COMPUTER AIDED WOVEN FABRIC DESIGN

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Abstract
Fabric properties and fabrics structure prediction are important in each industry domain. Generally all professional CAD for woven textiles system will be able to achieve basic fabric simulation and production output. A good CAD system should enable you to create design (dobby and jacquard woven fabric) ideas quickly and easily to enhance the way that you already work. The differences between competing systems fall mainly into the following categories: Ease of use; Speed of Operation; Flexibility of Operation; Advanced features; Technical support; Ongoing Software Development. Computer simulation or prediction is oriented on standard woven fabric, technical textile, composites.
Key words: fabric, properties, weave, sett, CAD, threads, warp, weft

1. Introduction

Generally computer fabric design that is oriented on standard woven fabric, technical textile, composites is possible to distinguish on two parts:

1) CAD systems which is possible to use for fabric design creation and production – weaving. These systems are compatible with electronic dobby or jacquard mechanism.
2) CAD systems for calculation woven fabric structure as well as for prediction individual woven fabric mechanical and end-use properties.

CAD systems should enable you to create design (dobby and jacquard woven fabric) ideas quickly and easily to enhance the way that you already work [1, 2, 3, 4]. The differences between competing systems fall mainly into the following categories: Ease of use; Speed of Operation; Flexibility of Operation; Advanced features; Technical support; Ongoing Software Development.

1.1 Possibilities in woven fabric CAD systems – selected CAD systems

1.1.1 3D Weave module

Has been developed by EAT's Thinktank [1]. 3D Weave gives the user the tools to create complex multi-layer weaves or to analyze existing weaves and complete JC files. Similar to the EAT simulation module, yarn thickness, colour, and warp and weft density may be set and displayed individually. Separate layers can be isolated and edited on its own or the whole fabric can be viewed and manipulated as a whole.

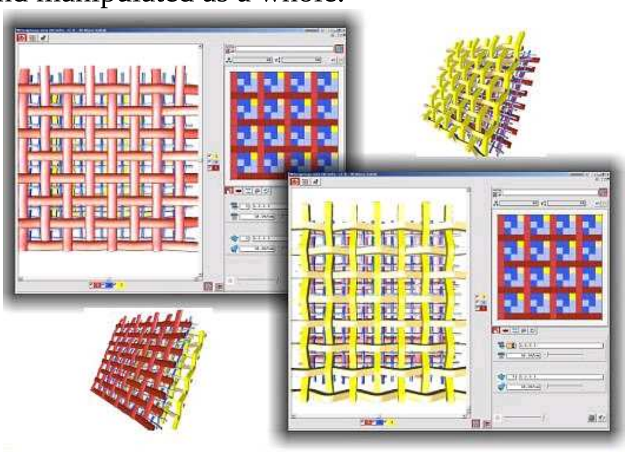

Figure 1. 3D Weave module possibilities, cross section visualisation

1.1.2 ScotWeave Technical Weaver

This system is possible to use for the creation of complex technical fabrics [4]. The software supports the creation of everything from simple single cloth structures to complex layered architectures, containing stacking orders and variable densities. Orthogonal and Angle Interlock structures are also fully supported. Technical data including density and tensile strength can be input to allow for future calculations based on the yarn and fibre composition. The cross-sectional shape of the yarn can be recorded for more accurate 3D weave schematics. Any weave, on up to 64 shafts for dobby, or 12,000 plus hooks for jacquard can be created, viewed and production data sent directly to the loom.

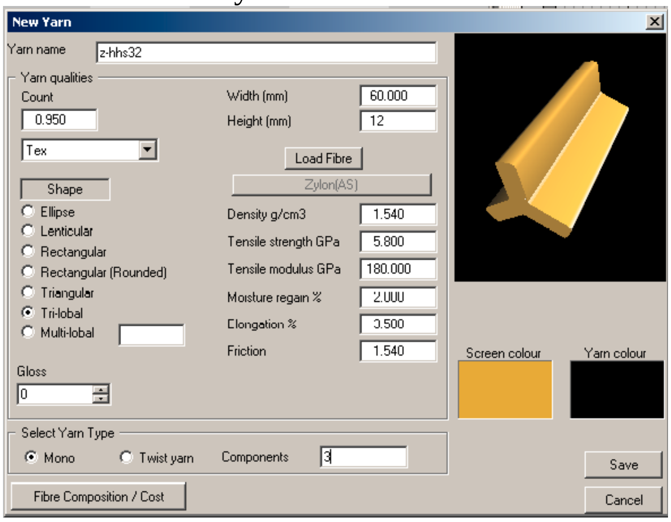

Figure 2. Technical Weaver possibilities

1.1.3 Modelling of internal geometry of relaxed & deformed textiles - WiseTex

Models of the internal geometry of textiles take full advantage of the hierarchical principle of textile modelling. The simulation algorithm uses extensively the minimum energy principle, calculating the equilibrium of yarn interactions. The models cover wide range of textile structures, either relaxed or after compression, shear or tensile deformation [5, 6,].

Input data: Yarn properties: geometry of the cross-section, compression, bending, frictional and tensile behaviour, fibrous content; Topology of the yarn interlacing pattern within the fabric repeat (graphical editor provided for all the textile type); Yarn spacing within the repeat.

Output: Unit cell dimensions, areal density, average porosity/fibrous content and yarn lengths in the unit cell; For any point within the unit cell: the fibrous content, the average orientation and an identification of the fibre material in the vicinity of the point; Yarn path geometry, position and size of the yarn cross-sections, fibre density and orientation distribution over the yarn cross-section.

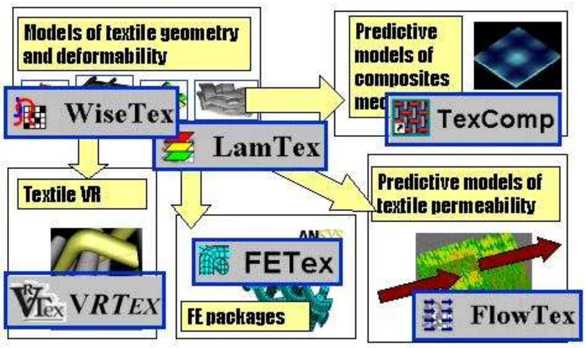

Figure 3. Possibilities in textile modelling

1.1.4 VRTex

Visualization of the textile internal geometry is done with OpenGL algorithms, as well as by VRML [7, 8]. Files, generated by WiseTex, can be transformed into an open VRML format that is readable by many free VRML viewers, mainly in form of www-browser plug-in. This facilitates building the virtual world description, providing GUI for lightings, viewpoints, avatar dimensions, texturing etc. The unit cell can be replicated to form a wide fabric surface.

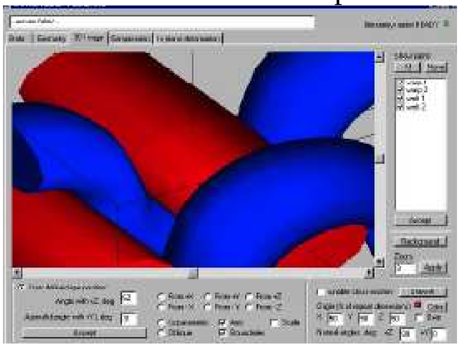

Figure 4. Visualization of the textile internal geometry

1.1.5 CAD-Simulation of 3D woven shapes

Simulation of woven geometry and the resulting orientation and density of warp and weft threads. This module is to describe and to simulate three-dimensional fabrics in respect of geometry and fabric design completely. The project is based on Shape Weaving, a new method for the production of 3D-woven shapes on the weaving loom [9].
Simulation of 3D-woven fabrics with consideration of weaving technological boundary conditions: quick check up of the feasibility of geometry from 3D-woven fabrics; forecast of woven structure and quality for each position of geometry; optimisation of parameters of the 3D-woven fabric (thread sizes, weave, thread distances) by simulation; economical prototype development.

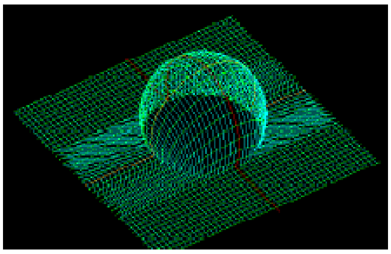

Figure 5. 3D woven shapes possibilities

1.1.6 Fabric Mechanics Software

Several digital fibres are assembled into a yarn, with yarns optionally assembled into tows. Fabric geometry is defined using topology and fibres properties. An analysis is performed to determine as-woven geometry, which can then be replicated for fabric analysis. The image shows the geometry of a 3D woven unit cell, which can be replicated to define a fabric and then used directly in a simulation. Alternately, the geometry can be provided to other users for use in creating a finite element model of the fabric [10].

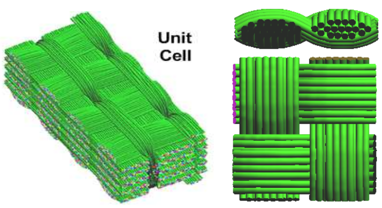

Figure 6. Simulation of a 3D woven unit cell

2. LibTex Computer AidedTextile Design

The system LibTex has been used for the prediction of structure, parameters and properties in the line fibre – yarn – fabric [11]. The system contains databases of fibre properties & fabric weaves, and the prediction is based on the complex of theoretical and regression models. The material and technological parameters for different materials, yarns and fabrics are included. The main use of this system is for optimal fabric design based on virtually created fabric. System can be used for the prediction of grey cotton dobby and jacquard fabric properties for technical and clothing applications.

2.1 Selected steps of fabric properties prediction

First – for prediction of selected woven fabric properties is necessary to know basic input yarn (warp and weft parameters) properties: count, material, irregularity, elongations, etc.

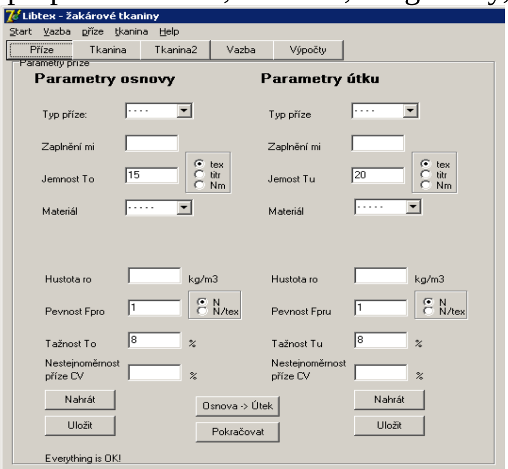

Figure 7. Input yarn parameters

Second – for prediction is necessary to know weave (dobby or jacquard design). Libtex is compatible with individual CAD systems for creation of dobby or jacquard design (EAT, NedGraphics, Arachne, ScotWeave, etc.)

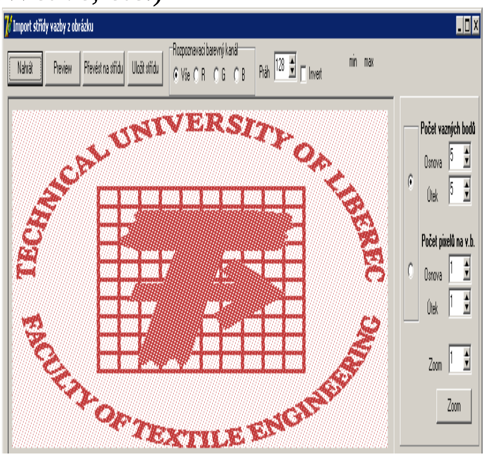

Figure 8. Weave possibilities (dobby and jacquard design)

Third – prediction of selected woven fabric properties on the basis of calculated or enters warp and weft set.

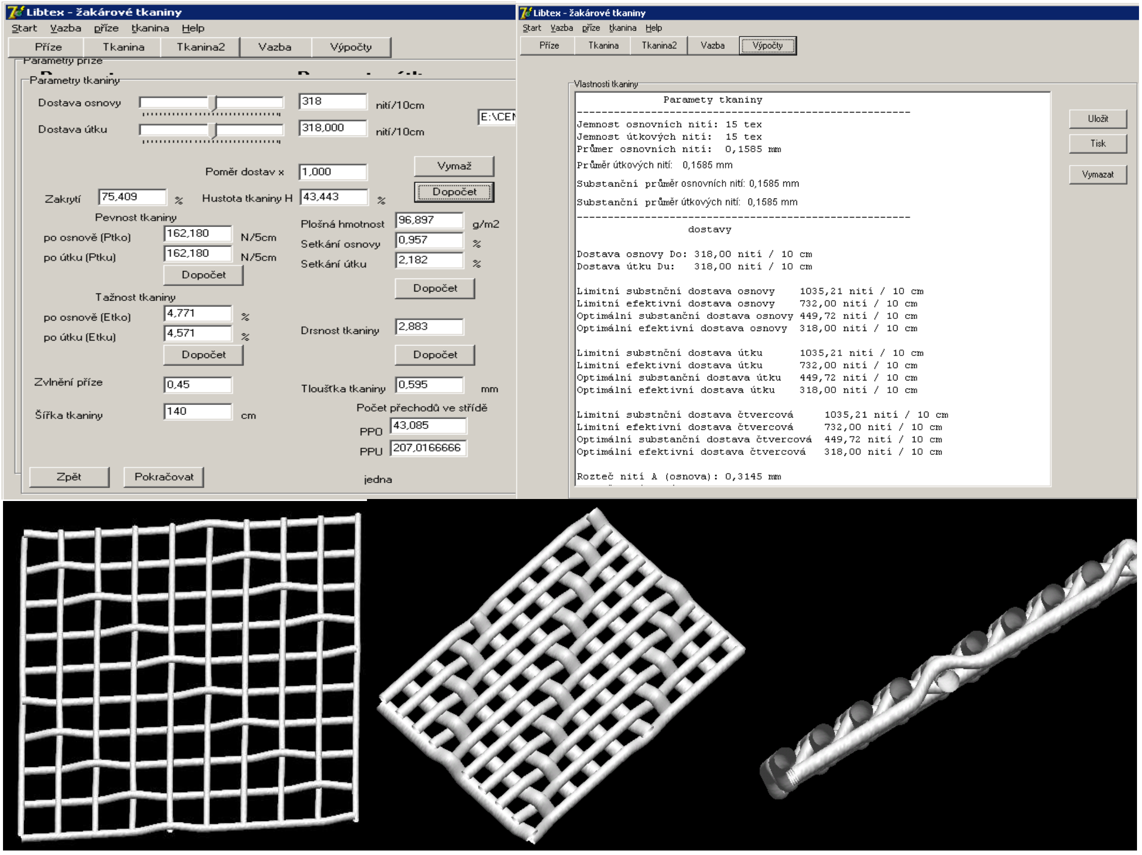

Figure 9. Properties prediction, certificate of calculation, 3D visualisation

2.2 Prediction of selected fabric properties

Generally, the expression of the fabric geometry and its behavior from the final properties viewpoint we can pursue on the basis of the various mathematical and geometric models [12, 13, 14, 15] as well as we can use different experimental methods [16, 17, 18]. In above-mentioned graphs we can see fabric properties behavior and comparison of theoretical values with experimental values.

Parameters of fabric samples: 100%POP two-ply staple ring yarn in two counts 20x2tex, 29,5x2tex, weaves (P - plain, T- twill, S – sateen), warp sett is identical for all the fabrics(12/cm) and the number in fabric code means the weft sett value (threads/cm) (P8 – plain weave, weft sett = 8/cm).

2.2.1 Areal weight of fabric

Weight of fabric depends on the warp and weft sett and on the yarn count as well as yarn crimp. We can distinguish two kind of fabric weight: M_1 *[g.bm^{-1}]* – the weight of linear meter of fabric and M_2 *[g.m^{-2}]* – the weight of square meter of fabric (standard: ČSN 800845). Predicted weight of fabric was calculated from two types of yarn diameter – maximal diameter of two-ply staple ring yarn and minimal diameter of two-ply staple ring yarn. Comparison of predicted and experimental fabric thickness is plotted in figure 10 (2x20tex fabrics) and 11 (2x29.5tex fabrics).

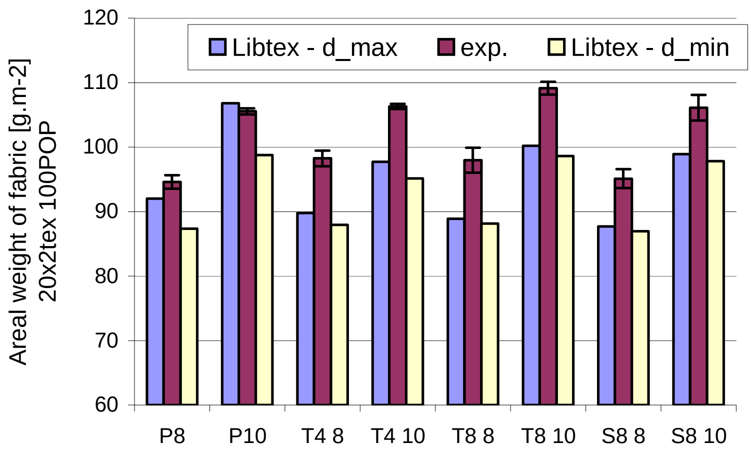

Figure 10. Areal weight of fabric

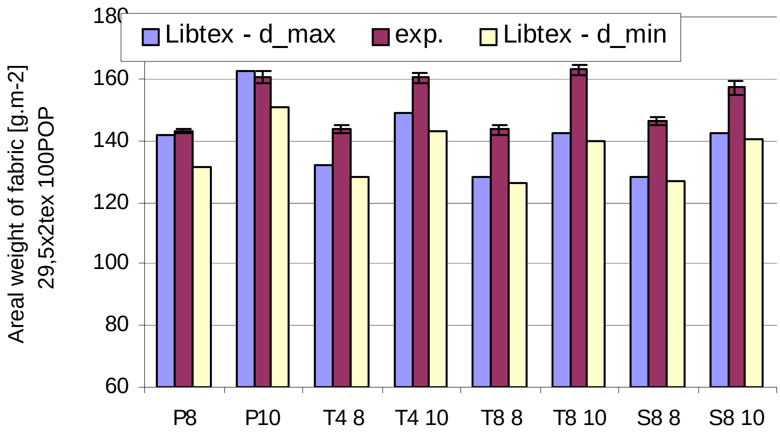

Figure 11. Areal weight of fabric

2.2.3 Fabric thickness

Fabric thickness depends on fabric geometry description. This property influences on the yarn input parameters (yarn count, yarn diameter, yarn irregularity, etc.) and fabric input parameters (weave, warp and weft waviness, warp and weft sett).

Predicted fabric thickness was calculated from two types of yarn diameter – maximal diameter of two-ply staple ring yarn and minimal diameter of two-ply staple ring yarn. Comparison of predicted and experimental fabric thickness is plotted in figure 12 (2x20tex fabrics) and 13 (2x29.5tex fabrics).

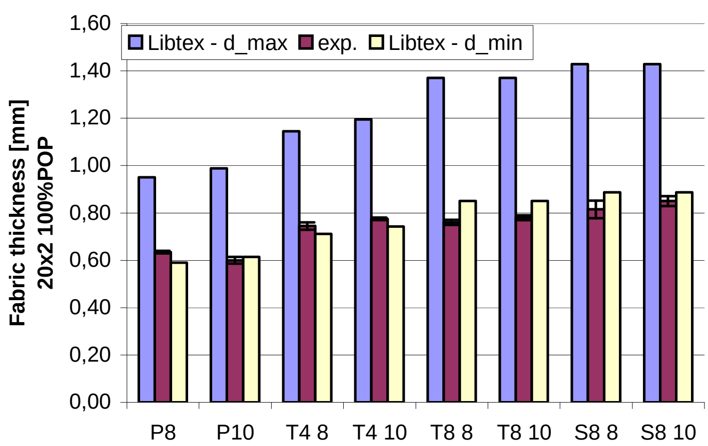

Figure 12. Fabric thickness

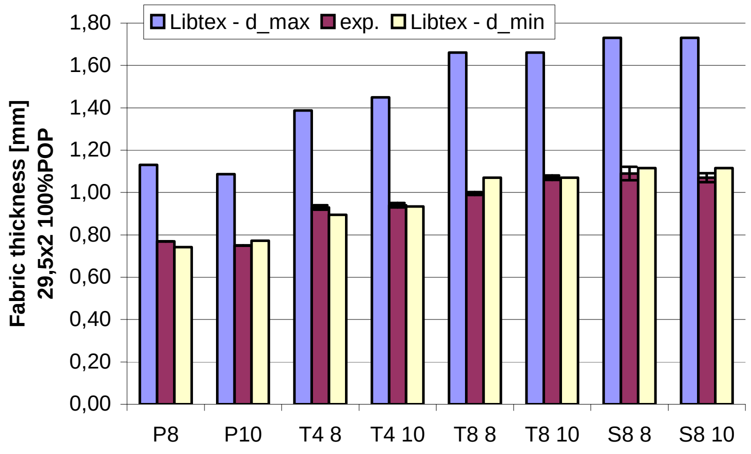

Figure 13. Fabric thickness

2.2.4 Fabric strength

Fabric strength in warp or weft direction depends on warp (weft) yarns and warp (weft) sets. The influence of second system on fabric strength value is neglected. Woven fabric strength not corresponds to sum of yarns strength per fabric width unit in straining direction only. Relation between fabric and yarn strength is corrected by coefficient of utilization of yarn in fabric in warp (weft) direction. It is assumed that coefficient includes influence of material and fabric weave. There are reasons why the utilization of yarns in fabric isn't total:

a) Yarn unevenness
b) Different way to yarn and fabric destruction.
c) Fabric structure unevenness.

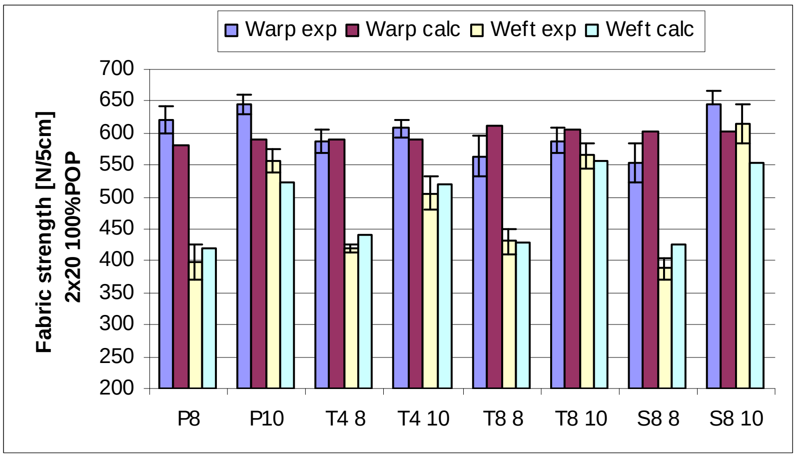

Figure 14. Fabric strength

Predicted strength value was calculated from experimental yarn tenacity. Comparison of predicted and experimental strength in warp and weft direction is plotted in figure 14 (2x20tex fabrics) and 15 (2x29.5tex fabrics). The correlation between experimental and predicted values is 0,92 for warp direction and 0,94 for weft direction.

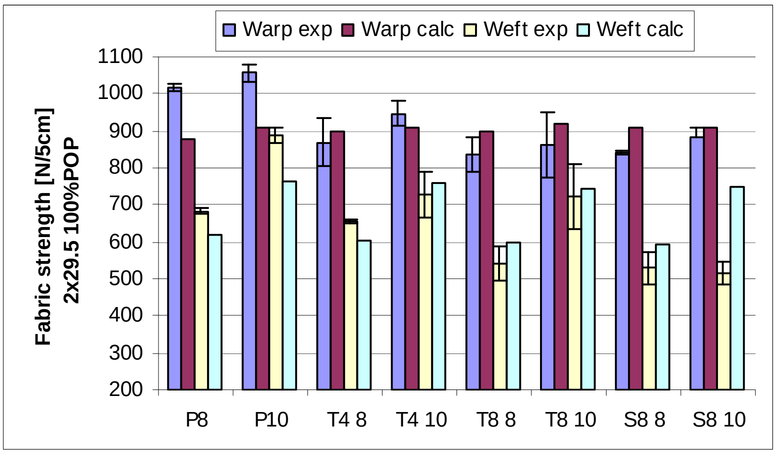

Figure 15. Fabric strength

2.2.5 Fabric elongation

Fabric elongation is given by ultimate elongation to initial fabric length. Fabric elongation in warp and weft direction depends on yarn elongation and yarn interlacing in fabrics (crimp, weave). Relation between fabric and yarn elongation is corrected by coefficient. It is assumed that coefficient includes influence of material.

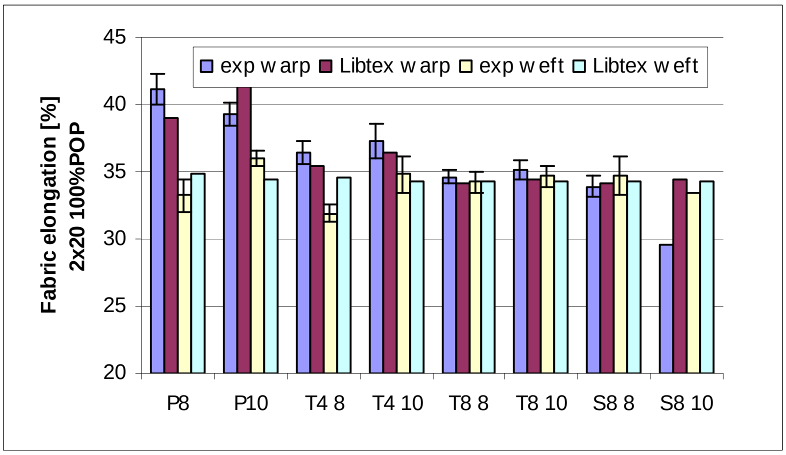

Figure 16. Fabric elongation

Predicted extension value was calculated from experimental yarn extension. Comparison of predicted and experimental extensions in warp and weft direction is plotted in figure 16 (2x20tex fabrics) and 17 (2x29.5tex fabrics). The correlation between experimental and predicted values is 0,9 for warp direction and 0,92 for weft direction.

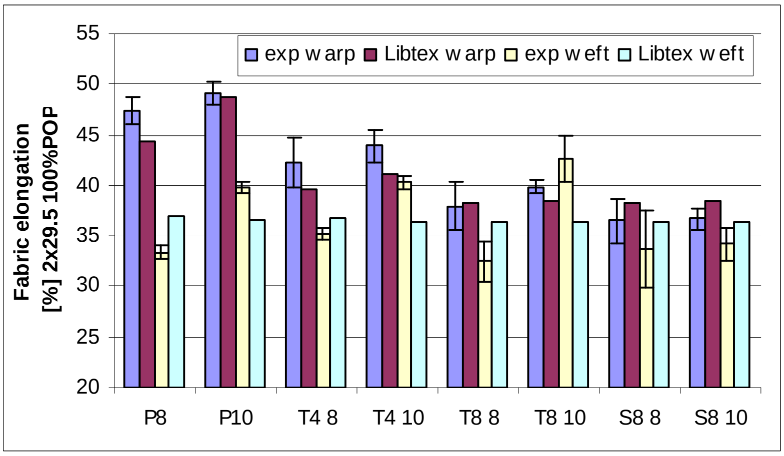

Figure 17. Fabric elongation

3. Conclusion

Prediction of mechanical and end-use properties depends on definition of input parameters of yarn as well as fabric. Input parameter of yarn – prediction is based on definition of yarn diameter. Behaviour and definition of yarn in cross section is different for single yarn as well as two-ply yarn. In above-mentioned graphs for objective evaluation of predicted and experimental selected properties were used two types of yarn diameters (maximal and minimal). Input parameter of fabric – prediction is based on definition of fabric geometry (warp and weft waviness, crimp, threads sett, etc.). Weave definition – this software is compatible with CAD systems for dobby and jacquard fabric design creation.

4. Acknowledgement

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