CONTRIBUTIONS TO DESIGN CHANNELS INJECTION INTO MOULDES FOR FOOTWEAR

LUCA Cornelia [1], IONESCU Cozmin[2]

[1, 2]*Technical University "Gheorghe Asachi" of Iasi-Romania, Faculty of Textiles, Leather and Industrial Management, E-Mail: cionescu@tex.tuiasi.ro; ionescucozmin@yahoo.com*

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

Abstract: *Semi products used in the shoe manufacturing are mostly made through polymer blend injecting in moulds. The injection moulds are designed with one or more cavities. When the mould has only one cavity the injection is made straight in cavity through one canal or through one main canal and more auxiliary canals. In multiple cavity injection always uses the primary canal and more auxiliary canals. The cavities of the mould may be posted symmetrically or asymmetrically referring to the main canal. The correct dimensioning of the injection system determines the quality of the injected pieces and the productivity of the manufacturing process.*
In the same time, the injection parameters have a lot of values depending of the injected plastic mass. The aspects of the designing of the moulds for shoe manufacturing are complex. The paper presents some contributions in the designing of the injection systems of the mould cavities in shoe industry. It develops some aspects about the optimization of the principal and secondary injection canals placing confronted by the mould cavities, some aspects about the injection canals placing straight contactly with the mould cavities depending on the shape and the dimension of the cavities and some aspects about the dimensioning of the injection canals.

Key words: *footwear, moulds, injection systems*

1. INTRODUCTION

The semiproducts used in the shoe manufacturing are mostly made through polymer blend injecting in moulds. The injection moulds are designed with one or more cavities.
The moulds with one cavity are used in shoe making straight on the vamp and in polymer blend shoe making.

The moulds with two cavities are used for making of the soles which were assembled on the vamps and for making of the inner soles with plastic mass injected joint.

The moulds with more then two cavities (always in an even number) are used in heels and heel covers making and, sometimes, in simultaneous making of two pairs of soles [1].
When the mould has only one cavity the injection is made straight in cavity through one canal or through one main canal and more auxiliary canals.

The cavities of the mould may be posted symmetrically or asymmetrically referring to the main canal.

The penetration of the polymer blend from the distribution canals to every cavity of the mould is made through one barrier which realizes a flow rate and a temperature increasing compensating the heat losses along the canals [2].

The unit between the injection nozzle, the canals and the barriers passed by polymer blend to the mould cavity make up the injection system of the mould.

The designing of this unit means to post the cavities and the injection canals in the mould, to dimension the canals and to post the contact points between the injection canals and the mould cavities.

The correct dimensioning of the injection system determines the quality of the injected pieces and the productivity of the manufacturing process.

The injected pieces of the shoe manufacturing use the systems with direct injection through only one unheated canal or through one unheated main canal and more auxiliary distribution canals, or through one heated canal and more auxiliary distribution canals [1,2].

The shoes, the shoe soles, the heels etc. have a large variety of shapes, dimensions and sizes. In the same time, the injection parameters have a lot of values depending of the injected plastic mass.

The aspects of the designing of the moulds for shoe manufacturing are complex and represent a problem for the specialists.

The paper presents some contributions in the designing of the injection systems of the mould cavities in shoes industry, about the placing of the main and auxiliary injection canals referring to the mould cavities, about the dimensioning of the canals and the barriers, about the placing of the injection canals straight contacting the mould cavities.

2. THEORETICAL AND EXPERIMENTAL CONTRIBUTIONS

2.1. The placing of the injection canals referring to the cavities of the mould

When the polymer melting is injected in many cavities of the same mould, it is used one main canal and more auxiliary canals.

The mould cavities may be placed symmetrically to the main canal (in this case, the auxiliary canals have equal diameters and lengths) or asymmetrically In the unsymmetrical placing case there are used auxiliary canals with different diameters and different lengths.

The grouping possibilities of the cavities around the main canal [2] are figured in Fig. 1.

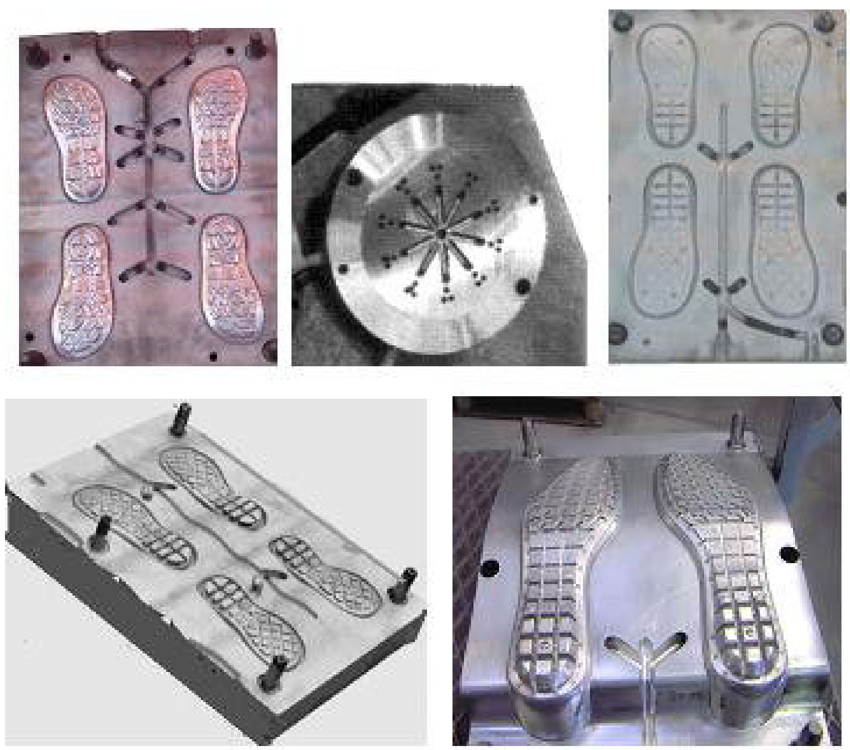

Fig.1: *The placing possibilities of the mould cavities referring to the main injection canal*

2.2. The dimensioning of the injection canals

When the distribution canals of the polymer melting is dimensioned in the mould cavities there are restricted: the filling of all mould cavities must take place in the same time; the friction head in the canals must be minimal and the filling volumetric speed of the cavities must be constant whatever of their placing referring to the main canal. The theoretical conclusions [2] show that the circular section of the distribution canals is better for polymer blend flowing. In this case, the flow speed has a second degree curve distribution along the section Fig. 2.

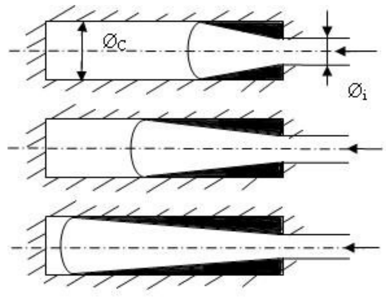

Fig. 2: *The polymer blend flowing through a circular section injected*

When the thermoplastic plastic masses flow (liquefied in injection equipment), the Reynolds coefficient has the following values: Re=0,5-0,05; so, the flowing is a parallel one. In this case, the friction and the friction head have big values.

The friction relation (1) is:

$$\lambda = \frac{64}{\mathrm{Re}} \cong 1280 \div 12800 \qquad \textbf{(1)}$$

This friction goes to the friction head, relation (2):

$$\Delta p = \lambda \frac{l}{D}\frac{v^2}{2}\rho = \frac{64}{\mathrm{Re}}\frac{l}{D}\frac{v^2}{2}\rho \qquad \textbf{(2)}$$

l - canal length, [m]; D- canal diameter, [m]; v- speed, [m/s]; ρ-density, [Kg/m^3].

Replacing the Reynolds definitely parameters, it results relation (3):

$$\Delta p = 32\frac{\eta l v}{D^2} \qquad \textbf{(3)}$$

H- dynamic viscosity.

Replacing the speed with the flow rate Q, in relation (3)

($v = \frac{4Q}{\pi D^2}$), it results: $$\Delta p = 40{,}77\eta\frac{1}{D^4}Q \qquad \textbf{(4)}$$

Relation (4) shows that a small diameter variation for the same flow rate Q goes to the variation of the friction head with a four exponent.

In working condition, the smallest diameter will be choose; so, the technological loses through the solidification of the plastic mass in the feeding canal will be reduced.

The dimensioning of the feeding canals must provide zero value for the speed loose. In general case, when the mould has "n" cavities, when the feeding of the cavities is simultaneously (having a uniform flow rate in each auxiliary canal) the diameter of the canals is in relations (5), (6) and (7).

$$nq = Q \qquad \textbf{(5)}$$

where:
n-number of the auxiliary canals;
q-flow rate through the auxiliary canal;
Q-flow rate through the main canal.

$$\frac{n\pi d^2}{4}v = \frac{\pi D^2}{4}v \qquad \textbf{(6)}$$

where:
D-diameter of the main canal [m];
d-diameter of the auxiliary canal [m].

$$nd^2 = D^2 \quad \textbf{(7)}$$

where:
d-diameter of the auxiliary canals, [m];
D-diameter of the main canal, [m];

Considering the friction head through the auxiliary feeding canals for a symmetrical placing, their diameter must be modified, so the flowing speed of the polymer blend will be constant. So, relation (7) becomes:

$$nd^2 \triangleright D^2 \quad \textbf{(8)}$$

The unsymmetrical placing of the cavities (referring to the main canal) imposes feeding canals with different diameters. The placing of the cavities in symmetrical positions (referring to the main canal) is the most important condition for a constant flow speed through the feeding canals, in the feeding of different cavities of the same mould.

3. RESULTS AND DISCUSSION

After years researches, the authors observed that the nozzles and the feeding canals of the moulds used in shoe manufacturing have small diameters, between 3 and 7 mm. Using bigger diameters (an advantage in the injection process) goes to the decreasing of the injection net efficiency because of the plastic mass solidificated into the feeding canal losses.

Table 1 shows some dimensions of the feeding canals of the moulds used in shoe manufacturing [3]. The dimensioning of the canals depends on the mass of the injected pieces and on the type of the polymer blend.

Table 1: *The diameter of the injection canals depending on the polymer and the mass of the injected piece*

Polymer	Mass of the piece , g				
	20-50	50-100	100-150	150-200	200-300
	Canal diameter, mm				
Polymerized vinyl chloride	4	4,5	5	5,5	6
Polystyrene	4	4,5	5	5,5	6
Polypropylene	5	5,5	6	6,5	7
Polyethylene	4,5	5	5,5	6	6,5
Polyamide	4	4,5	5	5,5	6

The values in Table 1 were calculated for a minimum level, for the moulds designing. If it will be necessary, when the moulds will be experimentally verified, the diameters of the nozzle and of the injection canals will be increased.

The length of the injection main canal depends on the size of the mould plates, on the number of the auxiliary canals and on the cavities volume. The recommendation is a ratio l/d between 5 and 9 (l-canal length; d-canal diameter).The penetration of the plastic material from the distribution canal to each cavity of the mould is through a barrier, Fig. 3.

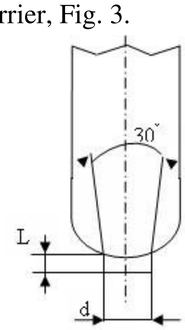

Fig. 3: *The representation of the injection canal barrier: d-barrier diameter ; l-barrier length*

The presence of the barrier determines a flow speed and a melting temperature increase compensating the heating losses along the canals. Generally, the designing of the barriers is for minimum dimensions; so, after the mould testing, the dimensions may be increased, in case. The dimensions of the barriers depending on the injected pieces mass are presented in Table 2.

Table 2: *Dimensions of the injection canal barrier*

No.	Piece mass ,g	Barrier diameter, mm	Barrier length, mm
1.	20-50	0,8-1,2	2
2.	50-100	1,2-1,8	2,5
3.	100-150	1,5-2,5	2,5
4.	150-200	1,5-2,5	3
5.	200-300	1,5-2,5	3

When the injection is made in cavities having large variations for the cross and longitudinal dimensions, the polymer melting moves forward in a jet, along a filling direction which is in an opposite direction in comparison with the injection nozzle; so, the mould cavity fills up through pressing while the injected polymer cools, Fig. 4. The cooling takes place layer by layer as long as the polymer blend contacts the walls of the mould cavity [1],[4]. When the whole cavity fills up, the pressure in the mould cavity has a maximum value; in time, increasing the feeding speed goes to the cooling of the polymeric material into the canal and to the sealing of the cavity.

An important aspect in the injection of the polymer melting is the placing of the contact points of the injection canals referring to the mould cavities.

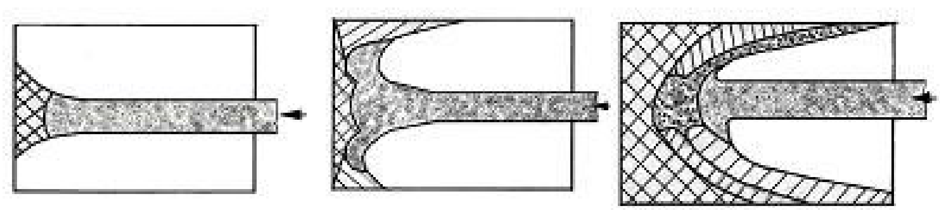

Fig. 4: *The filling up of the mould cavity through pressing*

When the injection of the shoe soles takes place, the phenomenon is more complex (due to the variation of the dimension along the two axes); so it has some solutions, [5] showed in Fig. 5.

When the injection point is chosen it must consider the polymer blend flowing but the soles aspects after the plastic mass solidification, too.

It is known that, after the breaking of the connection between the plastic mass from the feeding canal and the injected object, on that contact area appears a visible sign. The feeding along the length of the cavity goes to the most uniform filling up. But this solution is a rare one in the injection of the shoe soles, because of the contact area between the sole and the feeding canal, the sign being an aesthetic one. The solution will be adopt only if this inconvenient may be invisible. Often, the feeding of the soles cavities will be made along a normal line of those length.

When the soles injection is straight on the vamps (when the injection is made from the exterior of the cavity, respectively the sole area with non-slip relief) the placement of the injection point will be invisible due to the design of the relief.

In the case of soles injection obtained as semi-products which will be assembled with sewing or gluing on the vamps, the injection will be made from the exterior of the cavity. In this case, the choosing of the injection point will not be restricted by the esthetics conditions anymore.

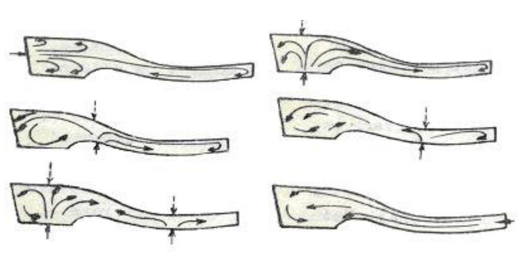

Fig. 5: *Some variants of the placing of the contact point between the injection canal and the cavity, in the soles injection*

When the main canals of the moulds are heated and the polymer blend is in a fluid state, it will make 2-3 auxiliary distribution canals. So, the injection efficiency will be increased without the increasing of the lost plastic mass which solidified into the canals.

4. CONCLUSIONS

The designing of the injection systems of the moulds used in the shoe manufacturing must respect the following conditions:

- When the feeding is simultaneous in more cavities, the cavities designing will be in symmetrical position relating to the feeding main canal. So, the flowing speed of the polymer melting through the canals is constant.
- When the distribution canal of the polymer melting in the mould cavity will be dimensioned, the filling up of all mould cavities must be in the same time; the flowing way of the polymer melting must be as short as possible; the passing from the main canal to the auxiliary ones must have big curvature radius; the pressure losses into the canals must be minimum; the volumetric filling up speed into the cavity must be constant even the position of the cavity is relative to the main canal.
- The nozzles and the feeding canals of the mould cavities used in shoe manufacturing have diameters between 3 and 7 mm. The using bigger diameters (which is a favorable situation for the injection process) goes to the decreasing of the injection net efficiency, because of the looses caused by the solidification of the plastic mass into the feeding canals.
- When the injection of the shoe soles is made, the placing of the injection canals in straight contact with the cavity will be adopt as the connection band on the sole surface to be invisible.

REFERENCES

[1] 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

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

[3] A. Dragomir and C. Ionescu *Emplacement possibilities of the cavities and some positioning possibilities of the injection channels in the moulds used footwear manufacturing*, Proceedings The " X International Conference on the Theory of Machines and Mechanism",sept. 2-4, 2008, Tehnical University of Liberec, , pp. 189-193, ISBN 978-80-7372-370-5, Czech Republic.

[4] 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

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