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GEOMETRICAL DESIGN ALGORITHMS FOR MOULDED SHOE SOLES

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Abstract. This paper presents geometrical design algorithms for moulded flat shoe soles and for mould nests execution patterns. The developed algorithms have applications in both manual design and two dimensions CAD/CAM dedicated systems (2D), and three dimensional CAD/CAM systems (3D).

1. INTRODUCTION

The shoe soles obtained by forming in moulds, are made as prefabricated parts or directly on the upper part of the footwear. The diversification of the shoe soles model is inexhaustible. There are multiple diversification criteria [1]: the spatialization degree, the heel height, the shoe sole thickness, the anti-skid pattern model, the model of the weight removal cavities, the material types and thermochemical processes through which are formed, colours, number of colours, etc.

Regarding the spatialization degree, the shoe soles obtained by forming in moulds can be flat, partially spatialized and spatialized.

The flat and partially spatialized shoe soles are made as prefabricated pieces which are mounted on the shoe upper part by gluing or sewing. The moulds in which are formed this kind of shoe soles are composed by two pieces, one main plate and one shutter plate. By closing this two plates the nests in which are formed the shoe soles is formed.

The spatialized shoe soles are obtained in two ways, as prefabricated pieces which are mounted on the upper part of the footwear by gluing or sewing. In the case of obtaining the shoe soles as prefabricated pieces, usually the moulds are composed of two pieces, one main plate and one shutter plate. In the case of the moulds in which the shoe soles are formed directly on the upper part of the footwear, the nests are formed by closing four pieces: one metallic shoe last, two side plates and a bottom plate. In this last case, before forming the shoe soles, the readymade footwear upper part is mounted on the metallic shoe.

The mould nests in which the shoe soles are formed have complex shapes. The complexity degree of the mould nests is determined mainly by the spatialization degree of the shoe soles, by their shape and dimension and by the anti-skid pattern model and the weight removal cavities.

The shoe lasts are the starting point for the shoe soles design and implicitly for the mould nests in which are formed. The shapes of the shoe are not similar to classical spatial shapes. Passing from the shoe last to their plane representation and then to the shoe soles and the mould nests, requires choosing design methods which are fast and highly precise. The last copy is made using high precision devices, digitizers attached to the PC or by other means. The number of outlines which are copied from the shoe last is conditioned by the shape of the designed shoe sole. Also, the spatialization degree of the shoe sole and, in some situations, functional conditions for the moulds, require different positioning variants of the shoe lasts in the copy machine in relation with the horizontal axis [6].

Depending on the nature of the polymers undergoing forming, are distinguished the following mould types: vulcanization moulds, injection-cooling moulds and injection-structuring moulds. In terms of component parts which form the nests, there are no essential differences between the three mould types. Also, there are no essential differences in designing the nests. The differences that stand out result from the nest feeding mode, from the mounting of the mould pieces on the specific equipment, from the movement trajectory of the mould pieces when closing and opening the nests and from the thermochemical forming processes. Considering the design particularities determined by the functionality of the machine on which the moulds are mounted, the designer must know exactly the design data in relation to the machine [2].

A set of patterns is needed for the execution of the mould. The greater the spatialization degree of the shoe soles and implicitly of the mould nests the higher the number of patterns needed.

The shoe soles and mould cavities design is made for the average number of the sizes series. The patterns for the entire series are obtained by grading, using the variation laws of the foot anthropometrical parameters. Therefore, whatever the spatialization degree, the collection of the data needed for shoe soles and mould nests design is made on shoe lasts with the average size number.

The design algorithms of the flat shoe soles, partially spatialized and spatialized, as well as mould nests in which the shoe soles are formed, have particular features for each individual situation.

This paper presents geometrical design algorithms for flat shoe soles and for the mould nests execution patterns, nests in which the flat shoe soles are formed.

2. FLAT SHOE SOLES DESIGN ALGORITHMS

For the flat shoe soles design, these steps are followed [4, 5]:

Step 1. Copying the shoe last. For the design of this kind of shoe soles is needed a copy of the bottom surface of the shoe last and to measure the heel height. The starting point of the flat shoe sole design is the footwear midsole. Its contour is identical with the bottom surface of the shoe last.

Step 2: Drawing of the axes and basic anatomical points needed in the design process on the midsole outline

These operations can be followed in figure 1.a. On the obtained pattern the insole axis and joint axis are drawn as well as the main anatomical points: 0, representing the back of the foot curvature amplitude; 2, representing the heel center; 3, representing the middle for the foot arch; 4, representing the center of the metatarsophalangeal articulations I-V and 5, representing the extremity of the Vth toe. The position of each of this points is calculated using the following formulas: point 1 is marked as the insole extreme back point; calculate the distances between: 0-1=0,025 L_p, 0-2=0,18 L_p, 0-3=0,48 L_p, 0-4=0,66 L_p, 0-5=0,81 L_p, 0-6= L_p. L_p, represents the foot length which is the same with the shoe last size number in centimetres. The segment 1-7 represents the length of the shoe last insole. The joint axis is drawn starting from point 1 at an angle γ in relation with the insole axis. The angle $\gamma = 6^0$ for children and teenagers insoles and $7\text{-}7.5^0$ for insoles for women and men. Through point 4, perpendicular to the joint axis is drawn the metatarsophalangeal articulations line I-V.

Step 3: Drawing the shoe sole interior contour.

The shoe sole interior contour is obtained by adding the thickness of the upper part materials to the midsole contour. Because of the footwear structure, this thickness is variable on different zones of the midsole. These zones with variable thickness are bounded in figure 1.a, by the curves a-1-a; a-b; b-c and c-7-c.

***Step 4: Drawing the shoe sole exterior contour*.**

The shoe sole exterior pattern is obtained by drawing a contour parallel to the shoe sole interior contour, at a distance equal with the welt width as in figure 1.a.

Step 5: Designing the longitudinal section through the shoe sole axis.

The longitudinal section through the flat shoe sole is represented in figure1.b. The procedure to design this pattern consist in: draw a horizontal axis on which are positioned the length of the interior shoe sole axis length represented by the segment $1'$- $7'$ and the exterior shoe sole length represented by the segment $1''$- $7''$; then are positioned the points 2-heel center and 4-metatarsofalangial articulations I-V center; on the perpendiculars through the points $1'$ and $7'$ the welt height will be measured, respectively the segments $7'$-8=$1'$-9; parallel to the horizontal axis are drawn the segments 8-$7''$= 9-$1''$, segments that represent the weld width; through the point 4 is drawn a perpendicular to the horizontal axis on which is measured the segment 4-$4'$ which represents the shoe sole width including the anti-skid pattern; through the point $4'$ is drawn a parallel to the horizontal axis, outlining the shoe sole width on the entire longitudinal section; from the parallel through the point 4 is measured the segment 11-12 which represents the heel height; from the point 1” is drawn the back shape of the heel, in the longitudinal section view, as a segment 1”-13; the length of the heel to the anterior part of the heel is represented by the segment 12-13; the shape of the heel on the back and between the posterior part and front sole can have a diversity of shapes; when drawing the shape of the heel is taken in account the restriction that the projection of the heel center, respectively the projection of point 2, must be inside the perimeter of the heel cap.

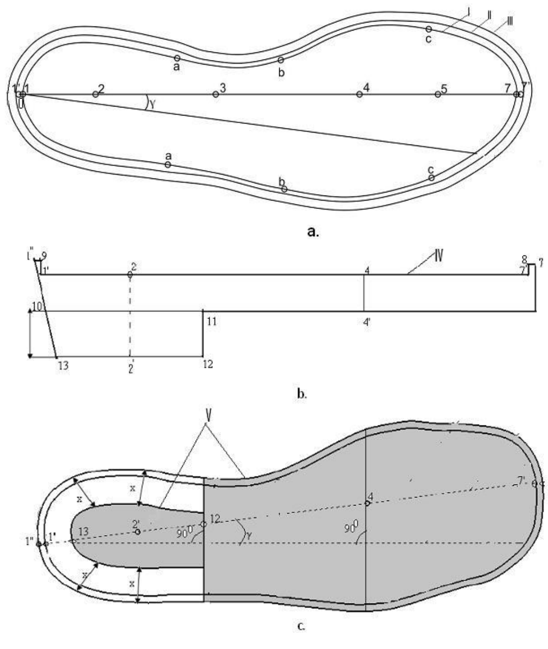

Figure 1. Designing patterns for flat shoe soles
I- shoe last midsole; II- shoe sole interior contour; II-I shoe sole exterior contour; IV- longitudinal section through the shoe sole axis; V- contour of the shoe sole with anti-skid pattern

Step 6. Designing the contour of the shoe sole with anti-skid pattern.

The procedure to obtain the shoe sole contour on which will be designed the anti-skid pattern consists in: the segment 12-13 is projected in plane, the length of the heel tap, from the longitudinal section in figure b, on the shoe sole axis in figure 1.c.; through point 12 is drawn a line perpendicular to the shankpiece axis which represents the front heel limit line; on the lateral zones, the heel tap contour is equally spaced in relation with the shoe sole exterior contour, both at the interior and exterior. The distance (x) at which is drawn the lateral contour of the heel tap in relation with the shoe sole exterior contour depends on the shape which will be given to the heel in cross sections; in the concrete cases, at the sole design, on the shankpiece and front sole zones, the contour of the shoe sole with the anti-skid pattern is noticeably smaller than the shoe sole exterior contour, with 0,5-1,5 mm, to obtain the right aspect of the shoe sole lateral surface, slightly rounded; this slightly decreased contour was not outlined in the figure 1.c. The anti-skid pattern is designed on the obtained contour.

Step 7. The design of the shoe sole weight removal cavities.

The weight removal cavities are designed on the surface that comes in contact with the upper part of the footwear and their role is to lower the shoe sole weight. The cavities must not lower the shoe sole resistance, must not contribute to the heel flatting or bending deformation and must not submit the foot to greater effort while walking. When designing the cavities should be taken in account the technology used in executing the moulds in which the shoe soles will be obtained.

The design methodology for the shoe sole weight removal cavities can be followed in figure 2. The proceedings consist in:

- On the surface outlined by the shoe sole interior contour is drawn the surface on which will not be made weight removal cavities. This surface represents the zone on which the lasted upper part is glued to the shoe sole.

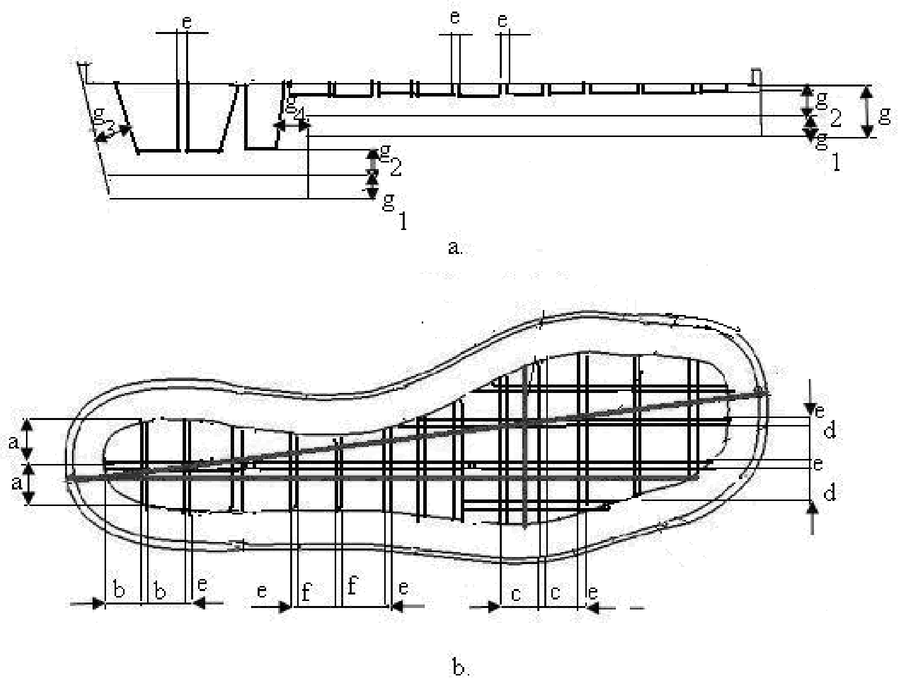

Figure2. Designing the shoe sole weight removal cavities

- The reinforcement network of the weight removal cavities will be provided by a set of ribs of width “e”, oriented in the longitudinal direction after parallel direction to the shankpiece axis and in transverse directions after perpendicular direction on the shankpiece axis. This variant is most common. In concrete cases, some designers, I order to change the plane shape of the cavities from rectangular to rhombus, on the forepart of the shoe sole, orients the ribs slightly rotated in relation with this direction. Also, depending on the thickness of the shoe sole, on the technologies and on the polymer blends of which are made, the cavities may take the form of a circle, ellipse or other shapes, situations in which the reinforcement network is not needed anymore in the space between the cavities.

- The cavities dimensions are variable depending on the shape and height of the heel and on the width of the shoe sole; this sizes have been dimensioned in figure 2 with the characters “b”, “d” and “f”.
- The cavities design in the longitudinal section through the shoe sole axis is obtained following this procedure: from the total thickness of the shoe sole “g” and from the height of the heel is established the thickness “g_1” on which will be designed the anti-skid pattern; from the total thickness “g” of the shoe sole is marked the thickness “g_2” which represents a minimal thickness of 4-5 millimetres which will provide the reliability of the shoe sole at repeated bending, respectively the reliability to deformation through flatting or flexing the heel. On the entire section of thickness “g_2” the shoe sole will be represented by a solid with uniform thickness in all longitudinal and transversal directions. In the case of high heels to which the cavities depth is big, is recommended to adopt the thickness “g_2” greater than 5 millimetres, its size will be established particular to the case, depending on the height, shape of the heel, the polymer blend from which is obtained the shoe sole etc. Also, this thickness can be greater in the zones between the front part of the heel and the front sole, with consequences over the overall weight of the shoe soles. The weight removal cavities will be made on the thickness left after removing the thicknesses (g_1+g_2) from the total thickness “g”. In the case of the heel should be provided the thickness “g_3” in the rear and lateral zones, respectively “g_4” to the front part of the heel to obtain the reliability needed while wearing.
- Depending on the destination, model, heel height, the polymer used to form the shoe soles, etc., the dimensions of the weight removal cavities can vary in relatively wide limits. Here are some examples: b=10-20 mm; c=5-15 mm; d=5-15 mm; e=2-4 mm; g_3, g_4 5-14 mm.

Step 8. Designing the anti-skid pattern.

The design of the anti-skid pattern is done on the shoe sole surface which comes in contact with the support plan, respectively on the pattern obtained at step 6. The design of the anti-skid pattern, its arrangement on the shoe sole surface is done in accordance with the skid tendency of the foot in the walking phases. In figure 3 is presented an anti-skid pattern model.

Figure 3. Design of anti-skid pattern

3. DESIGN ALGORITHMS OF THE EXECUTION PATTERNS OF THE MOULD NESTS FOR FLAT SHOE SOLES

The transition from the shoe sole patterns to the mould cavities pattern is done by increasing the shoe soles patterns with the values of the contraction coefficients of the blends of which are formed the shoe soles [3,4]. The contractions of the blends from which are formed the finite shoe soles are not uniform and are produced both in longitudinal direction and in transversal direction. Therefore, the increasing of the patterns is made both on longitudinal direction and on transversal direction.

The increasing is done starting from the pattern of the shoe sole interior contour of the average size number. On this pattern, represented in figure 4, is measured the segment 1-2 on the longitudinal axis, which represents the length of the shoe sole interior contour, L. On transversal directions, are established a set of widths l_{t1}- l_{t1}', l_{t2}-l_{t2}',…,l_{tn}-l_{tn}', which have different sizes because of the irregular contour of the shoe soles.

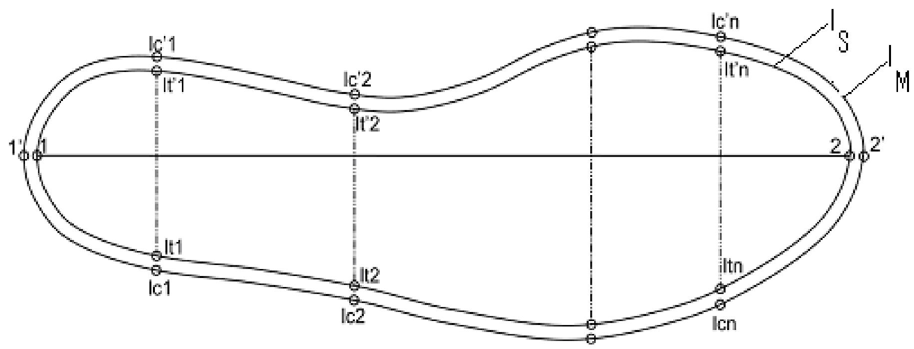

Figure 4. Obtaining the pattern for the interior contour of the nest
l_S- Shoe sole interior contour pattern; l_M- Mould nest interior contour pattern

The increasing on the longitudinal direction of the shoe sole is calculated with the relation $\Delta L = L \cdot C, [mm]$ (1).

$$\Delta L = L \cdot C, [mm] \tag{1}$$

where:
ΔL – represents the increasing on the longitudinal direction of the shoe sole, in millimetres;
L – the length of the longitudinal axis of the interior shoe sole, in millimetres;
C- contraction coefficient of the blend used to form the designed shoe soles, in percentage.
The increasing of the shoe sole contour on the transversal direction is calculated using the relation (2

$$\Delta l_i = l_{ti} \cdot C, [mm]).$$

$$\Delta l_i = l_{ti} \cdot C, [mm] \tag{2}$$

where:
Δl_i – represents the increasing on every transversal directions, l_{t1}- l_{t1}', l_{t2}-l_{t2}',…, l_{tn}-l_{tn}' of the shoe sole, in millimetres;
l_{ti} – the width of the shoe sole on the segment for which is calculated the increasing using the contraction index;

C - contraction coefficient of the blend of which are formed the designed shoe soles.

The transition from the patterns of the shoe sole interior contour to the mould cavity interior contour pattern is done proceeding like this:

- The ΔL value calculated for the longitudinal direction, in which the shoe sole has the maximum length, is divided by two. Half of the resulted value, $\Delta L/2$, is distributed along the longitudinal axis of the shoe sole in point 1, the other half is distributed in point 2. Consequently: $1\text{-}1' = 2\text{-}2' = \Delta L/2$.
- The values Δl_i calculated for each of the directions l_{t1}- l_{t1}', l_{t2}-l_{t2}',…,l_{tn}-l_{tn}' are also divided by 2; the values $\Delta l_i/2$ are distributed on each side of the points l_{t1}, l_{t1}'; l_{t2}, l_{t2}';…,l_{tn}, l_{tn}', obtaining the points l_{c1},l_{c1}'; l_{c2}, l_{c2}';…,l_{cn}, l_{cn}'.
- Through the points 1', l_{c1}', l_{c2}',.., l_{cn}', 2', l_{cn}, …, l_{c2}, l_{c1}, 1' is drawn the increased contour of the shoe sole. Concretely, is drawn in interior contour of the mould cavity.

In the series of sizes, the increasing on the longitudinal directions calculated for the average numbers of the series, the values ΔL, can vary between the limits from 2 mm to over 6 mm. Multiplying the patterns for the entire size series, these differences are significant even in the series of small sizes. In conclusion, in order to obtain the execution patterns of the mould cavities, the shoe sole patterns will be always increased on the longitudinal direction.

The increasing calculated on the transversal directions, the values Δl_i often in series of big sizes, is less than 1 mm. On the other side, within a series of sizes, the width of the shoe last does not increase significantly from a size number to another, the increases and decreases in relation to the average size number have values under 1 mm. This way, the dimensional modifications of the shoe soles on the transversal directions when removing from the mould, are not significant and don't have any significant influences over the assembling technologies with the upper part. In these situations, the obtained patterns from the shoe sole design will not be increased on their transversal directions. There are situations when the shoe last width is big and the transversal contraction of the shoe soles while removing from the moulds are greater than 1mm. In these situations the shoe soles patterns will be increased with the values resulted from the calculations also on their transversal directions.

Figure 5 presents the obtaining all the patterns needed to execute the mould nests in which the flat shoe soles are formed.

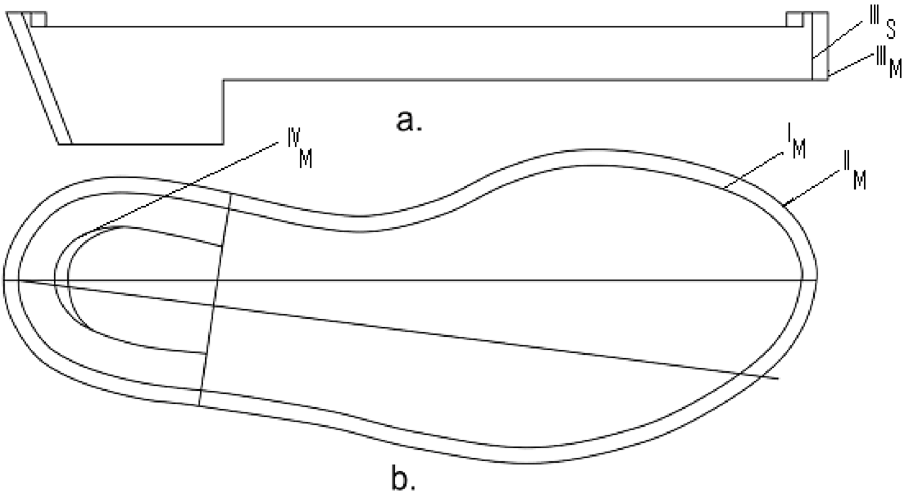

Figure 5. Patterns of the mould nest for flat shoe sole
I_M – Pattern of mould nest interior contour; II_M – Pattern of mould nest exterior contour; III_S – Pattern of longitudinal section through shoe sole; III_M – Pattern of longitudinal section through mould nest; IV_M – Pattern of mould nest with anti-skid pattern

The pattern of the nest exterior contour, from figure 5.b, is obtained by drawing a parallel contour to the interior contour of the cavity resulted in figure 4, at a distance equal to the shoe sole welt width.

The pattern of the longitudinal section through cavity presented in figure 5.a is obtained by increasing the pattern of the longitudinal section through the shoe sole. The increasing is done in accordance with the patterns of the cavity interior contour and the patterns of the cavity exterior contour represented in figure 5.b.

The cavity contour with anti-skid pattern from figure 5.b will be obtained taking in account the increasing produced on the length of the heel tap from the section in figure 5.a and the increasing produced on the of the cavity exterior contour in Fig.5.b.

The patterns designed by this procedure are obtained for the average size number of the sizes series. The multiplication for the entire sizes series is done through methods similar to the multiplication of the footwear upper parts.

4. CONCLUSIONS

- The footwear soles are complex geometrical shapes that can be obtained in an inexhaustible number of models, using various polimeric blends, through different thermochemical processes.
- The great diversity of shoe sole models leads to a large diversity of moulds. The more complex the shoe soles shape and especially the anti-skid pattern the greater the difficulty degree of mould execution, mainly mould nest execution. The mould manufacturers feature various execution technologies which are adapted to the available technical means. Not all the technologies are available to execute moulds in which the shoe soles with a high complexity degree are formed.
- The shoe sole design and implicitly the mould nests design often require the design of the nest execution patterns.
- There is now specialized software applications with all the equipment needed to perform assisted design activities, both for shoe soles and for moulds. The processing equipment for moulds is more efficient. The algorithms developed in this paper have applications in both shoe soles and mould nests manual design, using the drawing board, and specialized CAD/CAM bi-dimensional (2D) systems and CAD/CAM tri-dimensional (3D) systems.

References

1. Chirilã, E. (2008). „Solutions Of The Different Models Of Cavities For Soles Obtaining“. Anals of the Oradea University, fascicle of Textile Leatherwork, pp.313-318, ISSN 1582-5590.
2. Dragomir, A. (2007). „The Main Research Directions In Injection Technologies For Footwear Precast.“The International Scientific Conference Unitech Gabrovo Bulgaria, pp.168-173, ISSN 1313-230X.
3. Drişcu, M. (2008). “Modelarea formelor plane şi spaţiale ale încãlţãmintei”. Editura Pim Iaşi, ISBN 978-606-520-233-7.
4. Ionescu, C. (1995). “Matrite si procese de formare in matrite din industria de incaltaminte”, , Editura Cronica Iasi, ISBN 973-9206-09-3.
5. Ionescu Luca, C. & Mocanu, R. (2010). “Proiectarea matriţelor pentru încãlţãminte”, Editura Pim Iaşi, ISBN 978-606-13-0100-3.
6. Mãrcuş, L. (2008). „Aspects Regarding The Lasting Of Footwear Uppers Using Different Technological Variants“. Anals of the Oradea University, fascicle of Textile Leatherwork, pp. 331-336, ISSN 1582-5590.