ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ALGORITHMS FOR THE PROGRAMMING OF FOOTWEAR SOLES MOULDS ON WORKING POSTS OF INJECTION MACHINES

LUCA Cornelia[1], IONESCU Cozmin[2]

[1, 2] *"Gheorghe Asachi" Technical University of Iasi, Faculty of Textiles, Leather and Industrial Management, Dimitrie Mangeron Str., No. 29, 700050, Iasi, Romania,*
E-mail: cionescu@tex.tuiasi.ro; ionescucozmin@yahoo.com

Corresponding author: Ionescu Luca, Cornelia, E-mail: cionescu@tex.tuiasi.ro

Abstract: *The moulds stock necessary for realization in rhythmically conditions, a certain volume of footwear soles depends on some criterions such as: the range of soles for footwear volume daily realized, the sizes structure of those soles for footwear and, respectively, the sizes tally, the technological cycle for an used mould depending on the equipment efficiency, the provide necessity of spare moulds, the using and fixing conditions etc.*
From the efficiency point of view, the equipments may have two working posts, or more working posts (always, an even number), as 6, 12, 24, 40 posts.
Footwear soles manufacturing takes into account the percentage distribution of the size numbers of the size series. When o portative assembly is used for the manufacturing of the footwear soles using the injection with "n" working posts, it is very important an optimum distribution of the working posts. The disadvantages of these equipments are the situations of the no equilibrium programming of the moulds, so that, in one time, some working posts spread out of the work.
The paper presents some practical and theoretical solutions for moulds stock programming in portative assembly for footwear soles injection, so that an optimum equilibrium degree of the working posts will obtain.

Key words: *footwear, moulds, shoes soles, injection systems, designing*

1. INTRODUCTION

The moulds stock necessary for a certain product volume realization, in rhythmically conditions depends on some criterions such as: the range of products volume daily realized, the sizes structure of those ranges and, respectively, the sizes tally, the technological time for an used mould depending on the equipment efficiency, the provide necessity of spare moulds, the using and fixing conditions. The paper presents some results of the authors' researches about the optimum run of the injection and manufacturing of the shoe footwear soles in moulds and the placing of the moulds on the equipments algorithms, so that, an optimum equilibrium degree of the working posts will obtained. The equipments used in footwear soles manufacturing, by cooling and injection thermo chemical processes are, from constructive point of view, divided in two branches, equipments with injection straight on vamps and soles injection equipments, as semi finished articles which will be assembled on the vamps. From the efficiency point of view, the equipments may have two working posts, left-right, or more working posts (always, an even number), as 6, 12, 24, 40 posts.

These differentiations have a direct influence up to the manufacturing cycle time, respectively, up to the time between two identical successive steps of the process. Entirely, this time has two components: the impose time of the thermo chemical process and the time for the technological servicing of the equipment and of the mould.

When the footwear soles are injected using portative equipments with "n" working posts, the placing of the moulds on working posts has a great importance. This placing must provide the lots of the same kind products realization in contractual pre-established sizes tally, and, in the same time, the equipment working posts must be equilibrated used [1].

2. EXPOSITION

These moulds are for the shoe soles manufacturing, based on thermoplastic polymer blends. The injection takes place after the mould cavity is closed. Then the molding and partial cooling processes take place until it is realized a temperature which avoids the deforming of the products and then, the unloading of the products at high temperature (60-80ºC) depending on the polymer.

The injected soles manufacturing takes place in two situations: the injected soles realization straight on the vamps and the soles realization as semi finished articles which will be assembled on the vamps using gluing or sewing processes. When the soles manufacturing takes place straight on the vamps, there are used, for each pair and for each size number, two sets of moulds for each sole of each leg. Usually, these equipments have two shoe-lasts for each leg, one of them is into the mould (for the sole injection) and the other one has injected sole and waits the footwear unloading. The using of two shoe-lasts for the same mould determines a time for a fitting up of the vamps on the shoe-lasts (for the soles injection), respectively, a time for the unloading of the footwear with sole after the injection, out of the sole thermo chemical process manufacturing. The necessary technological time (a cycle time), (t_c), for one sole manufacturing is pointed [2[,[3] in formulas (1), (2), (3):

$$t_c = t_a + t_p + t_e \text{, (minutes)} \qquad \textbf{(1)}$$

$$t_d = t_a + t_e \text{, (minutes)} \qquad \textbf{(2)}$$

$$t_c = t_p + t_d \text{, (minutes)} \qquad \textbf{(3)}$$

where: t_c- cycle time for a finished sole manufacturing, minutes; t_a - fitting up time of the vamps on the metallic shoe-lasts of the mould, minutes; t_p- time of the thermo chemical injection, moulding and cooling of the polymer blend process, minutes; t_e – time for unloading of the products, minutes.

The process time has the following components: the time for the mould closing and the time for the injection and cooling of the polymer melting used in sole manufacturing. This time is the main one in the technological time, necessary in one product manufacturing and it depends on the polymer blend formula, on the object dimensions and on the cooling regime. For a good efficiency providing, on each working post, respectively, on each mould which realizes a pair of soles, the injection aggregates have refrigerating equipments which decrease the cooling time of the polymer melting after the injection into the cavity. The fitting on the vamps on the metallic shoe-last for the sole injection time (t_a), respectively, the unloading of the footwear with sole from the metallic shoe-last time (t_e) are components of the mould attending time (t_d). This time is during the waiting of the mould, just before or after the sole manufacturing process.

In these conditions, the efficiency of this aggregate (in pairs/480 min) for each working post is [4, 5]:

$$P = \frac{T - t_{pi}}{t_c} \text{, (cycles/480 min)} \qquad \textbf{(4)}$$

where: P- pairs/480 min; T- time per shift (480 min); t_{pi} – time for preparing and finishing the work, minutes; t_c – time for one cycle, minutes.

The preparing and finishing of the working time (t_{pi}) has the following components: the time necessary for the preparing of the equipment and of the moulds at the beginning of the work, the time for the cleaning of the moulds at the end of the work and the time necessary for the changing of the moulds during the shift.

The main problem in this case is the used mould number in a continuous process. The used degree of the moulds depends on the soles number sizes tally which must be realized per shift. Depending on this tally, considering the different working posts of the aggregate, the used degree of the moulds is between 6-100%. The adjustment of the moulds necessity, depending on the efficiency of the equipments, on the number of the size tally and on the working posts number of the portative equipment (6, 12, 24,…., 40), is a difficult problem, but a solvable one. The algorithms for establishing of the moulds stocks using program will be presented in the next paragraph and they represent a solution of the problem [4].

Considering that the time of the process (t_p) takes place in the same time with one rotation of the rotative equipment,(excepting the using time (t_d)), the number of the moulds working posts per one worker is:

$$n_m = \frac{t_c}{t_d} \quad (5)$$

where: n_m – number of the moulds a worker may use.

The rotation rhythm of the injection aggregate uniselector depends on the number of the working posts, respectivelly, on the number of the moulds (m), depends on the time of one cycle (t_c) and on the using time (t_d), as in formula (6):

$$t_c = m \cdot t_d \text{ (minutes)} \quad (6)$$

When the soles are obtained injecting straight on the vamps, experimental researches [5],[6] show that almost all aggregates (whatever how the number of the working posts is) have a medium efficiency for one mould, at about 100-200 pairs/8h. Industrial conditions show that the preparing and finishing time for one shift (t_{pi}), is about 30 minutes. Replacing the values in formula (4), the time of one cycle per mould (t_c), becomes about 2,25 minutes. This time will be completed with the time necessary for closing and opening the mould which is about 0,4 minutes. So, the time for one cycle per mould is about 2,65 minutes.

In the soles moulds case, the using time contains only the unloading time of the product. Providing of the necessary time of the process (t_p) (considering the using time to be maximum 0,2 minutes), increases the posts numbers of the uniselector till 24, even 40 working posts.

3. EXPERIMENTAL PART

3.1. The programming of the assembly of the moulds and the working posts balance in the researched case

The quantity of soles which must be processed on each working posts depends on the distribution of the moulds on the posts, for an optimum balance degree of the used equipments obtaining. The paper presents some theoretical and experimental conclusions of the authors and the results of the researches obtained [7],[8] using an uniselector with 12 working posts.

The lot of products taking into consideration, has the size P = 7500 pairs of footwear of the perforated type, for the teenagers, with injected soles straight on vamps, in the VAMOS model. To make the lot of footwear/shoes which covers sizes from 22 cm to 28.5 cm, it will be used a set of moulds which have a cavity corresponding to the model of the sole. The delivery of the footwear according to sizes and of the moulds in the VAMOS set is presented in the Table no.1 below. From Table 1, we draw the conclusion [8] that the set contains 20 pairs of moulds which will be set on the 12 working posts of the equipment to get different quantities of footwear according to size numbers; this will lead to the coupling of the moulds of different sizes on the same post, in order to ensure a balanced loading of the working posts.

It is considered that the balance of the working posts of the equipment may be appreciated by the degree of balance of the loading, symbolized by E, expressed in % and which may be determined using the equation (7):

$$E = \left[1 - \frac{M(n - n_{\min})}{(M-1)n_{\max}}\right].100 \text{, (\%)} \quad (7)$$

where: M- number of the working posts of the equipment; n- number of cycles of the rotating table necessary to make the lot of products P, for a certain assembly programmed and rolling of the moulds; $n_{\min}$ - minimum number of cycles of the rotating table necessary to make the same lot of products P, in the condition of an ideal balance of 100%, for M posts; $n_{\max}$ - possible maximum number of cycles necessary to make the lot of products in the condition of null balance, 0%, respectively, when all moulds of the set would be placed successively only on one working post. In short, the degree of balance, E, can be calculated using the equation (8).

$$E = \frac{M(P-n)}{P(M-1)}.100 \text{ ,(\%)} \quad \textbf{(8)}$$

Table 1:*Outfit of moulds for a certain production*

Footwear size, cm	Quantity, pairs	Number of moulds, pairs
22	40	1
22,5	80	1
23	130	1
23,5	420	1
24	780	2
24,5	690	2
25	1270	2
25,5	1010	2
26	1010	2
26,5	680	2
27	650	1
27,5	410	1
28	230	1
28,5	10	1
Total	7500	20

In the equation (8), the terms have the same meaning as in the equation (7). For the concrete case under discussion:

M=12

$n_{\min} = \frac{p}{m} = \frac{7500}{12} = 625$; $n_{\max}$=P=7500

$$n = \frac{P}{number \cdot pair / cycle} = \frac{7500}{6} = 1250$$

The degree of balance, E, calculated using both equations, has the value of 90,9 % in the case under discussion. To make the lot P=7500 pairs of shoes with the set formed of 20 pairs of moulds, which surpass the number of working posts (12) of the equipment, it appears the problem of establishing the type of coupling of the moulds of different sizes on certain working posts. This time, symbolized T, is expressed in hours and can be determined using the equation (9).

$$T = \frac{PAS(M.L + I - M) + \sum Ts_i}{3600} \text{, (hours)} \quad \textbf{(9)}$$

in where: PAS- rhythm of the equipment, seconds, that is the time between 2 successive injections; M- number of posts of the equipment; L - loading of the respective mould expressed through the quantity of products which are made on it, expressed in pairs; I - number of the order of the respective working post on the rotating table of the equipment; ΣTs_i - sum of the changing time of the moulds from other posts on which the moulds where replaced, seconds, if the replacement demanded to stop the equipment. At the injection installation of carousel type, the DESMA makes, PAS = 6s and ΣTs_i = 400 s [9],10].

3.2. The obtained results and their interpretation

Taking into consideration the concrete values of the above sizes, through the automatic processing of the data there were obtained the results presented in Table 2. The results [5], [9] in Table 2 show that out of the set of 20 moulds, only 19 will be used, when the equipment starts to function and they will be assembled on the 12 posts of the equipment in the following order: 28/1, 25/2, 25/3, 22.5/4, 28.5/5, 22/6, 25.5/7, 27/8, 23/9, 26.5/10, 26.5/11, 24.5/12. After producing the quantity of shoes, the moulds that correspond to the extreme numbers of the series will be replaced with others as follows: 28 ----27.5 (post 1), 22.5 ---26 (post 4), 28.5----26 (post 5), 22---- 25.5 (post 6), 23---- 23.5

(post 9), 26.5---24 (post 10), 26.5----24 (post 11). Through coupling the moulds of different sizes on the working posts shown, the variable loading is between the limits of (505 – 730) pairs/posts and after a number of 15.3 h of continuous functioning of the injection installation there can be achieved the entire lot of shoes of 7500 pairs.

Table 2: **Moulds placing on working posts**

Order number of working post	Size number of the mould set on the post(cm)	Quantity of shoes made on the post and mould(pairs)
1	initial 28 27.5	230 410 640
2	25	635
3	25	635
4	initial 22.5 26	80 550 630
5	initial 28.5 26	10 550 560
6	initial 22 25.5	40 505 545
7	25.5	505 505
8	27	650
9	initial 23 23.5	130 420 550
10	initial 26.5 24	340 390 730
11	initial 26.5 24	340 390 730
12	24.5	690
Total	19 moulds	7500 pairs

For the variant of distribution and use of moulds on the working posts of the presented equipment in Table 2, the concrete degree of balance of the equipment (E), calculated with the equation (8), has the following value of the equation (10):

$$E = \frac{12(7500 - 730)}{7500(12 - 1)}.100 = 98{,}47\% \qquad \textbf{(10)}$$

4. CONCLUSIONS

- To balance the loading of working posts of the injection installation of Carousel type presented in the paper, can be achieved only when the number of moulds of the set is bigger than the number of the working posts of the equipment.
- The balance degree (E) is influenced by the type of rotation of the set of moulds on the working posts of the equipment, the total size of the lot of shoes, the series of sizes in the lot, the quantity of shoes, on each size number of the series.

- The automatic processing programmed of data used in the concrete case presented in the paper has a general character and it is used in all cases which obey the specified restriction in the first formulated.

REFERENCES

[1] E. Chirilã , *Theoretical number of the nests that a cast must have*, Buletinul I.P.Iaşi, Tomul LIV(LVIII), Fasc. 1-3, Secţia Construcţii de Maşini Iaşi, 2008, pp.125-129, ISSN 1011-2855, Romania

[2] E. Chirilã, *Solutions of the different models of cavities for soles obtaining*, Annals of the University of Oradea, fascicle of Textiles-Leatherwork, volume IX, 2008, p.236-240, ISSN 1582-5590, Romania

[3] V.Cociu, R.S. Volocariu, and C. Ionescu, *Matriţe şi dispozitive de formare*, Rotaprint, Universitatea Tehnicã "Gheorghe Asachi" Iaşi, 1994, Romania.

[4] R. McNeel, R., *Shoe Design and Visualization*, Institute of Biomechanics of Valencia, Rhinoceros Advanced Training Series, 2005 Available from: https://anna.nscad.ns.ca/help/pdfs/rhino_shoe.pdf

[5] C. Ionescu, *Matriţe şi procese de formare în matriţe din industria de încãlţãminte*, Editura Cronica Iaşi, ISBN 973-9206-09-3,1995, Romania.

[6] C. Ionescu Luca and A.Dragomir, *Algorithme de projection des moules pour contreforts de chaussure,* Buletinul I.P.Iaşi, Tomul LIV(LVIII), Fasc. 1-3, Secţia Construcţii de Maşini, p. 383-389, ISSN 1011-2855, Romania

[7]C. Ionescu Luca, *Contributions for establishing the right number of nests that a cast must have,* Annals of the Oradea University, Fascicle of Manage Contributions for Establishingment and Technological Engeneering, Vol. VII (XVII), 2008, pp. 863-866, ISSN 1583-0691, Romania

[8] M. Iuhas and C. Ionescu, *Flexible technologies for footwear soles injection marking*, Annals of the University of Oradea, fascicle of Textiles-Leatherwork, volume IX, 2008, p.240-246, ISSN 1582-5590, Romania

[9] Project No.401064/2007 SIMSANO, (2007-2013). Modern Interventional Footwear Design And Rapid Prototyping System For Compensating Locomotors Deficiencies And Prophylaxis Of Foot Disorders. Undergoing research project under the framework of Romanian National Research Programmed. Available from: www.simsano.ro

[10] Project no. 134124-LLP 2007-RO-LMP, Project no. 2007-3111/001-001 LE3-MULPRO Available from: (http://www.virtual-shoedesign.com/).