11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

MULTI-SCALE MODELLING OF THE MECHANICAL BEHAVIOR OF TEXTILE REINFORCEMENTS

H. Attia[1,2], D. Durville[1] and P. Letallec[2]

[1] LMSSMat Ecole Centrale Paris, 92290 Chatenay-Malabry France
houda.attia@ecp.fr, damien.durville@ecp.fr
[2] LMS Ecole Polytechnique, 91120 Palaiseau France
patrick.letallec@polytechnique.edu

Key words: *Textile Reinforcements, Multi-scale Strategies, Mechanical Properties*

Introduction

The role of textile reinforcements is particularly important in the development of composite materials with optimal performances in terms of mechanical behavior and weight, whose use is increasing in various fields such as tire, aeronautic and automotive industries.

In our study we are interested in unidirectional textile reinforcements, made of bundles of fibers which are twisted together to form yarn. The global mechanical behavior of these yarns is very complex, and largely controlled by contact-friction interactions taking place between elementary fibers. This kind of structure is characterized by continuous features along its longitudinal direction, although it should be considered as a discrete assembly in its transversal directions. Since the trajectory of each filament within the yarn depends on the assembly process, the initial configuration of such structures can not be known a priori, and the assembly process needs therefore to be simulated.

Besides mechanical properties at macroscopic scale, the determination of local stresses at the fibers scale is very important to predict the occurrence of damage. A finite element code, based on an implicit solver, has been developed in order to simulate the mechanical behavior of such fibrous materials [1, 2]. However, due to computational costs, the use of this approach is limited to structures made of few hundred fibers, whereas cords in the scope of our study are formed of few thousand fibers.
The purpose of this work is to develop a multi-scale approach to characterize mechanical properties of such material with a large numbers of fibers, at different scales. This approach is based on the introduction of so-called macro-fibers, aimed at representing the behavior of bundles of filaments.

Multi-scale approach

Macroscopic scale:
The problem at macroscopic scale is set on assemblies of macro-fibers. The identification

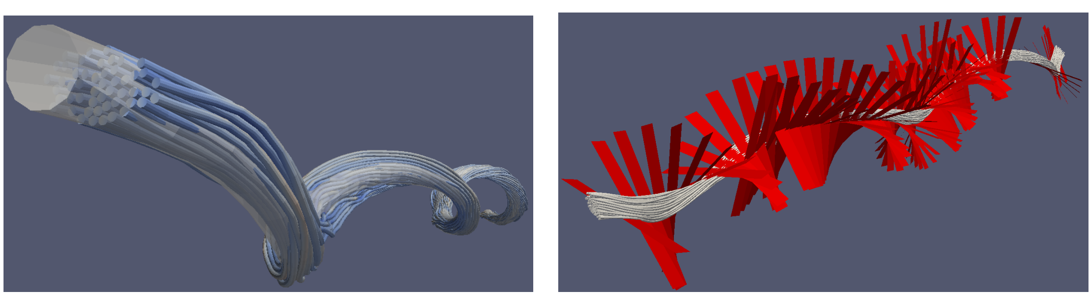
of an accurate mechanical behavior of macro-fiber, able to represent deformations in transverse directions mainly governed by friction interactions within the discrete assembly of filaments, is very complex. To avoid this difficulty, the present approach is based on the assumption that the main features of the mechanical behavior at microscopic scale can be represented at macroscopic scale through compaction effects. An adapted contact law between macro-fibers is developed for this purpose to control their local density. Parameters of this law are adjusted based on the analysis of phenomena originating at microscopic scale, in relation with the compaction of fibers.

Microscopic scale:
The objective here is on one hand to assess the local stresses within fibers in order to predict damage phenomena and on the other hand to access to the local density of fibers chosen as an error estimator. The formulation of the problem at the microscopic scale is driven by relevant selected quantities inherited from the problem at macroscopic scale. Two kinds of boundary conditions derived from results at macroscopic scale are applied to the local problem:

- The trajectory of the macro-fiber imposed by means of average conditions to the set of fibers forming the macro-fiber;
- Normal contact interactions between macro-fibers applied to the local problem through moving planes whose normals have the same orientations as contact interactions.

Numerical results

The proposed multi-scale strategy has been implemented in a finite element code. First numerical results are presented.



(a) (b)

Figure 1: Example of numerical result - a) Local geometry of the set of filaments inside a macro-fiber ; b) Local problem with moving planes.

REFERENCES

[1] D. Durville. A finite element approach of the behaviour of woven materials at microscopic scale. *Mechanics of microstructured solids*, 39–46, 2009.

[2] D. Durville. Contact-friction modeling within elastic beam assemblies: an application to knot tightening. *Computational Mechanics*, 49 (6), pp. 687-707, 2012.