MODERN METHODS FOR DESIGN OF TEXTILE DEVICES FOR HERNIA REPAIR

Ph.D student. Eng. **Razvan Scarlat**[1]**,** Prof. Dr. Eng. **Mirela Blaga**[1]**,** Dr. Eng. **Emilia Visileanu**[2]**,**
Dr. Eng. **Alexandra Gabriela Ene**[2]**,** Dr. Eng. **Carmen Mihai**[2]**,** Eng. **Alina Florentina Vladu**[2]

[1] ,''Gheorghe Asachi" Technical University of Iasi, Faculty of Industrial Design and Business Management, Romania, [2]The National Research & Development Institute for Textiles and Leather, Bucharest, Romania

REZUMAT.Plasa chirurgicală este un dispozitiv medical care este utilizat ca suport permanent sau temporar pentru țesutul slăbit sau deteriorat pentru toate tipurile de hernie. Pentru proiectarea structurilor textile tricotate destinate realizarii acestor dispozitive, pe lângă metoda clasică, a fost folosit un software specialziat pentru simularea comportamentului presiunii peretelui abdominal in cazul acestor tipuri de plase. Această simulare este utilă pentru a analiza starea de tensiune din dispozitivul textil. Pe baza rezultatului simulării, s-au proiectat parametrii plaselor tricotate realizate din fire de poliester multifilamentar.

Cuvinte cheie: plase tricotate; dispozitive medicale; interventie chirurgicala; simulare computerizata.

ABSTRACT.Surgical mesh is a medical device which is used either as a permanent or temporary support for weakened or damaged tissue for all kinds of hernia. For design of the knitted textile structures meant for the development of these devices, besides the classical method, in order to simulate the behaviour of abdominal wall pressure for these types of meshes, a dedicated software was used. This computer simulation is useful for analyzing the tension state of the textile device.Based on the result of the simulation, the parameters of the knitted meshes made of multifilament polyester yarns were designed.

Keywords: knitted meshes; medical devices; surgery; computer simulation.

1.INTRODUCTION

Hernia repair is one of the most common surgical procedures performed globally. Hernias occur when parts of an organ protrude through the abdomen wall, causing defects ineither the groin or abdomen. Worldwide, 20 million hernia surgeries are performed every year, and80% of operations involve synthetic meshes [1].

The surgical operation is the most used techniqueto treat herniadisease with a hernia repair mesh.The surgical mesh is a medical device which is used either as a permanent or temporary support for weakened or damaged tissue for all kinds of hernia. The application of these devices has greatly expanded due to the results of research and innovation obtained in both textile technologies and medical procedures while the use of synthetic fibers has triggered a real revolution in medicine, imposing a different choice and approach of the operational techniques depending on the specific field of use.Synthetic meshes are positioned to reinforce tissue defects, they should allow healthytissue in-growth for incorporation into native tissues, retaining enough strength to withstandabdominal pressureand enough elasticity under physiological pressure and correspondinganisotropy. The mechanical properties of different devices have been explored intensivelyover the last few decades [2].

2. DESIGN USING DEDICATED SOFTWARE

The textile medical devices must meet both specific biofunctional requirements (biocompatibility, chemically inertia, non-immunogenicity, sterilizable etc.) and certain physical-mechanical characteristics, such as: high strength (min. 20 N/cm), low weight (50-100 g/m^2), optimum elasticity and flexibility, adequate size and distribution of the pores.The pore size must be larger than 0.75 mm to preserve tissue integration without filling the pores with scar tissue. The geometry of pores goes from rectangular to more complex and hybrid structures.

In order to simulate the behaviour of abdominal wall pressure for these type of meshes, a dedicated software was used. This computer simulation is useful for analyzing the tension state of the textile device (a knitted mesh). For this purpose, it was calculated the Von Mises stress, that is a metric measurement to determine whether the structure has started to yield at any point.

The concept of Von Mises stress arises from the distortion energy failure theory. Distortion energy failure theory is comparison between 2 kinds of energies, 1) Distortion energy in the actual case and 2) Distortion energy in a simple tension case at the time of failure. According to this theory, failure occurs when the distortion energy in actual case is more than the distortion energy in a simple tension case at the time of failure. The Von Mises stress equation is represented as follows:

$$\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2} \geq \sigma_y$$

where $\sigma_y$is the tensile yield strength of the material [3].

For simulation initialization (fig. 1), the following input data have been established:Material - polyester; Dimensional constraints - greater radius - 150 mm; Minimum radius - 100 mm; Constraints analysis – geometry status - closed; Dimensioning of the mesh — 3rd dimension (thickness) - 0.24 mm. Fig. 1 shows that the obtained simulated structure is close to a knitted mesh.

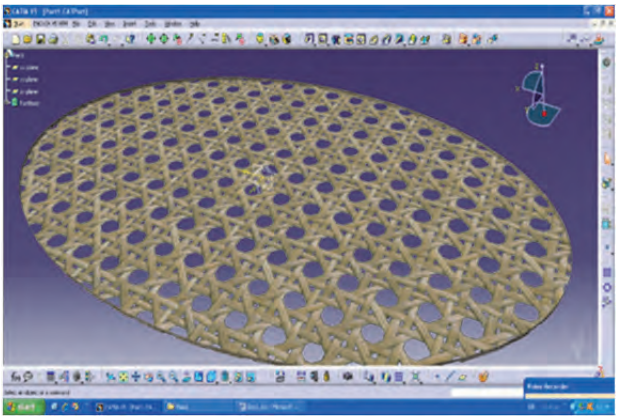

Fig. 1. Simulation initialization

In fig. 2 it is represented the structural analysis of the obtained structure. The value of the applied pressure was of4166N/sqmwith distributed forces of 150N.

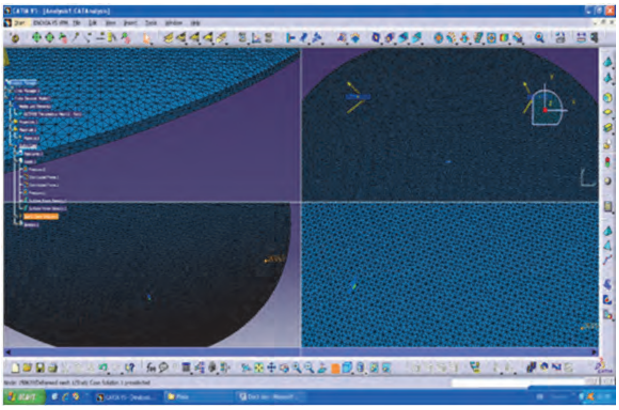

Fig. 2. Structural analysis

For the deformation analysing, the obtained translational displacement vector values are from 0 mm to 0.02mm. A displacement is a vector whose length is the distance from the initial to the final position of a point P. It quantifies both the distance and direction of an imaginary motion along a straight line from the initial position to the final position of the point. A displacement may be identified with the translation that maps the initial position to the final position. A displacement may be also described as a „relative position", that is, as the final position of a point relatively to its initial position.

Also, the corresponding displacement vector can be defined as the difference between the final and initial positions [4].

In fig. 3 can be observed that the longest displacement is in the middle of the mesh (red colour).

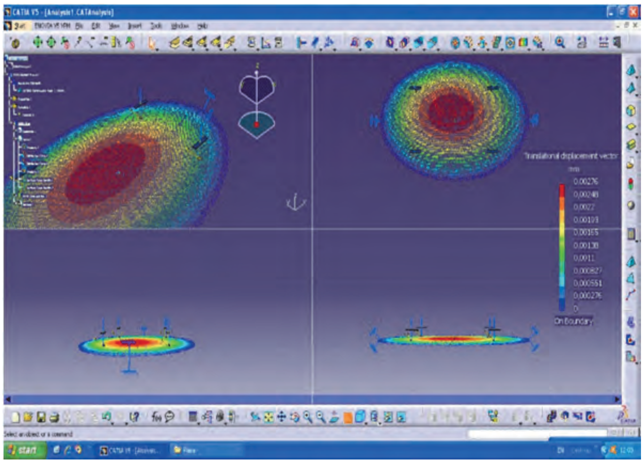

Fig. 3. The translational displacement vector

The obtained results based on the Von Mises stress criteria indicated that the structure has started to yield at the edge of the mesh, (yellow and redcolour), more specifically in the suture points (fig. 4).

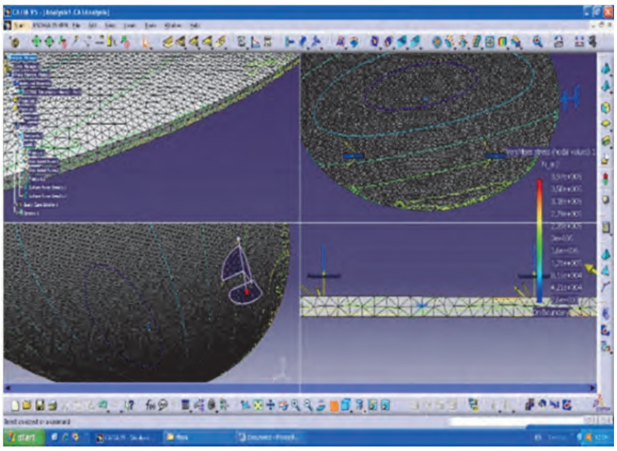

Fig. 4. The Von Mises stress yielding points

3.DESIGN OF THE STRUCTURAL PARAMATERS

The structural parameters have been designed for two variants (V14 and V15) of warp knitted mesheswith the adequate structure to obtain desired pore size: pillar stitch structure with additional weft yarns inserted at 1-4 rows and 2-5 wales. These structures have been made of two types of yarns: 150 dtex multifilamentar polyester (for V14) and75 dtex multifilamentar polyester(for V15).

Firstly, has been determined the diameter of the yarns (F_s):

$$F_s = \frac{c_{1s} \cdot \sqrt{N_{tex}}}{31.6} \qquad (1)$$

where c_{1s}= 1.3 is a coefficient depending on the density of the material (polyester) and

$N_{tex}$is the count of the yarn, in Tex.

Then, the stitches density was determined:

Horizontal density:

$$D_h = \frac{50}{A} \qquad (2)$$

Vertical density:

$$D_v = \frac{50}{B} \qquad (3)$$

where A, is the distance between the centres of two stitches from successive wales and B is the distance between the centres of two stitches from successive rows [5].

A≈T, where T is the distance between two successive needles, T = 0.7 mm ⇒ A = 0.7 mm.

$$B \geq B_{\min} + (a-1) \cdot F_s \qquad (4)$$

$$B_{\min} = 2.5 \cdot F_s \qquad (5)$$

The value for B was asumed to be 0.28 mm for V14 and 0.14 mm for V15.

where: a – amplitude; a = 0 for pillar stitch type.

Applying these calculations, the results for density are:

- horizontal density, D_h = 71 wales/50 mm (for V14 and V15) and

- vertical density, D_v =192 courses/50 mm (for V14) and D_v = 357 courses/50 mm (for V15).

The stitch length was determined with the following formula [5]:

$$l_{ol} = 4.71 \cdot F_s + 3 \cdot B \qquad (6)$$

Accordingly, l_{ol}= 1.53 mm (for V14) and l_{ol}= 0.93 mm (for V15).

The length of the weft segments (l_{sb}):

$$l_{sb} = 0.5 \cdot \pi \cdot d + \frac{\sum \sqrt{(b \cdot A)^2 + B^2}}{n} \qquad (7)$$

where d - diameter of the weft segments, d=0.5 ·Fs

b –amplitude of the weft segments, b=2

n – number of the weft segments, n=4.

Accordingly,l_{sb} =0.49 mm (for V14) andl_{sb}= 0.48 mm (for V15).

The mass(M) was determined with the following formula:

$$M = 0.4 \times D_h \cdot D_v \cdot 10^{-3} \cdot \sum_i R_i \cdot l_t \cdot N_{texi} \qquad (8)$$

where Ri is the pass and R_i=1for this structure and l_t is the total length, $l_t = l_{ol} + l_{sb}$.

Accordingly, M = 165 g/m^2(for V14) andM= 87 g/m^2 (for V15).

4. CONCLUSIONS

For design of knitted mesh variants meant for development of new medical devices dedicated software was used, in order to simulate the behaviour of abdominal wall pressure for these types of meshes. The simulation has demonstrated that the structure has started to yield at the edge of the mesh, more specifically in the suture points. Based on the result of the simulation, the structural parameters of the knitted meshes made of multifilament polyester yarns were designed, obtaining 2 variants of meshes with needed characteristics.

REFERENCES

[1] Wahba, S, M.,*Evaluation of lightweight polypropylene mesh in Stoppa pre-peritoneal repair of bilateral inguinal hernias*, J. Am. Sci. 2014, 10, 116–124..

[2] Miao, L.,Wang, F., Wan, L., Zou, T., et al., *Physical Characteristics of Medical Textile Prostheses Designed for Hernia Repair: A Comprehensive Analysis of Select Commercial Devices,Materials* 2015, 8, 8148–8168; doi:10.3390/ma8125453.

[3] https://www.learnengineering.org/what-is-von-mises-stress.html.

[4] https://en.wikipedia.org/wiki/Displacement_(vector)

[5] *** Manualul Inginerului Textilist - Editura AGIR, Romania.

About the author

Ph.D student Eng. **Razvan SCARLAT**
INCDTP Bucharest, România

He graduated the Technical University “Gh. Asachi ”Iaşi, Faculty of Textiles and Leather in 1996 and since 2019 is a Ph.D student at The Industrial Design and Business Management Faculty, Iasi,.
Activity: elaboration and coordination of research projects in the textile field, coordination and participation in research projects within national and international research programs. He is author of 2 patents and co-author of 2 other inventions. He has published as co-author 3 books and as author or co-author over 50 papers in scientificjournals and in the proceedings of national/ international conferences.