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SPATIAL STRUCTURE`S ANALYSIS OF 3D KNITTED SPACER FABRIC

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ABSTRACT

The subject of this paper concerns an identification of a spatial structure of a warp-knitted spacer fabric, paying particular attention to the structure of the inner layer. The transverse elasticity of the knitted fabric, both in static and dynamic terms, will depend on the properties of the monofilament, its shape and Young's modulus. The environments of OptaView and Inventor programs were used in the research. Analytical activities were selected that enabled the creation of theoretical models. The empirical verification showed the compliance of the model objects with the actual shape of the threads. It has been proved that the developed methodology can be used in the description of the spatial structure of the spacer knitted fabric as an indispensable element in the numerical experiment of the mechanical properties of the knitted fabric.

KEYWORDS

Spacer fabric, 3D modelling, monofilament, Inventor.

INTRODUCTION

Knitted spacer fabrics are modern 3D textile structures, consisting of two knitted outer layers connected by monofilament threads. The inner layer creates a distance that can vary from 2 to 100 millimetres [1]. These materials are widely used both in everyday objects and in more complex technologies, such as: car textiles, including car seat covers; composites; medical textiles such as orthoses or anti-bedsore mattresses; vibration reduction materials; sports textiles, parts of backpacks or sports shoes and insoles therefor; in breathable panels in clothing, helmet linings and even in modern architecture [2]. The most commonly used description of the structure of such knitted fabrics is based on two sections, along courses and wales. Few publications explore the issue of the three-dimensional structure of the inner layer.

An important feature of technical knitted fabrics is transverse bending elasticity, designed depending on the application of the material. It depends on many features, such as bending elasticity of the filament yarn (Young's modulus), its thickness, length and shape [3,4]. The aim of the research was to determine the method of analysing the spatial shape of the threads in the inner layer of spacer knitted fabrics, needed to model its elasticity under dynamic (impact) compression conditions.

MATERIALS AND METHODS

The research material was a 9 mm thick 3D spacer knitted fabric. The design and simulation of its construction was carried out using the ProCad Warpknit program. The visualization of the designed material is shown in Fig. 1 a-c. The structure of the stitch consists of: 1- double thread chain, 2- weft thread, 3-chain with inner layer connectors, 4-double thread chain, 5-weft thread. The outer layers of the material are made of polyester multifilament yarns, while the inner layer is created by monofilaments with a diameter of 0.2 mm. The average compressive stiffness modulus of this fabric is equal 230.17 Pa. The 3D spacer fabric was produced on a Nippon Karl Mayer LTD double-comb warp knitting machine with the needle number E18.

The actual structure of the knitted fabric was identified using a stereoscopic microscope equipped with an OPTO-TECH digital camera (Fig. 1d). It was assumed that by juxtaposing two 2D photos showing perpendicular sections of the knitted fabric, it was possible to determine the coordinates of the points (x, y, z) through which the monofilament passes.

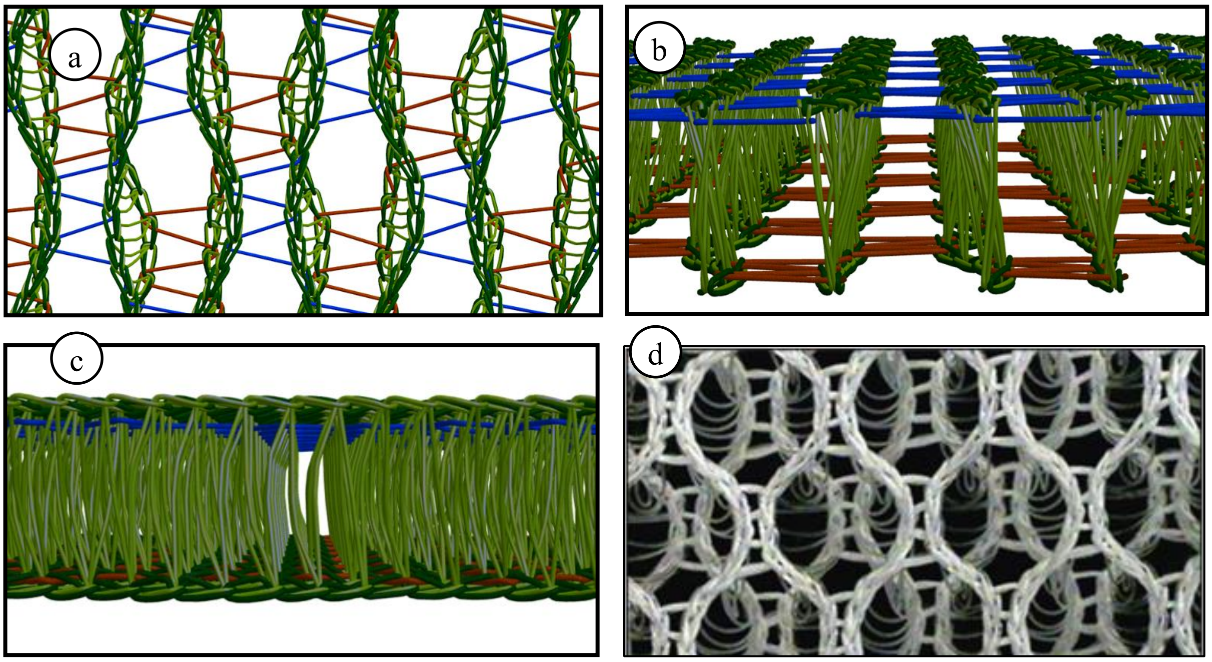

Figure 1. a, b, c - simulation of knitted fabric in ProCAD Wapknit, d - photos of knitwear made on a microscope.

The methodology of identifying the spatial structure of the inner layer includes two stages. The first step was to prepare the sample. As at this stage it was important to confirm the compliance of the model with the real object, the knitted fabric was cut so that the selected monofilament (marked with an indelible marker) was visible from all sides. Therefore, the smallest possible piece of material had to be cut out, while maintaining the structure. Further considerations focus on the monofilament element marked with green. It should be remembered that each monofilament can be curved in space differently depending on many variables, including its position in the weave, the finishing process or the external forces. The images showing knitted fabrics at 0, 90, 180, and 270 degrees were saved using the OptaView program. To create the model, two perpendicular views were selected, showing the marked monofilament (Fig. 2a and b).

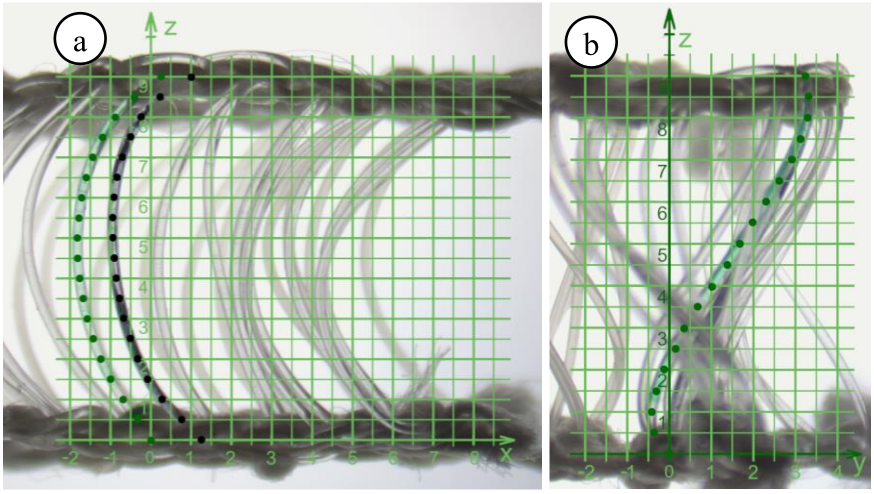

Figure 2. Pictures of the spacer knitted fabric at 0 ° (a) and 90 ° (b).

In the graphic program, a scale was applied to the longitudinal and transverse view of the knitted fabric, adjusted to the thickness of the material (9mm). Then, points were marked on the monofilament image, with 0.5 mm graduation on the axes. Y and z axes are perpendicular to the outer layers of the knitted fabric (x axis). The coordinates of the yarn shape were determined and saved in Excel file in the form of a table (it is necessary to enter the unit in the A1 field so that Inventor can choose the scale).

The second stage of the research was carried out using the Inventor program environment. It is an Autodesk CAD program. It can be used for solid 3D modeling, allowing you to make assembly and manufacturing drawings, etc. Using the "import points" tool, available in "3D sketch", the saved set of points was imported (Fig. 3a).

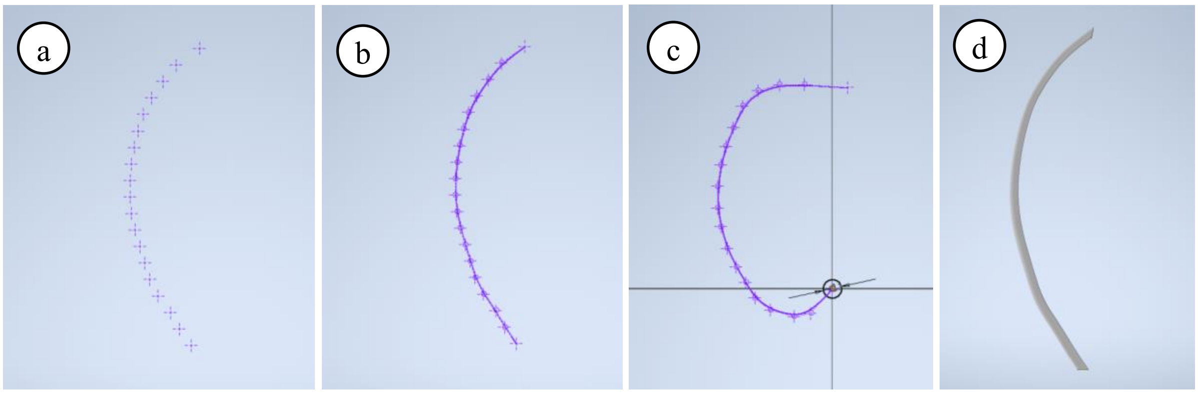

Figure 3. a - point import, b - spatial curve, c - adding a circle, d - dragging and creating a 3D model.

In order to create a 3D object, a curve is necessary, along which the cross-section of the model will be “dragged”. The points were connected using the "spline" function (Fig. 3b). There are two options: "interpolation" and "control vertex", the second one allows for a better effect, closer to the actual shape of the monofilament. The next step was to draw a circle on the plane where the curve starts. The "circle" tool was used, available in the "sketch" menu, and the diameter was the same as the monofilament one, i.e. 0.2 mm (Fig. 3c). To obtain the volume of the yarn model, the drawn circle was "dragged" along the curve with the tool from the 3D model: "sweep", selecting the curve as the sweep path (Fig. 3d).

RESULTS AND DISCUSSION

The model of monofilament yarn in the inner layer of 3D spacer fabric, obtained in the Inventor program environment, was compared for four views (on both sides for the xz and yz planes- Fig. 4a-d) with the microscope photos (Fig. 4e-h) in order to verify the correctness of the model. The top and bottom view of the created thread in the xy plane (Fig. 4j, k) and the xyz spatial arrangement are also shown (Fig. 4i).

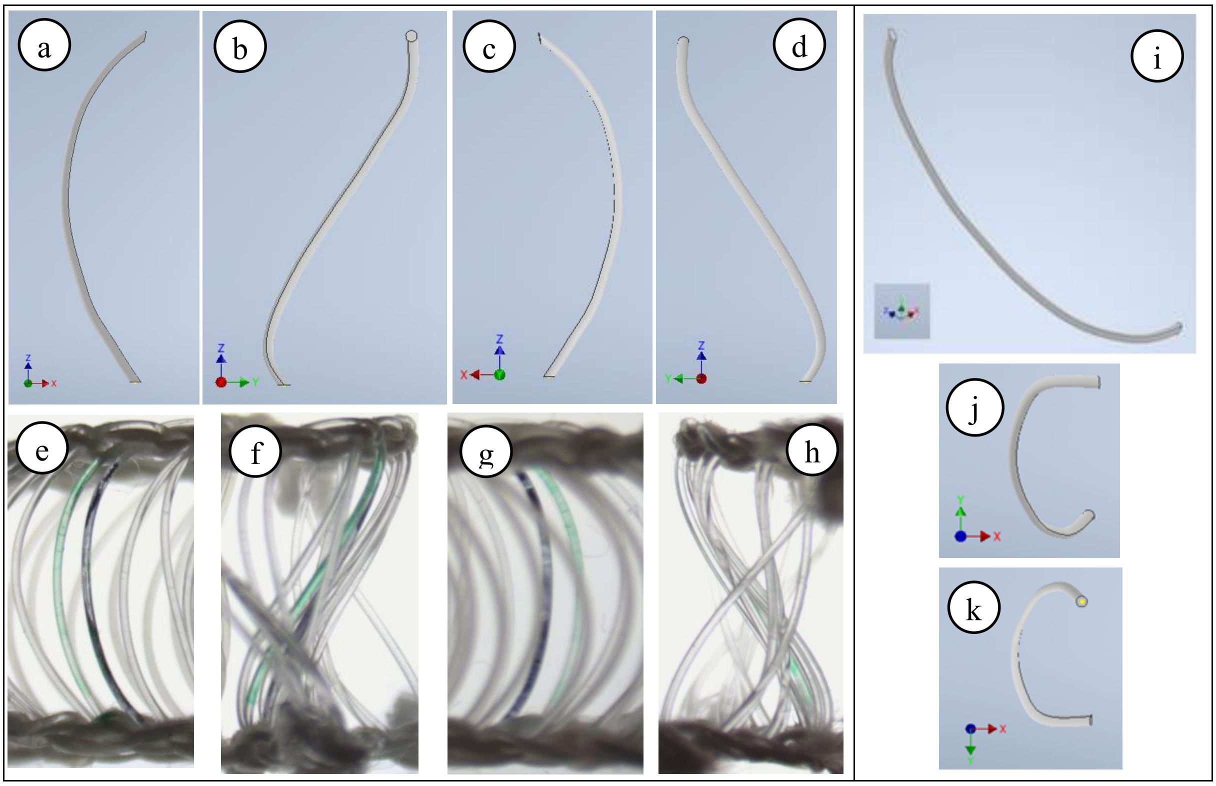

Figure 4. a-h comparison of the model with the actual monofilament structure (green) in the xz and yz planes; I - spatial view of the monofilament in the xyz system; j, k - top and bottom views in the xy plane.

CONCLUSION

As can be seen in the comparison above, the computer-generated monofilament reflects the actual shape of this yarn with great accuracy. Therefore, it can be concluded that the developed modelling methodology, based on 2D images in order to create a 3D model, is correct and allows for the creation of three-dimensional objects simulating the inner layer of the spacer knitted fabric. Models created on the basis of the developed method can then be used in computer simulations of processes such as compression or stretching of the spacer knitted fabrics.

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