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Modelling of Textile Structures

Josef Žák

VÚTS, a.s., Svárovská 619, Liberec XI, Czech Republic
josef.zak@vuts.cz

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Abstract: In our work we tried to find a simple and reliable method to determine geometric properties of a textile structure with the main respect to the woven fabrics. We were using primarily means of classical mechanics and we tried to avoid as much as possible the use of computer resource demanding tools. Also we were concerned by the as large as possible applicability of results in design of our weaving machines.

Introduction

By modelling textile structures such as a woven fabrics, double or triple twisted threads or knitted structures one soon realizes that a mathematical model is needed to describe their form or properties. There are several methods to do it, most of them using a geometric interpretation of the structure without taking into account the mechanic properties of the constituting yarns (Pierce's model). Some methods are using them, e.g. Oloffson for woven fabrics, but neither those latter ones do cover completely the characteristics of the structures. There exist some methods said modern, although the term trendy or popular should be more appropriate, that use the instruments of classic mechanics to determine the properties of textile structure. Here come mainly methods based on finite elements. Their drawbacks lie primarily in requirements on computational resources, secondly, the method necessarily requires a complete set of physical constants to enter in the computation - and to be determined by a cost demanding experiment - and thirdly, its versatility is - for a given input - only limited.

Principles of method

The presented method uses a combination of geometric methods with the principle of minimization of energy of a system. As design variables it takes such parameters which characterize the shape of a geometric model. The minimum of energy is then found in terms of those parameters. Unlike the classical variational methods this method does not determine the unknown shape, for example by searching a weak solution of differential equation.

Examples of use

In this section we give some examples of use of the method applied on different textile structures.
Double twisted yarn. It consists of two identical simple yarns which are twisted together. The sense of twist is most commonly opposite to the spinning twist. Each yarn is modelled by using helical model as presented in [1].

Cross section of such a structure is shown in Fig.1. In this case only one design variable, common to both yarns and determining unequivocally the shape is used. Energy to be minimized consists of energy of elongation of individual yarns due to the twisting and of energy of deformation of their cross section, see [1]. By expressing this energy in terms of design variable we can find easily its minimum. In Fig. 2 we can see the resulting shape of twisted yarn, either in model and in reality.
Fabric binding point. Another, more practical example is the guess of shape of one binding point in plain weave. Unlike the previous example we must use here several design variables, it is to say one per yarn (weft or warp) and one variable common to both. This said we are taken to solve a system of

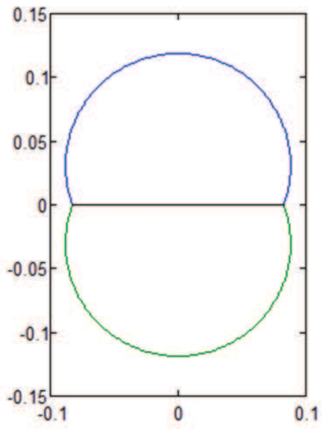

Fig. 1: Cross section

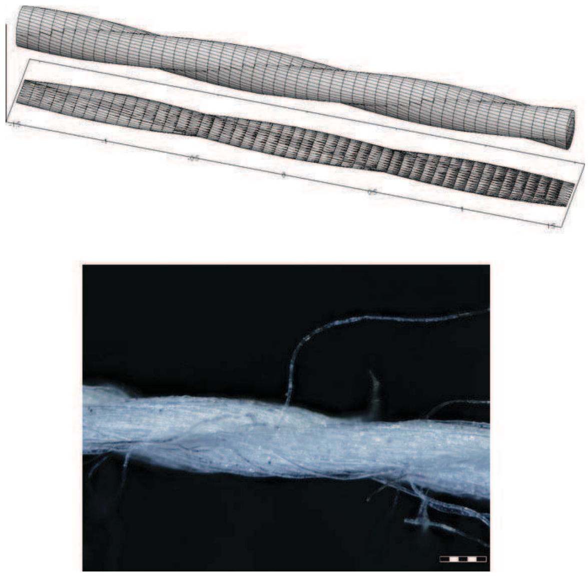

Fig. 2: 3D representation and real yarn

three non-linear algebraic equations. Using e.g. Newton - Raphson's method we obtain three values characterising the resulting shape.

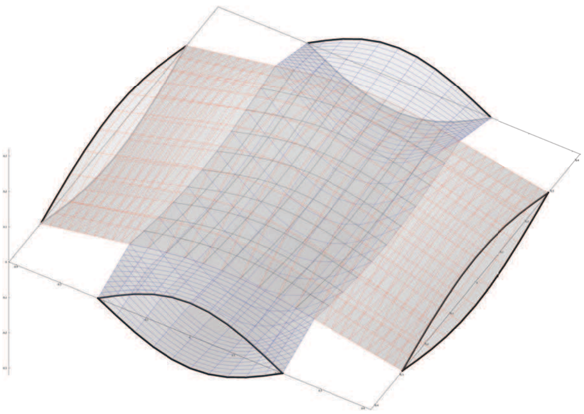

Fig. 3: Model of binding point

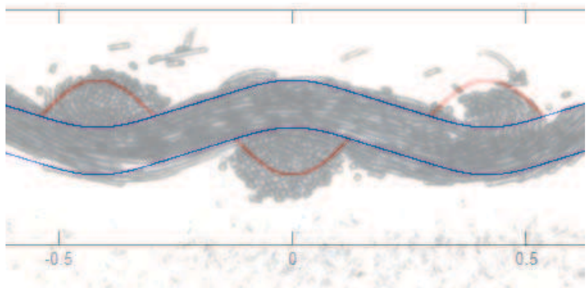

Fig. 4: Comparison of model and real shape

In Fig. 3 the model of one binding point in plain weave is represented and in Fig. 4 we can see a comparison of calculated shape with a section of corresponding real fabric.

Summary

Using methods of classical mechanics we have succeeded in determination of the shape of various textile products. Although this method has its own drawbacks it offers a good tool to predict the behaviour of such textile structures.

References

[1] J. Žák, Mechanische Eigenschaften des Garns, in: 14. Chemnitzer Textiltechnik-Tagung '14, (2014) pp. 183-190.