ИЗСЛЕДВАНЕ НА СВОЙСТВАТА ЗА МЕХАНИЧЕН КОМФОРТ НА МНОГОСЛОЙНИ АРАМИДНИ ТЪКАЧНИ СТРУКТУРИ ЗА ЗАЩИТНИ ТЕКСТИЛИ

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INVESTIGATION OF MECHANICAL COMFORT RELATED PROPERTIES OF MULTILAYER WOVEN ARAMID STRUCTURES FOR PROTECTIVE TEXTILES

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INTRODUCTION
For several protective textiles, the resistance against penetration is very important property and is kept high enough by using combinations of up to 20 layers of different fabrics [1]. For many applications which are used in the protection area, aramid woven structures are normally used [2]. Due to the fact, that many layers are required, it is assumed, that the using of multilayer woven structures could improve the stab resistance, but reducing the total weight of the assembly [3].

Keywords: *aramid woven fabrics, multilayer, weight, thickness, simulation, Wisetex.*

Woven pattern

To determine the influence of the single parameters of the structures and the influence of the interlacement between the layers, four different aramid fibre narrow fabrics with different properties and pattern, were produced and tested by determining the thickness, compression behaviour, bending rigidity and the mass per unit area. In this study, the first results for the thickness and mass per unit area are presented. The structures of the weaving types are as follows:

English angle interlock with additional binding pattern

The English binding pattern consists out of three layers, where each layer is connected with the ground warp and the binding warp (***Figure 1***). There are eighteen picks per repeat and eight heddle frames should be used. The fabrics were woven with the weft density 8.2picks/cm and 9.3 picks/cm.

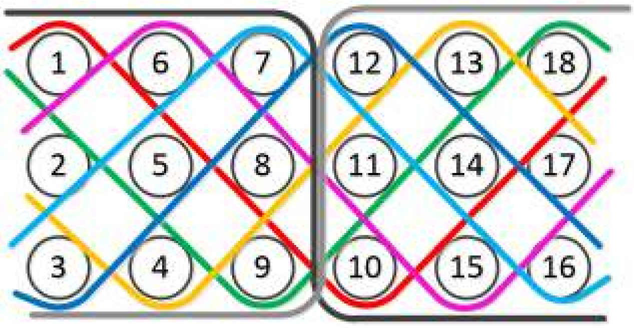

Figure 1 English binding

English binding pattern without binding warp (standard angle interlock):

The pattern also consists out of three layers [5] (***Figure 2***). Each layer is connected with ground warp but without binding warp comparing to the first pattern. The fabrics were woven with the weft density 8.2 picks/cm, 9.3 picks/cm and 12.1 picks/cm.

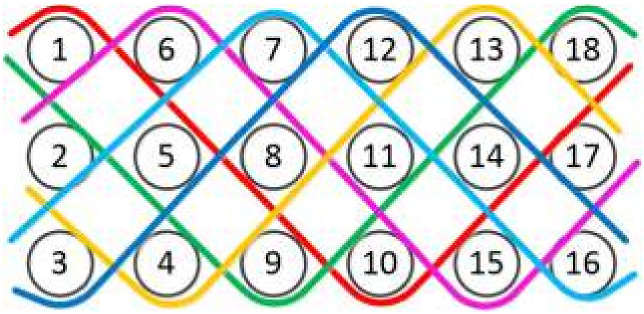

Figure 2 English binding without binding warp

Simple two layers pattern

The interlacing of ground warp yarns and weft yarns is presented in ***Figure 3***.

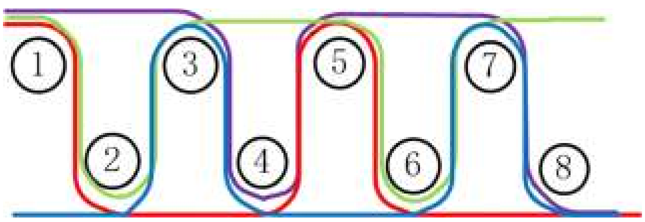

Figure 3 Simple 2 layers pattern- ground warp and weft yarns

Figure 4 shows the interlacing of binding warp yarns and weft yarn. This pattern has two layers, which are connected with a ground warp and a binding warp with four picks per repeat. The fabrics were woven with the weft density 3.2 picks/cm, 4.6 picks/cm and 6.7 picks/cm.

Figure 4 Simple 2 layers pattern- binding warp and weft

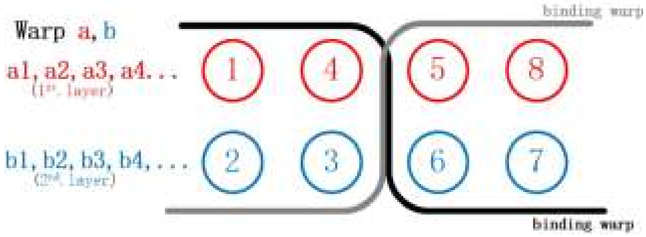

Figure 5 Two layers with twill

Figure 5 presents the interlacing of binding warp yarns and weft yarn. This pattern has two layers and both, top layers and bottom layers are twill pattern. The two layers are only connected with the binding warp. Three warp beams are used to weave this pattern. The first warp beam is for the binding warp yarns. The ground warp yarns of the top layer come from the second warp beam. And the ground warp yarns of the bottom layer come from the third warp beam. The fabrics were woven with the weft density 12.1 picks/cm.

Experimental

All samples are produced on Jakob Müller Narrow Weaving loom NFJM with width of 50 mm with the mentioned weft densities. As warp material Aramid yarns with a fineness of 930 dtex were used.

Weft yarns with a fineness of 667 dtex were used, and because of the using of needle as weft insertion device, there are always double wefts inserted. The selvage is produced in Weave system 2 (with helping yarn).

All samples are relaxed after the production in under standard climatic conditions for more than 24 hours.

Simulation

The fabrics were simulated with software Wisetex [3]. The software requires all data about the pattern, but as well several physical parameters of the yarns. It calculates a geometrical configuration of the fabrics and then performs optimisation of its shape trying to find the state with the minimal potential energy of the system:

$$\min(E) = \min\left(E_{tension} + E_{bending} + E_{compression}\right)$$

Based on this configuration, are simulated values for the thickness, mass per unit area and compression curve.

English interlock pattern with and without binding

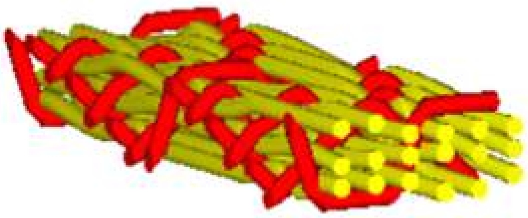

Figure 6 3D image of English binding

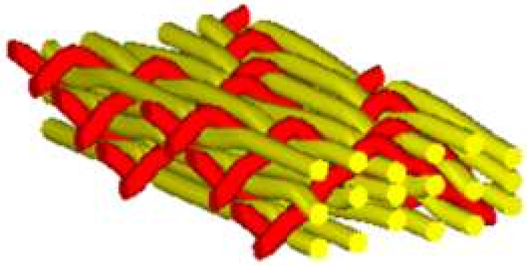

Figure 7 3D image of English binding without binding warp

The Figure shows the 3D simulation of the English binding. Warp yarns are red, and weft yarns are yellow.

Simple two layers pattern

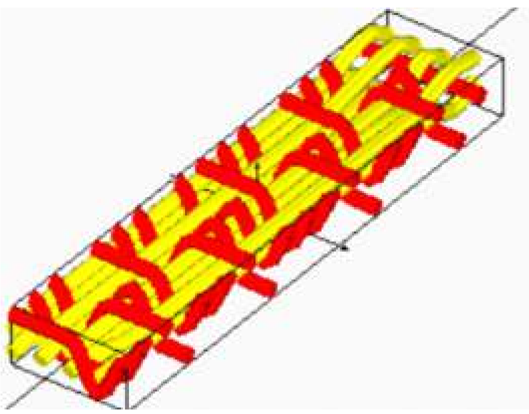

Figure 8 3D image of simple two layers

Figure 8 shows the 3D simulation of the simple two layers. Warp yarns are red, and weft yarns are yellow.

Two layers with twill

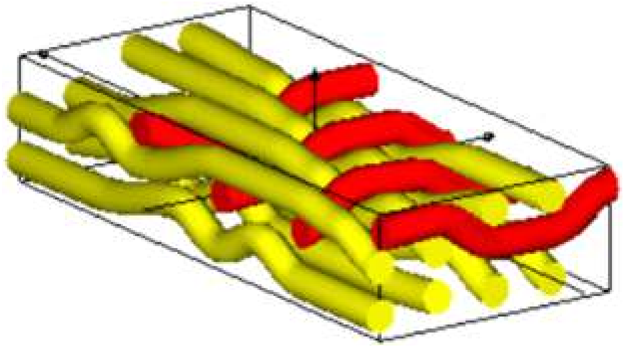

Figure 9 3D image of two layers with Twill

The Figure shows the 3D simulation of the two layers with twill pattern. Warp yarns are red, and weft yarns are yellow. The picture shows the interlacing of warp and weft yarns of either top or bottom layer.

Comparison between the simulation and experimental measurement

The results for the measured and calculated thickness and area densities are as follows:

English binding pattern

Table 1

Parameters of the English binding pattern

Weft densities	8.2pick/cm	9.3picks/cm
Measured thickness [mm]	2.45	2.34
Calculated thickness [mm]	2.36	2.30
Measured weight [g/m²]	800	827
Calculated weight [g/m²]	921	979

English binding pattern without binding warp:

Table 2

Parameters of the English binding pattern without binding warp

Weft densities	8.2 pick/cm	9.3 picks/cm	12.1 picks/cm
Measured thickness [mm]	2.32	2.38	2.27
Calculated thickness [mm]	2.20	2.28	2.17
Measured weight [g/m²]	646	678	749
Calculated weight [g/m²]	731	782	892

All results of the English binding with and without binding warp are presented together in one diagram to have a better overview of the results, which have to be compared.

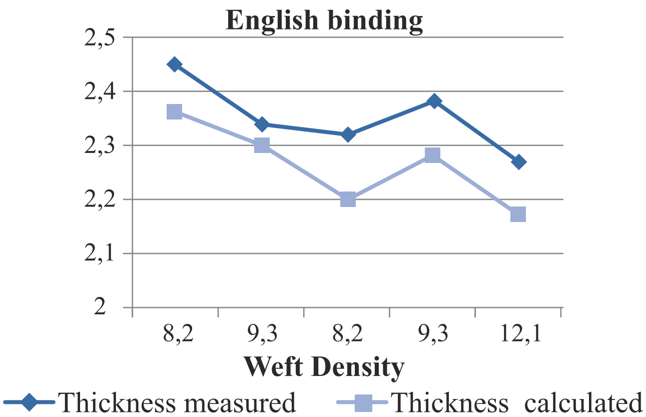

Figure 10 Results of the thickness of the English binding

The calculated values are always lower than the measured ones. Nevertheless they show a good correlation between the results. The weight presents high deviations between the measured and calculated results. The calculations are always much higher than the measurements.

Simple two layers pattern

Table 3

Parameters of the simple 2 layers pattern

Weft densities	3.2 pick/cm	4.6 picks/cm	6.7 picks/cm
Measured thickness [mm]	1.85	1.96	2.05
Calculated thickness [mm]	1.73	1.72	1.68
Measured weight [g/m^2]	692	729	809
Calculated weight [g/m^2]	534	578	661

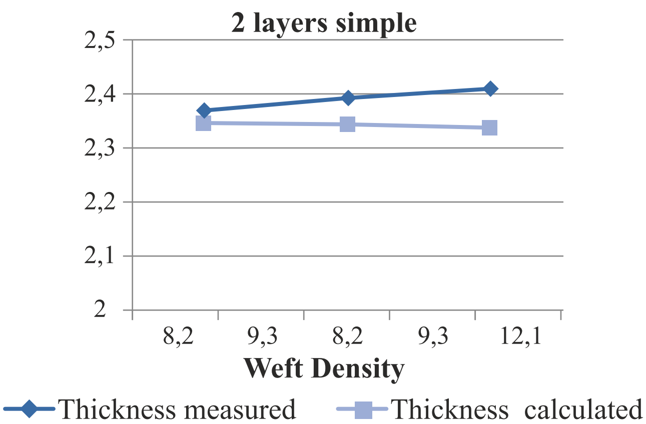

Figure 11 Results of the thickness of the 2 layers simple pattern

The thickness results are similar for both test series- for the measurements and the calculations. The calculated thickness is always a little bit lower than the measured one. Also the weights differ between the measured and the calculated results, the calculations are also lower than the measurements.

Two layers with twill

Table 4

Parameters of the 2 layers with twill pattern

Weft densities	12.1 picks/cm
Measured thickness [mm]	1.57
Calculated thickness [mm]	1.66
Measured weight [g/m^2]	756
Calculated weight [g/m^2]	753

Table 4 gives an overview of the measured and the calculated values of the pattern. The thickness is comparable with a difference of just 0.08 mm, which is equal to 5% between the measurement and calculation.

The results of the 2 layer twill pattern present comparable values, the difference between measured and calculated thickness is less than 0.1 mm.

The overall comparison of the thickness results shows, that at the more dense structures the difference between the simulation and the experiment is larger than of the more open structure. This can be results of the higher compaction and reorientation of the multifilament in the yarn cross section, which cannot be directly considered during the modelling with Wisetex.

The comparison of the calculated and measured mass per unit area of the English binding pattern shows, that the calculated are always higher than the measured results. The simple two layer pattern has the opposite results, the calculated are always lower than the measured results. The two layer twill pattern shows comparable values for both results.

Conclusion

The long term aim of this work is the selection of most suitable weave pattern for ballistic protection and stab resistance protection, but considering the wearing comfort. The densest structures have very good stab resistance, but these are too stiff and hard for wearing. Using proper interlacement between the layers, the softness of the fabrics can be increased significantly without significant loss of penetration resistance.

The study showed that the thickness results give a good correlation between the experiments and the simulations. The English pattern and the simple two layers pattern have always lower calculated thicknesses than the measured thicknesses, the 2 layer with twill present opposite results. The results of the mass per unit area analysis present very high deviations between measurements and calculations Anyway, the results of the created geometries show good correlation with experimental results and these can be used later for FEM simulations of penetration behaviour.

References

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