NUMERICAL MODELLING OF THE WEAVING PROCESS FOR TEXTILE COMPOSITE

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Abstract: In order to develop 3D carbon textile structure into turbine blade for civil airplanes, we have to predict its geometry and its mechanical properties. NUMTISS project aims to develop a model for composite production, from the weaving process until the resin infusion. Carbon fibres are damaged during the weaving process which leads to mechanical strength losses of the fabric. The purpose of this study is to develop a numerical model of the deformation of the yarn. The existing softwares for fabrics modelling are only used for a geometrical modelling of the free structure without resin. NUMTISS contribution is from getting distorted dry fabric structure, by "reproducing" numerically the weaving process. The expected advantage is a precise geometrical modelling of the modified structure without resin.

1. Introduction

Over the past decade there has been a significant amount of research interest in the field of textile process modelling and fabric-reinforced geometrical modelling. Indeed some numerical model exists for the braiding [1] process and the knitting process [2], but not yet for the weaving process. Existing tools like Wisetex [3] or Texgen [4] are only reproducing a geometric modelling with no strain deformation. Especially, our research should bring a sharp knowledge of the mechanical fields from the pre-stressing dry structure and ideally modelling yarns damages.

2. Experimental study

To understand the mechanics of weaving process in a Dornier loom, the tracking of parts motion of some strategic elements on the industrial weaving loom (reed, heddles, rapier,..) have been carried out. The tracking obtained from the video of the high speed camera will help us to check the cinematic of the numerical model.

2.1. Images tracking of the loom parts

The videos were taken on a Dornier® loom, using a high speed camera Photron APX (maximum resolution of 1024 x 1024 pixels to 2000 FPS), producing a fabric with multifilament fabric 1100 dtex PES (yarns density: 10.5 yarns/cm for warp density and 10 yarns/cm for weft density). An appropriate lighting device appropriate was used to film in good conditions the kinematics of weaving. Images tracking has been performed for production speed of 350 RPM and 450 RPM.
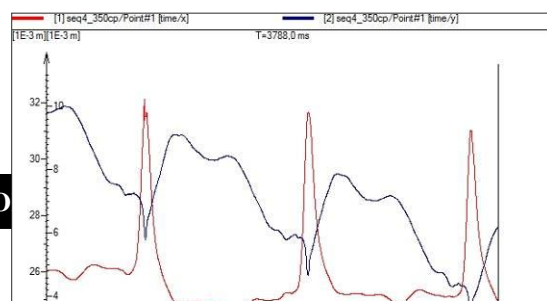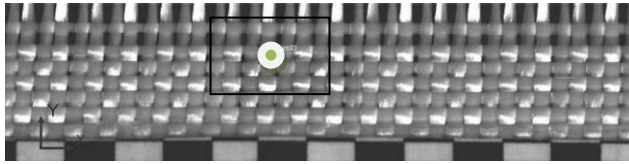
Figure 1*: Frame took with the high speed camera (top view).*

Figure 2 shows a periodic peak corresponding to the deformation of the weft yarn when it is beaten by the reed. The video tracking results will help us later to confirm the numerical modelling performed on Radioss.

3. Numerical model (FEM)

For the numerical modelling of the weaving process using finite element method, we considered all elements (cf. Figure 3) like rigid solid, and we will make the hypothesis that yarns are transverse isotropic elastic materials.
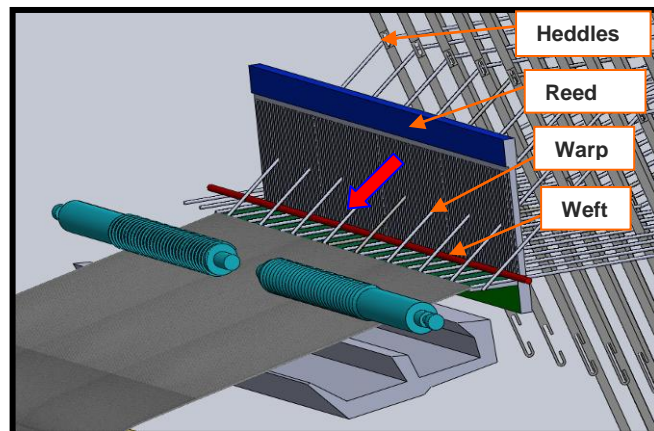
Figure 3*: Geometrical modeling of the weave forming zone [5].*

For finite element modelling of weaving, HyperMesh was used like a pre-processor (for setting up), RADIOSS Block (Explicit schema) like solver, and HyperView for post-processing (results visualization) [6].

For modelling, it was decided to represent firstly only three warp yarns and four weft yarns. Indeed, high speed camera results achieved previously on a loom have highlighted that the influence zone of reed compaction spreads over 4 weft yarns (cf. figure 1).
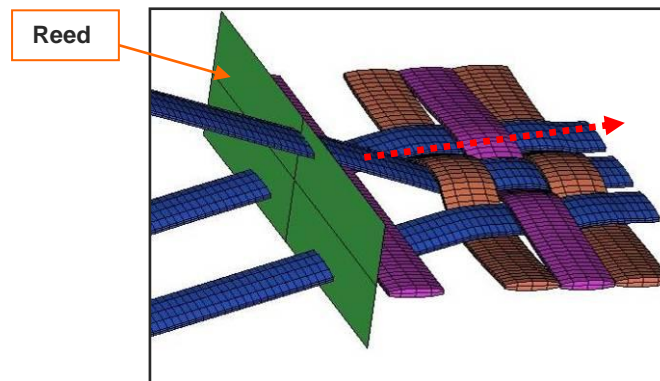
3.1. Yarns setting up

Yarns were modelled with a transverse isotropic elastic law. For meshing parts, 8-nodes hexahedra solid elements were used (figure 4). Material law of aramid yarn was embedded in a first place, but will be replaced later by E-Glass material law.

Figure 4: *Meshing of yarn section with solid elements.*

3.2. Reed setting up

Reed was modelled by a steel plate composed of 4 quadrilateral elements, in which an horizontal displacement has been imposed (figure 5).

Figure 5: *Configuration of the weave forming zone in the present study.*

3.3. Contact setting up

Contacts between weft yarns and warp yarns were represented like contacts between deformable surface, and contact between the reed and the weft yarns as a contact between a master surface (reed) and slave nodes (weft) [7].

3.4. Boundary conditions

-Warp yarns displacement is set by the simulation of heddles vertical move.

-Weft yarns are constrained to a free horizontal movement. Weft yarns tension that occurred during weaving is modelled by blocking weft yarns extremities.

-The weave forming zone is modelled by a rigid plate that can stop weft yarn when the reed is beating.

Heddle

3.5. Kinematic simulation with Radioss

Since the model is computed using explicit schema with finite element code Radioss, it was decided to perform an acceleration of the weaving kinematic for decreasing computation time. The weaving cycle which lasts 600 ms for a weaving speed of 100 RPM, was accelerated to 1.6 ms for our model. Being at high speed is not a problem for the moment, as the material behaviour's law is independent of strain rates. The computing time required was approximately 4 hours –with 4 CPUs, for modelling the production of a weave fabric compounds of 3 warps and 4 wefts yarns.
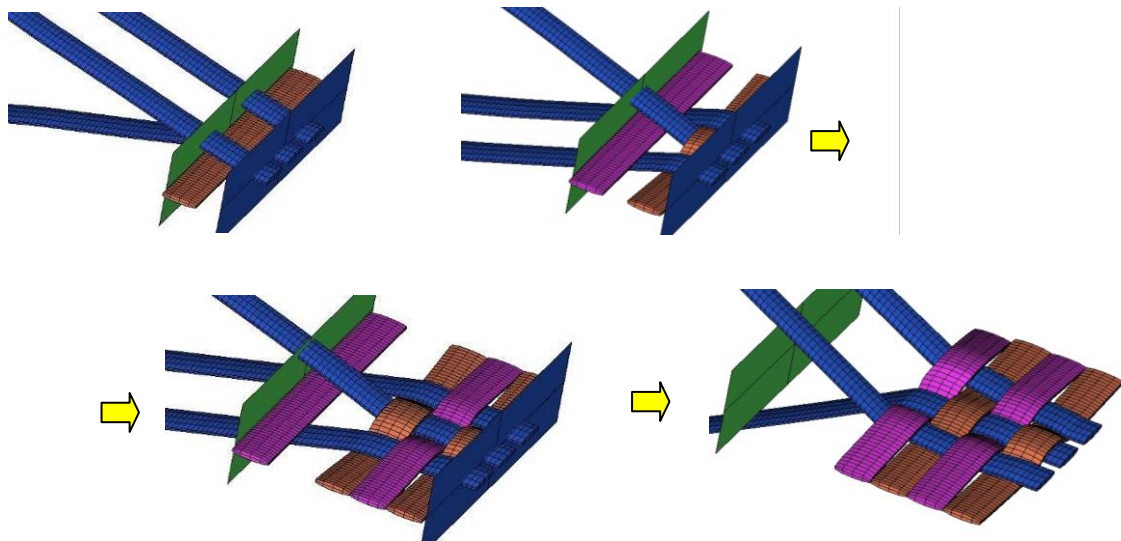
Figure 7: Kinematic simulation of the weaving process.

A numerical model was performed to describe strain phenomena of yarns when we produce plain weave. The current model will be refined taking into account the geometry of a glass cross section, which will be obtained by curing yarns on a loom. Good stiffness

coefficients, good friction coefficients and a "transverse" behaviour's law will be implemented later. The sequencing of the weaving process will be optimized in the model to match the weaving process on a Dornier® Loom.

In mid-term, a comparison of the actual geometry and that one from the numerical simulation will be performed using simple criteria to define. The actual fabric geometry should be scanned by tomography or another method.

Acknowledgements :

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