NUMERICAL MODEL OF THE MECHANICAL BEHAVIOUR OF MEDICAL COMPRESSION STOCKINGS

Inés Pita Miguélez [(1)], Damien Soulat [(1)], Xavier Legrand [(1)], Ahmad Rashed Labanieh [(1)]

1. Laboratoire GEMTEX, ENSAIT Roubaix - Université de Lille, France

Introduction

One of the most frequent disorders affecting adults' lower extremities worldwide is chronic venous insufficiency (CVI). The cornerstone of CVI prevention and treatment is compression therapy, which seeks to reduce edema and enhance venous and lymphatic return from the lower limb. Thanks to their unique structures and fabrication techniques, compression fabrics can adapt to varied body shapes by delivering controlled compression, being highest at the ankle and gradually lowering up the garment [1].

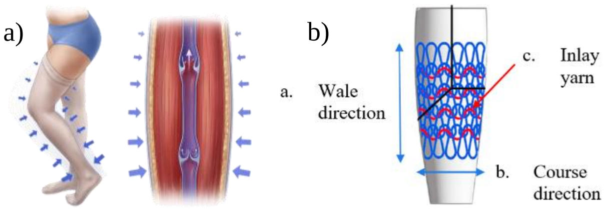

Figure 1: (a) Representation of controlled pressure distribution along the MCS. (b) Representation of the knitted pattern of the MCS

The principle of pressure exertion is based on the circumference of the garment C_1 being smaller than the circumference of the body C_2, so that the threads of the inlay yarn are stretched and under tension when the product is in place [2]. The elongation ratio τ (%) can be defined by

$$\tau\,(\%) = \frac{C_2 - C_1}{C_1}\ ;C_2 > C_1 \qquad (1)$$

Precisely, the amount of compression is proportional to the degree of elongation, the elastic modulus of the material, and the contact surface between the product and the body [3].

The aim of this project is to represent, through a finite element model, the behaviour of a Medical Compression Stocking (MCS). By integrating a specific leg morphology, this model will allow to analyse the distribution of the pressures exerted, and thus adjust the characteristics of the MCS according to the needs of each patient.

Methods

To make the representation of the MCS by means of finite elements, the code is created in Python (Spyder), to be executed in Abaqus (Simulia, Dassault systems).

According to the norm for the manufacture of medical compression products, for each course of the knitted structure, there must be an inlay yarn, which will be the main responsible for the compression.

To design the model, firstly, a geometrical characterisation of the MCS is carried out, taking into account the production parameters. Then, the MCS and its components are experimentally analysed to determine the behavioural laws that define them.

A first numerical model is created integrating the basic characteristics of the MSC, in which the two fundamental components are represented: the knitted structure and the inlay yarn. To represent the knitted structure, quadratic membrane elements are used to form a tube of similar dimensions to the MCS, and for the inlay yarn, connectors are used to create a helix along the length of the tube.

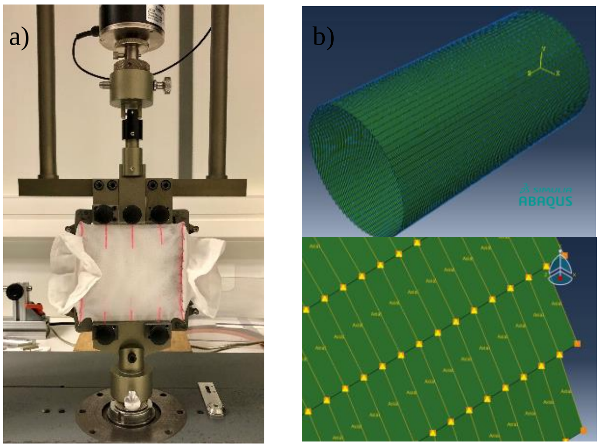

Figure 2: (a) Tensile test on the ankle part of the MCS to analyse its mechanical behavior. (b) Finite element model of the MCS depicting the knitted structure and the inlay yarn.

Results and discussion

This study constitutes the first steps towards the creation of a complete numerical model representative of the behaviour of Medical Compression Stockings. For this, it is necessary to continue with the characterisation of the different compression zones present in the MCS, both geometrically and mechanically. This will allow the properties of each part of the model to be correctly established for a realistic representation of the behaviour during use.

References

1. Liu et al, Textile Research Journal, 87:9,1121-1141, 2016
2. Chattopadhyay et al. The Journal of The Textile Institute, 103:6, 636-642
3. Bruniaux et al, Textile Research Journal, 82:18, 1833-1845, 2012.

Acknowledgements

This work was granted by BPI France as part of the project SYMPHONIES.