Textile Process Simulation for Composite Structures

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1 ARENA2036 DigitPro: The digital Prototype

Since about three years, DigitPro, a sub-project of the government funded research project **A**ctive **R**esearch **E**nvironment for the **N**ext generation of **A**utomobile (ARENA2036) works on the development of a digital Protoype, a closed simulation process chain which covers different simulation disciplines starting with process analysis right up to crash. Along this chain various material modeling approaches on the micro-, meso-, and macro level of a carbon fiber reinforced plastic (CFRP) components are being used. The research work of ITV in DigitPro are basically process simulations using thread models are which are weaving, draping and infiltration. Braiding simulation is difficult but less complex as weaving simulation, so braiding simulation is used to test and validate new functions of LS-DYNA (explicit). Micro µ-CT technology is used to analyze reinforcement fabrics in structure, fiber orientations permeability determination, modelling and validation propose. In the presentation, focus is laid on a new weaving process called "Open Reed Weaving" (ORW). Here an additional thread system is added to a plain 0°/90° woven fabric which leads to an multiaxial woven textile with local reinforced areas. As part of the process chain the goal is to generate realistic models to investigate the material properties of this multiaxial fabric with by simulation.
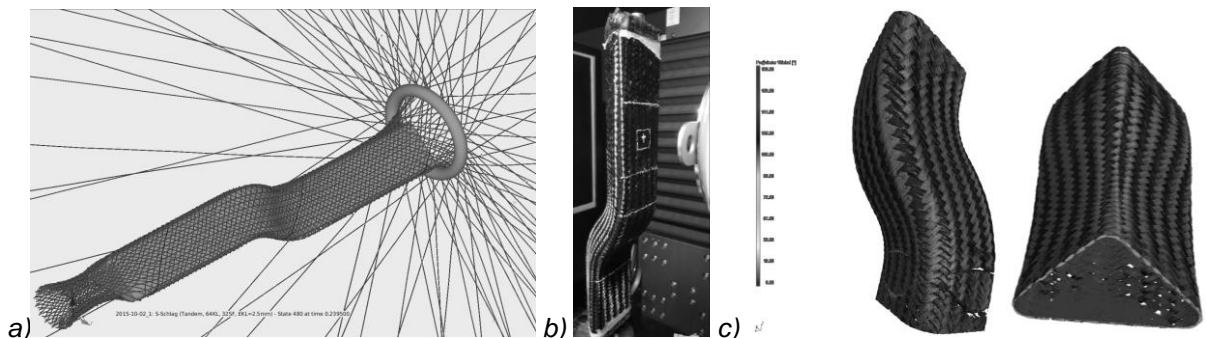
2 Braiding process simulation

Fig.1:   Triaxial braiding simulation (a), µ-CT analysis (b), fibre orientation analysis of CT-scan (c)

The triaxial braiding simulation fig. 1a for a challenging triangle and s-curved geometry allows analyzing influence of braiding parameter as thread tensions, speed, mandrel movement and the friction dependent fiber laying to the mandrel. The model is validated by high resolution X-ray (µ-CT, nanotom m) and fiber orientation analysis (fig. 1c). The process simulation was improved referring reduction of computation time, contact and numerical stability. To reduce the simulation time, threads should be extended during process simulation. This could be achieved by using combination of ***ELEMENT_SEATBELT_RETRACTOR** and ***ELEMENT_SEATBELT.** This lead to good results, but now by using the new implemented functionality ***ELEMENT_BEAM_SOURCE** (requested by ITV since several years) the computation time could be further reduced by approx. 20%. Therefore, this solution is the first choice for the complex and very computationally intensive weaving simulations.

3 Open Reed Weaving process – Multiaxial woven textiles

Here two additional thread systems are placed in the plain 0°/90° woven fabric. The Open Reed Weaving (ORW) technology enables the addition of diagonal threads into the weaving process by using horizontally movable thread guides arranged between the reed and weaving shafts of the weaving machine. These additional warp fibers can be added partially or covering the whole width of the textile. Orientation of the 3rd or 4th thread system can varied independently between 0° and nearly

90° along the warp direction depending on the yarns linear density. The ITV has produced a wide range of textiles with various designs and textile constructions composed of varying materials and roving types. Fig. 2a shows the weaving machine with a multiaxial fabric composed of glass fibers with local carbon fiber reinforcement. The multiaxial yarns are supplied from the top (middle of the image) and being lead through the horizontal movable needlebars (large white blocks). Fig. 2b shows a version to reinforce areas of holes in composites.
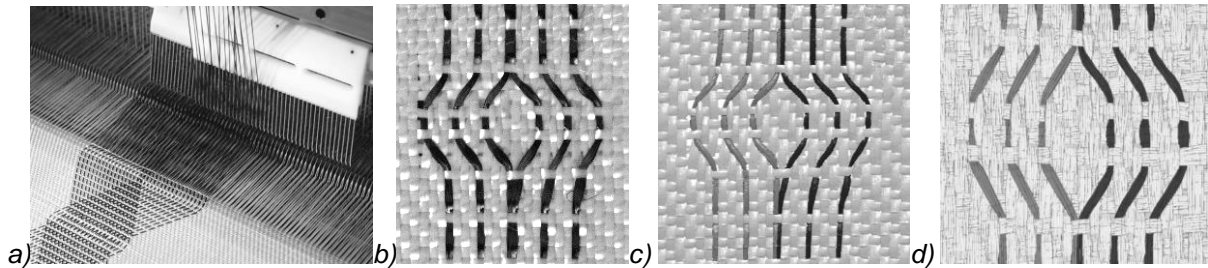

a)   b)   c)   d)

Fig.2: Open Reed Weaving Machine (a), Textile made of glass fiber twill as base fabric and local carbon fiber reinforcement threads (b), result of μ-CT (c) and FEM simulation (d).

The pre-processing of such a complex weaving machine with many threads is a tedious and error-prone task. Therefore, a parameter driven python program has been developed to perform this repeatable task with minimal effort and minimal error. All machine parts are modeled as rigid bodies, boundary conditions are put up automatically for all parts, depending on the given weaving parameter as they are used for real weaving machine. Threads are modeled as beams using the new beam source functionality for each filament. Fig. 3b show the result of ORW fabric with hole reinforcement.
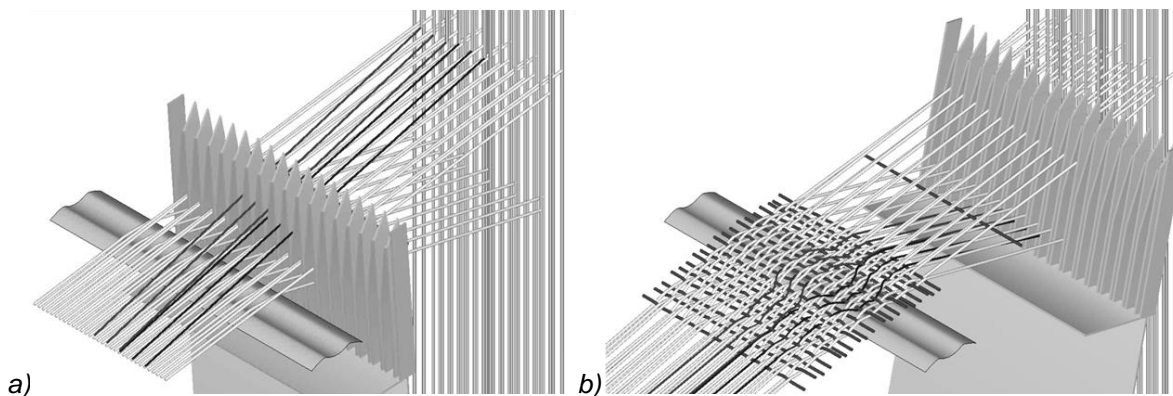

a)   b)

Fig.3: Initial simulation model after generation from python code (a), Result ORW-Simulation (b).

4 Post-processing and verification by computer tomography

Due to computation time in process simulation monofilaments are used. To transform singe filament in multifilament model the exported beam mesh is reimported into developed python code where a multifilament yarn on the centerline of beam mesh is generated. By using initial penetrations check a very realistic multifilament model of the ORW fabric (fig. 2d) could be is created. The comparison to high resolution micro-CT scan (fig. 2c) shows that the simulation of the weaving process is capable to of generating a realistic multifilament model of an ORW woven textile.

5 Outlook

Described process simulations will be improved further on and will be an important tool to get realistic simulation models using input parameters from real braiding and weaving machine. This models will be used to compute mechanical properties and by homogenization methods to evaluate large composite parts before it is produced and so play an important part of the closed simulation process in to evaluate the virtual material properties and to assess the whole modeling approach.

6 Summary

This presentation gives an overview on the potential of the newly developed process simulations "Braiding" and "Open Reed Weaving" and will introduce the use of virtual textile for material testing.