"Simulation Of Three-Dimensional Technical Textiles"

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ABSTRACT

Within the bounds of a research project, sponsored by the Nordrhein-Westfalen Innovationsfond 2001, will be created an appendix module for a 3D-capable standard CAD-system at the Hochschule Niederrhein. This module should describe and simulate three-dimensional textiles with regard to geometry and material data. The simulated textiles base on the three-dimensional weaving method, Shape Weaving.

INTRODUCTION

Textile fabrics in general

Conventional textile fabrics are two-dimensional. In many cases these fabrics are made of threads (yarns, cabled and folded yarns, monofilaments, wires) or fibres or filaments. Textiles made of threads are woven, knitted and stitched fabrics. Textiles made of fibres or filaments are needled, pads and wool felts. These fabrics are wound onto a cloth beam at the end of the production process.

Conventional design processes

Until now the production of textile fabrics, adapted to a three-dimensional form, were achieved by the following methods:

1. Transforming:
   deep drawing of a two-dimensional textile
   limit: drape ability of the 2D-textile

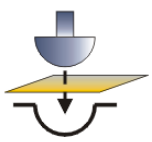

Fig. 1: Transforming

2. Manufacturing:
   cutting/punching out and assambly (through sewing, sticking together etc.)
   limit: quality and costs

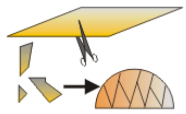

Fig. 2: Manufacturing

3. Fibre spraying:
   application of cut fibres through the spraying method
   limit: mechanical load-bearing capacity

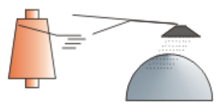

Fig. 3: Fibre spraying

By now there are possibilities to adjust textile fabrics already to a certain shape during their production process: the so-called 3D-textiles. Through this processes the later ready-made is not necessary. Disturbing and eventually quality reducing joins will be avoided. A high strength and form stability of the textile can be guaranteed. The final product has a lower weight and a more homogeneous surface. Furthermore, the lower number of personnel and the clear reduction of cutting waste save costs.

OVERVIEW OF 3D-TEXTILES

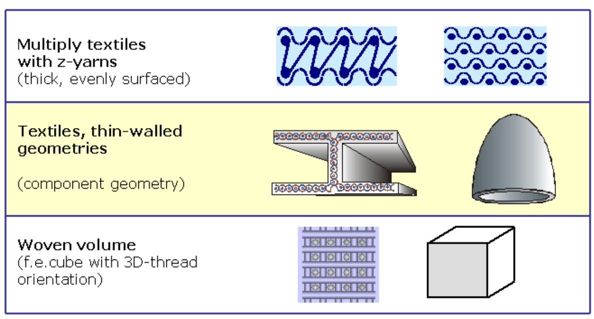

Fig. 4: 3D-textile

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SHAPE WEAVING

One process to produce 3D-textiles directly on the weaving machine is the Shape Weaving process developed by the company Shape 3 Innovative Textiltechnik GmbH. The integration of different long warp and weft yarns during the weaving process is the principle of this process. Through these surplus yarn lengths the textile expands into the third dimension.

Problems

The writing of a database for the 3D weaving is very expensive at this stage.
First, it has to be determined which length is needed for every warp yarn. This is done by manual measuring of the prototypes regarding warp and weft yarn lengths. Hence, the quality of a 3D-textile depends largely upon the accuracy of this measurement. In a second step the weave constructions – adjusted to the 3D shape - have to be defined. These will be defined on the basis of experience values. Only by weaving of the whole product the problem areas will be apparent. To control any made changes the complete product has to be rewoven. Until now, only after extensive single trials you got a sufficient result. There is also the fact, that the determined data are not reproducible and the database has to be completely redone by the use of minimal changes (yarn strength, fabric weight etc.)

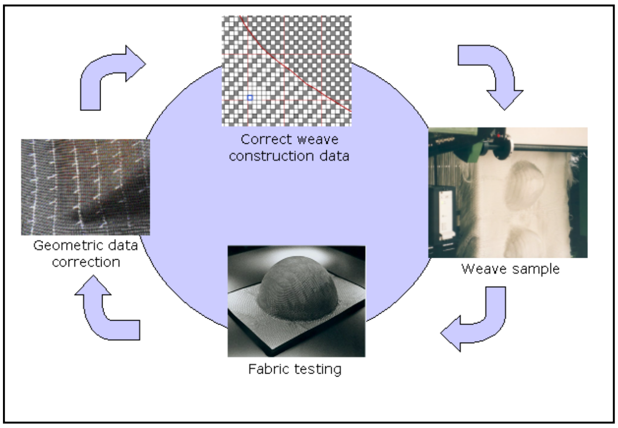

Fig. 5: Previous procedure, optimisation weaving trials

To reduce this expenditure, a CAD-appendix-module to the AutoCAD program was created, with them, in the future, a simulation will replaces the weaving trials.

CAD-SIMULATION

Modules

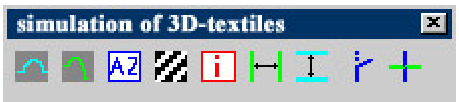

Fig. 6: Menu simulation

1. drawing up of the warp yarns
2. drawing up of the weft yarns
3. drawing up of file with warp yarn lengths
4. drawing up of weave construction file
5. dialogue box to determine the limiting values
6. control and maintaining of the maximum weft and warp yarn distance
7. control of the maximum warp yarn disorientation
8. control of maintaining of the minimal cross angle of warp and weft

Production of warp and weft yarns

By activating the button "drawing up of the warp yarns " a dialogue box starts, in which the user has to determine the textile data (yarn density, material, order of warp-ends, yarn courses). Hence, the simulation process is detailed shown in the following figures 7 up to 14

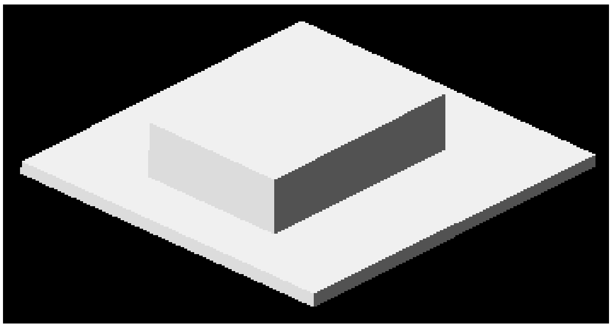

Fig. 7: Component geometry

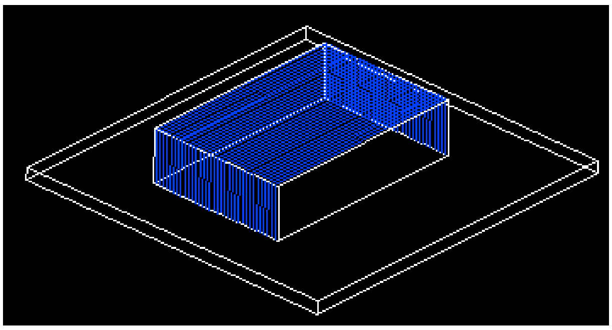

Fig. 8: Component analysis: cross-section in weft direction

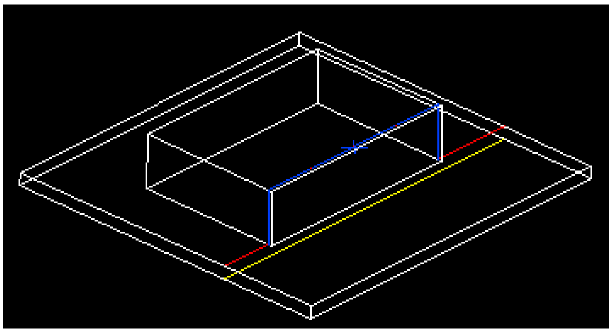

Fig. 9: Guideline for the spreading lays at the widest part of the component.

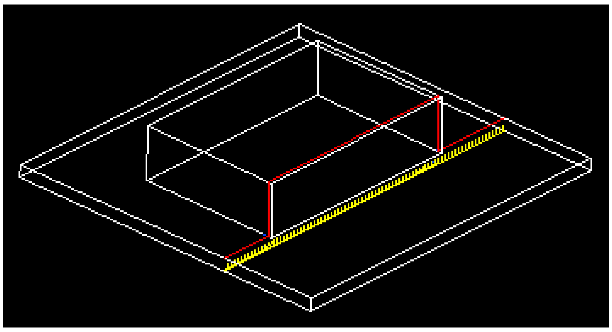

Fig. 10: Place points with the distance of the guidelines in the 2D-area.

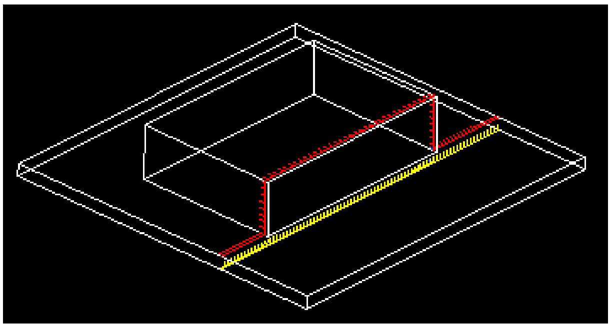

Fig. 11: Transmit 2D-distance in 2D- and 3D-area => spreading

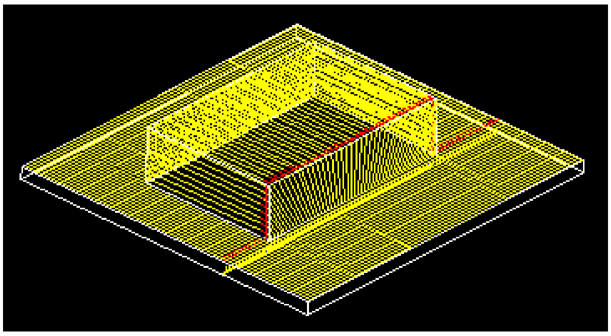

Fig. 12: Spreading of the guidelines

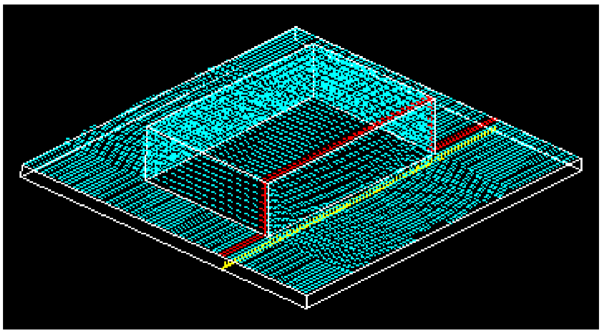

Fig. 13: Placing of the warp yarn points on the guidelines

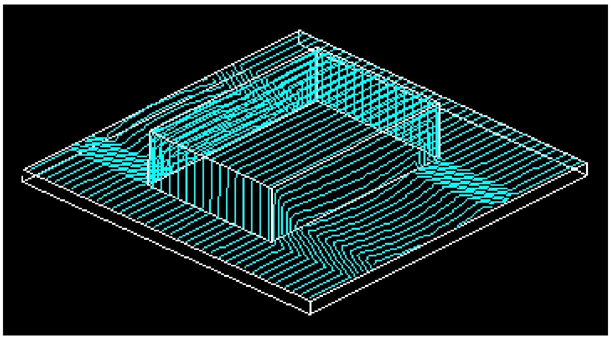

Fig. 14: Warp yarns by connecting the points

The drawing up of the weft yarns takes place in the same way as that of the warp yarns. It will be created guidelines, on which the guide points for the weft yarns are placed. The drawing up of both yarn systems consequently takes place completely independent of each other.

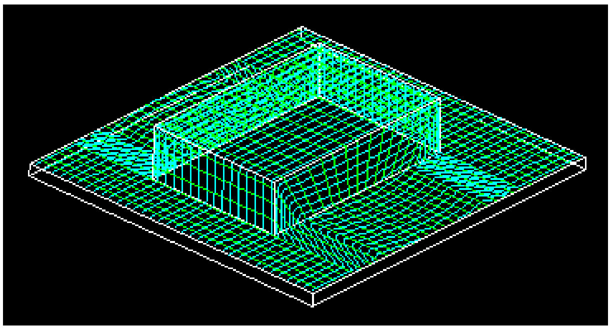

Fig. 15: Parallel warp and spread weft yarns

Examination of the limiting values

The production of a 3D-textile is tied to certain restrictions (limiting values):

- Yarn lengths and yarn distances:
  The individual length of a warp and weft yarn, is dependend on the machine and is limited to a maximum value, which has to be determined here. This must not to be exceeded in the textile construction. Furthermore, the slipping strength and the cover factor limit are the biggest or rather the smallest permitted yarn distances.

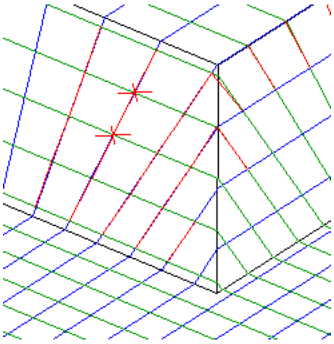

Fig. 16: Schematic depiction yarn distance

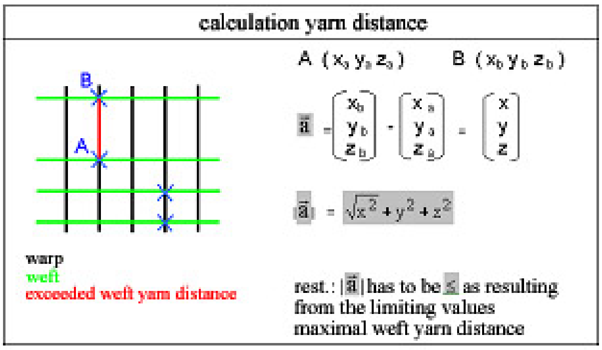

Fig. 17: Calculation yarn distance

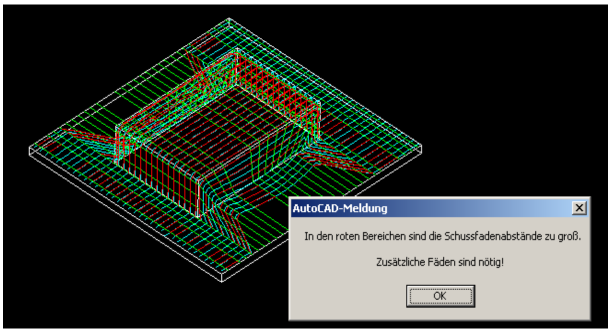

Fig. 18: Screenshot yarn distance

If the maximal yarn distance is exceeded, a red mark on the prevailing place appears in the simulation and the insert of minimal one additional weft yarn is necessary.

- Maximal yarn disorientation:
  This value describes the change of the yarn orientation (warp = 0°, weft = 90°) both geometry wise and also caused through the user by means of some machine elements. The maximal permitted disorientation depends on the yarn strength, the yarn density and the material, here for example 40°.

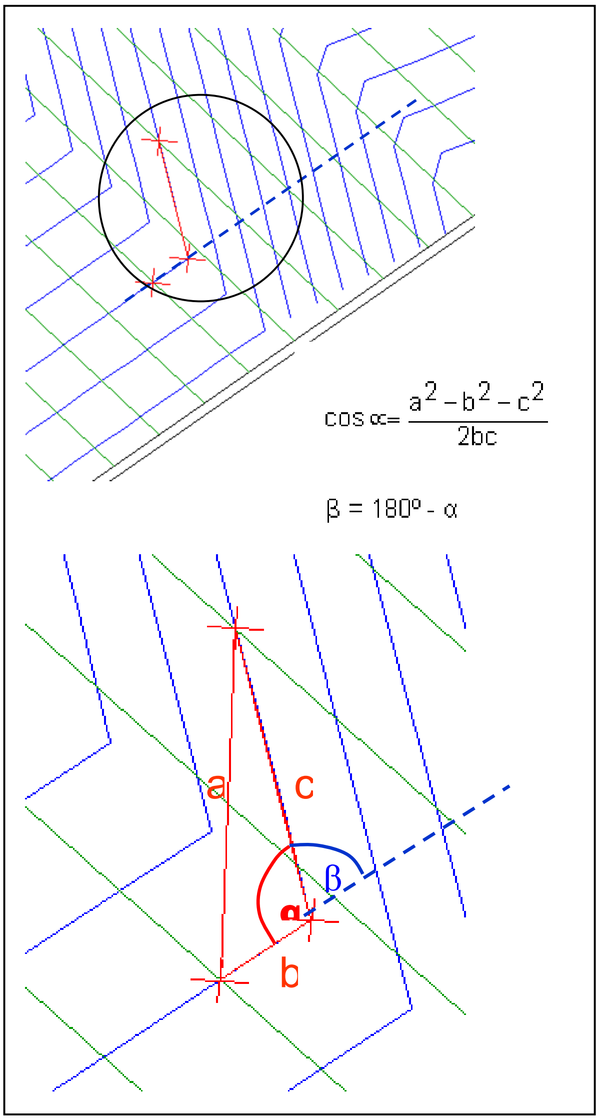

Fig. 19: Schematic depiction yarn disorientation

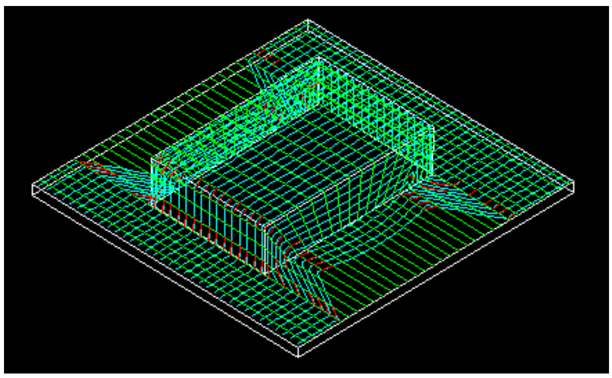

Fig. 20: Screenshot yarn disorientation

Yarns, which create the component without spreading, that means they have in every point the same distance to each other, will be disorientated from their original straight course because of the geometry. Too strong disorientations lead to heading formation, creases or other fabric faults.

- Deviation of the cross-angles:
  Owing to the 3D shape the cross-angles between warp and weft change from 90° to other values. This limiting value depends on the textile construction and has to be redefined depending on yarn strength and yarn density. For example, as limiting value can be tolerated a derivation of 5° for a 67tex Ramie yarn with 12 threads/cm in warp and weft.

Results of the project:
comparison of simulation and practice

As an example a rectangle suitcase shell is simulated as 3D-carbontextile. The demands affect especially the visible surface, which as a clear-varnished design area should not contain defects and irregularities if possible. The warp yarns are laid with a constant distance across the whole shape. The weft yarns are planned in the 2D-area of the textile with constant distances and in the 3D-area of the textile with constant spreading, which is brought proportional into line with the surface enlargement.

The result of the simulation shows clearly the problematic areas of the 3D-textile. The surrounding 2D-textile is strongly compressed on both sides of the suitcase shell from the outer edges to the middle. The warp yarns do not anymore orientate themselves in production direction, but incline towards the textile centre. Simultaneously the warp yarn density increases up to 56% of the origin yarn density. It becomes clear, that especially the weave construction has to be designed in the right way to weave the shape satisfactory.

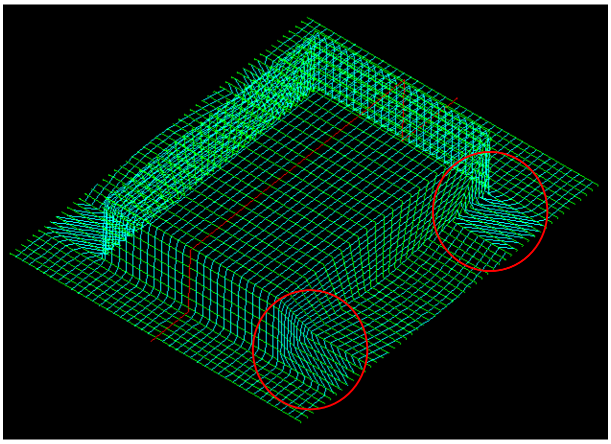

Fig. 21: CAD-simulation suitcase shell

Fig. 22: Result: 3D-woven suitcase shells

The geometry woven to control of the simulation shows in fact the feared defects on the described areas. Because the weave construction was here not adjusted, the textile bulges uncontrolled into the air caused by the increased yarn density outside of the original suitcase shell.

This first practice comparison makes clear, how the 3D textile construction can be improved through the simulation.

CONTINUATION

The current work on the simulation look into the graphical depiction of the weave construction as well as into the combination of weave constructions and yarn densities. Here the right prediction of the cover factors is particularly important. Furthermore, weaving trials should be carried out, which allow a comparison between simulation and practice.