# COMPOSITE REINFORCEMENT FORMING SIMULATION: CONTINUOUS AND MESOSCOPIC APPROACHES

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## 1 Introduction

Continuous and discrete approaches are possible for the forming simulations of composite textile reinforcements because of their multi-scale structure In this paper a continuous modelling based on a hypoelastic constitutive model is first presented. A discrete (or mesoscopic) approach is also considered in which each yarn is modelled by shell finite element and where the contact with friction and possible sliding between the yarns are taken into account. Finally the semi-discrete approach that is more or less intermediate is presented. The advantages and drawbacks of the different approaches are discussed.

## 2 Continuous and discrete approaches

The approaches to model the forming of textile composite reinforcements belong to two main families that are related to the scale at which the analysis is made. The textile reinforcement is a set of yarns (and a set of fibres). The analysis of the deformation can be made considering and modelling each of these yarns (or fibres) and their interactions (contact with friction). In this case the approach is called discrete or mesoscopic. Of course the number of yarns is high and the interactions are complex. On the opposite, the continuous approaches consider a continuous medium juxtaposed with the fabric and the mechanical behaviour of which is equivalent to those of the textile reinforcement. This mechanical behaviour is complex because it concerns large strains and strong anisotropy. Furthermore, it strongly changes during the forming.

The present paper aims to present continuous and discrete approaches for thin (2D) composite reinforcements forming simulations. First a continuous approach is described within a membrane assumption. An algorithm based on a hypoelastic behaviour is proposed for the simulation of composite reinforcement forming processes. It is shown here that using hypoelastic law with an objective derivative based on the warp and weft fibre rotation tensors can correctly trace the specific behaviour of the woven materials (Fig. 1).

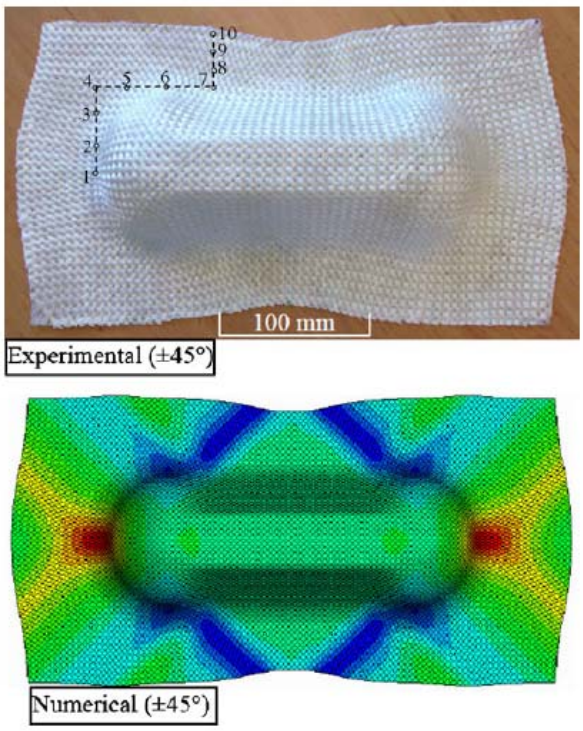


Fig.1. Simulation of the double dome forming (international benchmark described in [1]) using a continuous hypoelastic approach [2]

In discrete modelling (also called meso-modelling in the case of textile material), the modelling does not directly concern the textile material but each fibre bundle. This one is modelled by elements simple enough to render the computation possible because it concerns the forming of the whole composite

reinforcement and the number of yarns and contacts between these yarns is very large. The interactions between warp and weft directions are taken into account explicitly by considering contact behaviour and relative motions between the yarns are possible [3].

The fibrous nature of the yarn is taken into account in this model especially in order to have rigidities in bending and transverse compression very small in comparison to the tensile stiffness. In any case, a compromise must be found between a fine description (which will be expensive from the computation time point of view) and a model simple enough to compute the entire forming process

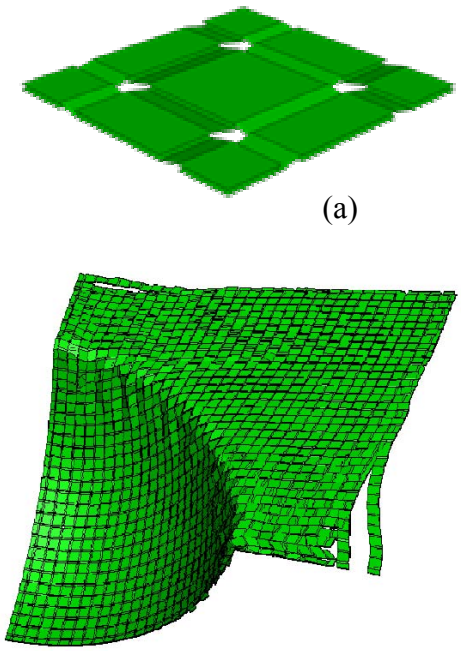


Fig. 2. Simulation of hemispherical forming test using a discrete approach based on the unit cell model (a)

The discrete (or mesoscopic) approach is attractive and promising. The very specific mechanical behaviour of the textile material due to the contacts and friction between the yarns and to the change of direction is implicitly taken into account. If some sliding occurs between warp and weft yarns, they can be simulated. This is not possible by the continuous approaches that consider the textile material as a continuum. This is an important point because it can be necessary to prevent such a sliding in a process.

The semi-discrete approach aims to avoid the use of stress tensors and directly define the loading on a woven unit cell by the warp and weft tensions and by in-plane shear and bending moments [4]. These quantities are simply defined on a woven unit cell and above all they are directly measured by standard tests on composite reinforcements (biaxial tension, picture frame, bias extension and bending tests).

A set of simulations of mono and multilayer forming using semi-discrete elements such as show figure 3 will be presented.

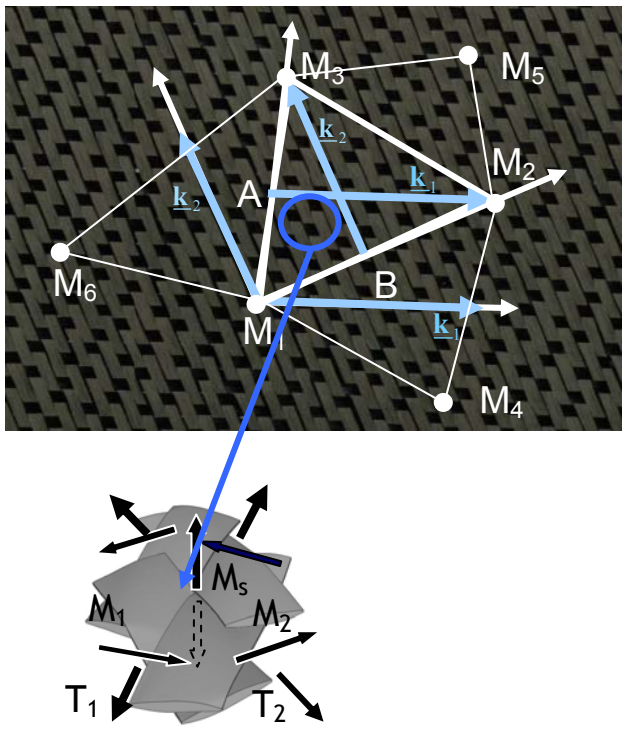


Fig 3. Rotation free three node finite element made of unit woven cells[4]

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