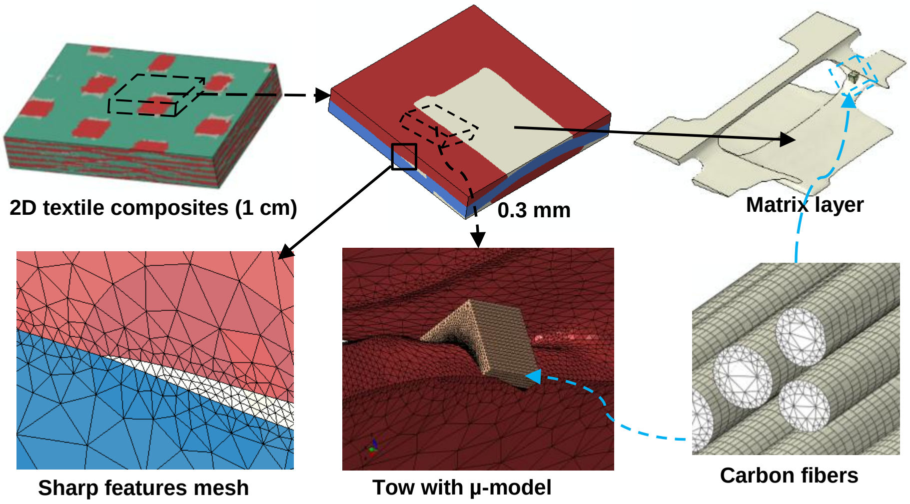

Figure 1 *Image-based model construction*

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