ISSN 1407-8015 TRANSPORT AND ENGINEERING 2007-24
MAŠĪNZINĀTNE UN TRANSPORTS

MECHANICS
MEHĀNIKA

FUNCTIONAL FEATURES OF COMPRESSIVE KNITTED PRODUCT

ADĪTA KOMPRESIJAS PRODUKTA FUNKCIONĀLĀS ĪPATNĪBAS

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Keywords: varicose, knee-length stocking, pressure, spiral local strips

1. Introduction

The elaboration concerns the products of medical purpose, namely to the compressive-type devices for treatment and prophylaxis of chronic venous insufficiency and lymphostasis. For treatment and prophylaxis of varicose veins dilating in lower extremities, the compressive articles that create pressure on superficial veins are widely used. The articles are used for fastening blood circulation in veins, in this way preventing and lessening stagnation causes in the extremities, which eliminates the danger of joining inflammation changes [1]. All the known compressive knitted articles have a special recommended pressure arrangement on different parts of the article. However, according to the latest medical science literature [2], one should refer to the anatomical data on the vein system of human lower extremities, in order to improve the functional properties of compressive knitted article. The muscular vein wall tissue has a complex helical constitution. This spring-like arrangement of muscular tissue is the basic mechanism that ensures the returning of the vein wall to the initial state after: the contratation of muscular tissue of the vein; a mechanical influence from ankle muscles and joints, and close arteries. The formation of the up going venous blood flow is provided [3]. Thus, in order to improve the compressive knitted article, the action of which is, before all, aimed at the prevention of development of complications of chronic venous insufficiency (trophic ulcers), medics recommend creation of local massage effect which is especially important on the high-risk areas at the level veins of the Koketa I, II, III PV [4], and also at the level of the knee and foot joints.

2. Aim of the study

To elaborate helical local strips by jersey interlacing, which go along the whole product, similar to the histological constitution of vein wall. To record analytical dependencies connecting physical-mechanical characteristics of a product's material with its geometrical parameters and biochemical characteristics of the patient's body, which the product comes in contact with.

3. Method

The set aim is achieved by inserting an additional thread Polyamide 5.0 tex by a plate interlacing, in the basic interlacing of compressive knitted article on local areas (width 1 – 1.5 cm), and the said thread with the basic thread will create an additional pressure on the surface of human body at 3 - 5 Hg mm higher than the pressure of basic interlacing at the corresponding area of the article. Taking into account the lessened elasticity of compressive knitted article at the local areas and the spring-like constitution of the strips, a substantial restriction of the movement of muscular tissue, and a venous system massage is provided, which is significance for areas with the high risk of trophic ulcers. The beginning of the strips is in the distal part of the ankle, because the compressing of the soft foot tissue, including the venous system, is one of the most important factors ensuring the venous flow. The rise of the helical strip is elaborated at an angle of 58°, similar to the histological constitution of vein wall. Taking into account the analysis of medical science literature and the fact that the anastomoses on the knee and foot areas are without valves, to improve the work of joint pumps, the compression strips fully bend the knee and foot areas. The spring-like function of the local strips of a compressive knitted article influences the eliminating of cellulite. The lymph flow and the intercellular exchange processes are being activated, the joining tissue are strengthened. According to the medical scientific publications, the blockage of oxygen diffusion is one of the theories of venous ulcers development [5]. Building upon general provisions of deformable firm body mechanics [6], there is a need of acquiring the analytical dependencies connecting physical-mechanical characteristics of a product's material with its geometrical parameters and biochemical characteristics of the patient's body, which the product comes in contact with. In order to do that, the following kinematical models are to be recorded: of the local spiral-like strip of a compressive knitted article and a human leg.

3. 1. Kinematic model of the human leg cross sections

To invent new knitted structures with additional local spiral ribbons, first the mathematical model of the leg must be studied, to approximate the real system for each patient. The length H of the lower leg has been measured from the popliteal cross section to the ankle section z = H (Fig. 1). The section with maximal area is at the distance $z = k \cdot H$, where k is constant.

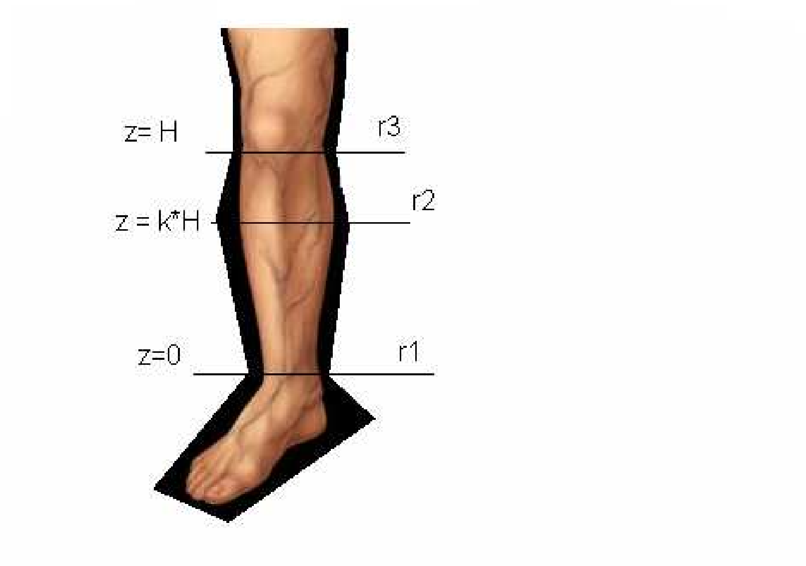


Figure 1. Cross sections of a leg

In these three sections, the average value of cross section radiuses are respectively r1, r2 and r3 (Fig. 1.). To identify the real value of radiuses, circuits L1, L2 and L3 of cross section may be measured and then r1, r2 and r3 are derived from these equations:

$$2 \cdot \pi \cdot r1 = L1; \quad 2 \cdot \pi \cdot r2 = L2; \quad 2 \cdot \pi \cdot r3 = L3. \qquad (1)$$

In our investigations approximation five step polynomial formula for radius r(z) was used:

$$r(z) = a0 + a1 \cdot z + a2 \cdot z^2 + a3 \cdot z^3 + a4 \cdot z^4 + a5 \cdot z^5, \qquad (2)$$

where a0, a1, a2, a3, a4, a5 - six constants.

These six constants may be calculated from the next six boundary conditions (in sections r1, r2 and r3).

$$z = 0,\ r(0) = r1,\ \frac{dr(z)}{dz} = 0; \quad z = k \cdot H,\ r(k \cdot H) = r2,\ \frac{dr(z)}{dz} = 0; \quad z = H,\ r(H) = r3,\ \frac{dr(z)}{dz} = 0;$$

3.2. Example of calculation

Given:

$2 \cdot \pi \cdot r1 = 0.23, \quad 2 \cdot \pi \cdot r2 = 0.40, \quad 2 \cdot \pi \cdot r3 = 0.35, \quad z2 = 0.20, \quad z3 = 0.3,$

$r1 = a0, \quad 0 = a1, \quad r2 = a0 + a1 \cdot z2 + a2 \cdot z2^2 + a3 \cdot z2^3 + a4 \cdot z2^4 + a5 \cdot z2,^5$

$0 = a1 + 2 \cdot a2 \cdot z2 + 3 \cdot a3 \cdot z2^2 + 4 \cdot a4 \cdot z2^3 + 5 \cdot a5 \cdot z2^4 ,$

$r3 = a0 + a1 \cdot z3 + a2 \cdot z3^2 + a3 \cdot z3^3 + a4 \cdot z3^4 + a5 \cdot z3,^5$

$0 = a1 + 2 \cdot a2 \cdot z3 + 3 \cdot a3 \cdot z3^2 + 4 \cdot a4 \cdot z3^3 + 5 \cdot a5 \cdot z3,^4$

$$\text{Find}\,(a0, a1, a3, a4, a5, r1, r2, r3, z2, z3) \rightarrow \begin{bmatrix} 3.6605636911135927227 \cdot 10^{-2} \\ 0 \\ 1.5517606951459795237 \\ 2.4315338527928454076 \\ -56.146327146307521230 \\ 110.5246603603842762 \\ 3.6605636911135927227 \cdot 10^{-2} \\ 6.3661977236758134308 \cdot 10^{-2} \\ 5.5704230082163367519 \cdot 10^{-2} \\ 0.20000000000000000000 \\ 0.30000000000000000000 \end{bmatrix},$$

$z := 0, 0.001, \ldots 0.3$
$a0 := 3.66056 \cdot 10^{-2} \quad a1 := 0 \quad a2 := 1.551760$
$a3 := 2.431533 \quad a4 := -56.14632 \quad a5 := 110.5242$
$r(z) := a0 + a1 \cdot z + a2 \cdot z^2 + a3 \cdot z^3 + a4 \cdot z^4 + a5 \cdot z^5.$

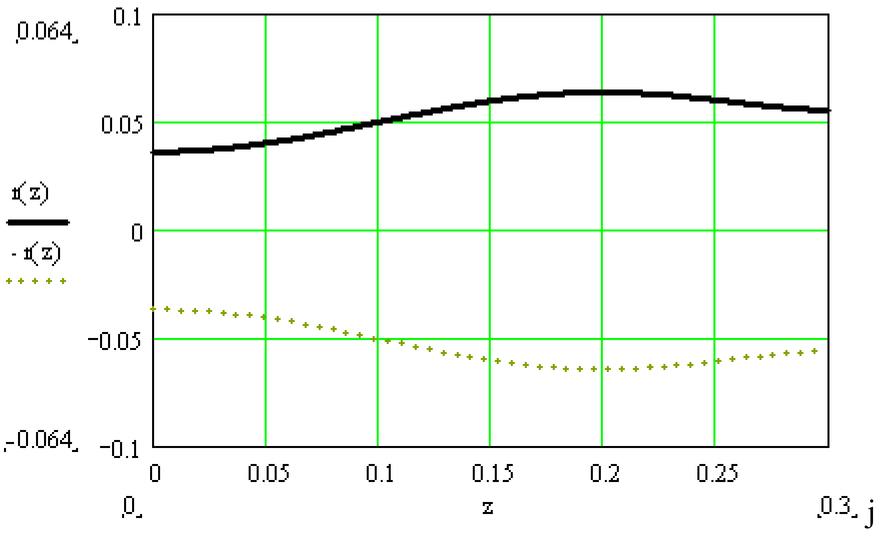
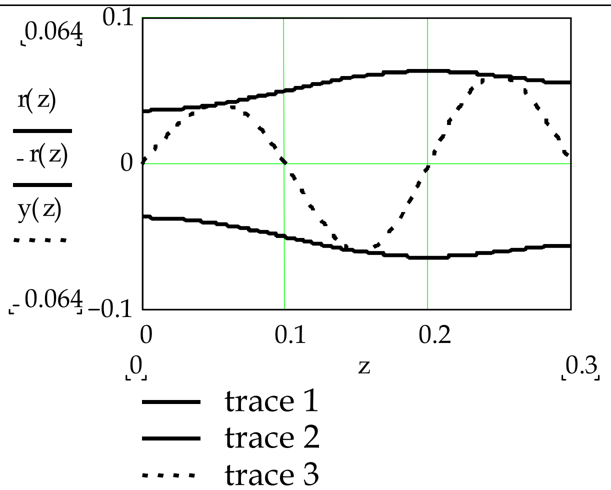


Figure 2. Scheme of the leg approximation

3. 3. Kinematic model of the additional local spiral ribbon

When the kinematic model of leg is known the spiral ribbon of new knitted structures may be invented. These structures may be very simple (right or left side with constant step) or more difficult (right, then left side with variable step along leg). Examples of calculation of spiral ribbon are shown in Fig. 3 - 6.

$$x(z) \;:=\; r(z)\cdot\cos\left(\frac{2\pi\cdot 1.5\cdot z}{0.3}\right); \qquad\qquad y(z) \;:=\; r(z)\cdot\sin\left(\frac{2\cdot\pi\cdot 1.5\cdot z}{0.3}\right).$$



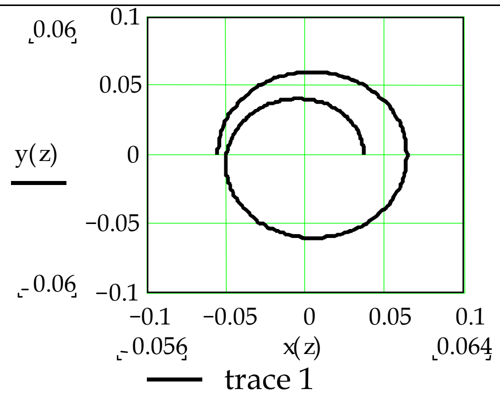


Figure 3. Projection of spiral ribbon on plane surface z; y(z) with constant right step rifling and 1,5 turn	Figure 4. Projection of spiral ribbon on plane surface x(z); y(z) with constant right step rifling and 1,5 turn

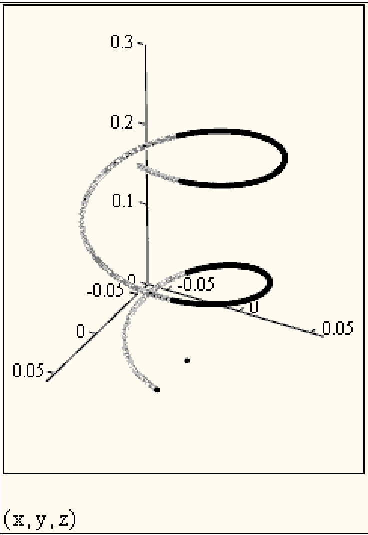


Figure 5. Spiral ribbon in space with constant left step rifling and 2.0 turns

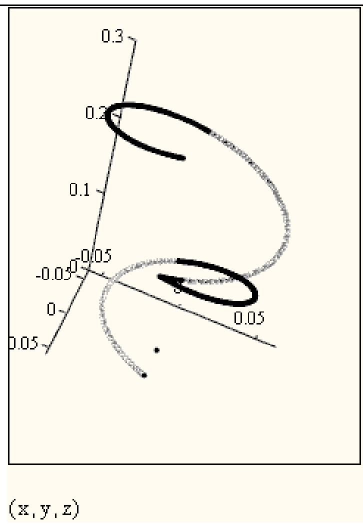


Figure 6. Spiral ribbon in space with constant left, then right step rifling and 2.0 turns

3. 4. Simple dynamics of the model

In the first approximation first task of classical mechanics may be calculated in which law of muscle motion is given in the harmonic form:

$$r(z,t) = r(z,0) + \lambda \cdot \sin\left(\frac{z \cdot \pi}{H}\right) \cdot \sin(\omega \cdot t), \qquad (3)$$

where λ, ω - constants; t – time and see equation (2), Fig. 7.

$r(z,0) = a0 + a1 \cdot z + a2 \cdot z^2 + a3 \cdot z^3 + a4 \cdot z^4 + a5 \cdot z^5$.

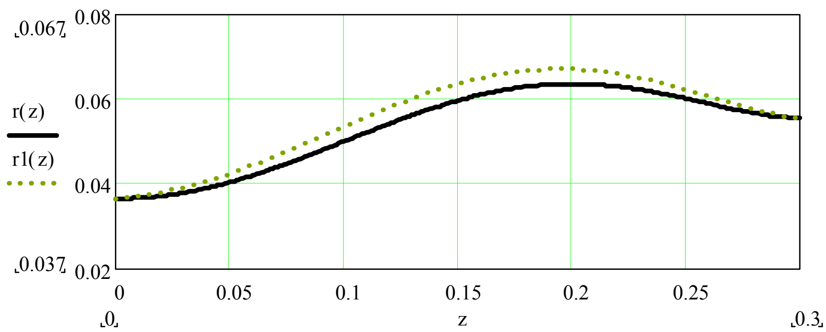


Figure 7. Profile of the leg in one time moment, when motion is harmonic with fixed boundary cross sections (x = 0; z = H)

4. Conclusions

Therefore using the formula (3) and selected kinematic model of the spiral ribbon (see part 3.3) the following may be calculated:
- additional normal reaction of ribbon;
- additional deformation of ribbon-like spring;
- massage effect of ribbon;
- energy dissipation along the ribbon.

Acknowledgements

This work was supported by project LV 1-26/10 6808, TOP DHE 04-07 of Latvia Ministry of Higher Education.

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Ļašenko I., Gonca V., Vība J. Adīta kompresijas produkta funkcionālās īpatnības
Izstrādājums pieskaitāms pie izstrādājumiem ar medicīnisku pielietojumu, t. i., kompresijas tipa izstrādnēm hroniskās venozes un limfozes ārstēšanai un profilaksei. Darba mērķis ir spirālveida lokālu strēmeļu izstrāde, kas veidotas ar žakarda pinumu, kuras vijas caur visu izstrādājumu un ir analogas venozo sieniņu histoloģiskajai uzbūvei. Lai izgudrotu jaunu adīto struktūru ar papildus lokālām spirālveida strēmelēm, iepriekš tika izstrādāts kājas matemātiskais modelis, kas imitē katra pacienta reālo sistēmu. Balstoties uz vispārējām mehānikas likumsakarībām, deformējot cietu ķermeni, tika iegūtas analītiskās atkarības, kas saista materiāla izstrādājuma fizikāli-mehāniskās īpašības ar tā ģeometriskajiem parametriem un pacienta ķermeņa biomehānisko raksturojumu, ar kuru izstrādājums ir kontaktā. Darba izpildes gaitā izstrādāti sekojoši kinemātiskie modeļi: kompresijas adītā izstrādājuma lokālai spirālveida strēmelei un cilvēka kājai. Jaunās adītās struktūras spirālveida strēmeli var izstrādāt tikai tad, kad ir zināms cilvēka kājas kinemātiskais modelis. Turpmāk, izmantojot iegūtos rezultātus, var izrēķināt: papildus normālo strēmeles reakciju; papildus spirālveida atsperes deformāciju; strēmeles masējošo efektu un izkliedes enerģiju gar strēmeli.

Lyashenko I., Gonca V., Viba J. Functional features of compressive knitted product
The elaboration concerns the products of medical purpose, namely to the compressive-type devices for treatment and prophylaxis of chronic venous insufficiency and lymphostasis. The aim of the study - to elaborate helical local strips by jersey interlacing, which go along the whole product, similar to the histological constitution of vein wall. To invent new knitted structures with additional local spiral ribbons, first the mathematical model of the leg must be studied, to approximate the real system for each patient. Building upon general provisions of deformable firm body mechanics there is a need of acquiring the analytical dependencies connecting physical-mechanical characteristics of a product's material with its geometrical parameters and biochemical characteristics of the patient's body, which the product comes in contact with. In order to do that, the following kinematical models are to be recorded: of the local spiral-like strip of a compressive knitted article and a human leg. When the kinematic model of leg is known the spiral ribbon of new knitted structures may be invented.Using the results of research the following may be calculated: additional normal reaction of ribbon, additional deformation of ribbon-like spring, massage effect of ribbon, energy dissipation along the ribbon.

Ляшенко И., Гонца В., Виба Я. Функциональные особенности вязаного компрессионного изделия
Разработка относится к изделиям медицинского назначения, а именно к устройствам компрессионного типа для лечения и профилактики хронической венозной недостаточности и лимфостаза. Целью данной работы является разработка спиралевидных локальных полосок, выработанных жаккардовым переплетением, которые проходят вдоль всего изделия, и сходны с гистологическим строением венозной стенки. Для изобретения новой вязаной структуры с дополнительными локальными спиралевидными полосками, предварительно была разработана математическая модель ноги, чтобы аппроксимировать реальную систему для каждого пациента. Основываясь на общих положениях механики деформируемого твердого тела, получены аналитические зависимости, связывающие физико-механические характеристики материала изделия с его геометрическими параметрами и биомеханическими характеристиками тела пациента, с которым контактирует изделие. В порядке проведения работы были записаны следующие кинематические модели: локальной спиралевидной полоски компрессионного вязаного изделия и человеческой ноги. Спиральная полоска новой вязаной структуры может быть изобретена, когда известна кинематическая модель ноги. Используя результаты исследований, далее можно рассчитать: дополнительную нормальную реакцию полоски; дополнительную деформацию спиралевидной пружины; массажный эффект полоски; диссипативную энергию вдоль плоски.