ANNALS of the ORADEA UNIVERSITY.

Fascicle of Management and Technological Engineering, Volume VII (XVII), 2008

RESEARCH STUDIES ON THE TEMPERATURE UNIFORMING OF THE MOULDS FOR INJECTION CONCAVE TERMOPLASTIC PIECES WITH THICK ROALLS.

Ştefan MIHĂILĂ[1], Radu MĂRIEŞ[1], Mihai GROZA[1], Sorin ILIE[2]

University of Oradea[1],SC. Plastor SA Oradea[2]
E-mail: mihailasna@yahoo.com

Key words: mould, thermoplastic, temperature, cooling.

Abstract

In this work it is presented the new methods regarding the injection moulds cooling for thermo plastically materials, having special references to the complex pieces shape having a great weight of walls.

In this case it is presented three cooling solutions for the moulds having many nests, for moulds with only one nest and for those moulds having problems to the cooling system.

Finally, it is shown a case study where it is presented the deformation of the five types of material used in practical.

1. MOLD TEMPERATURE, COMPONENT OF INJECTION PROCESS

Injection process knowledge involves work procedures, chemical structure, thermoplastic material properties and individual factor reciprocal influence knowledge. That's why mold temperature adjustment issue has to be solved function of these individual factors, which have an important role in injection process. This is the reason why the injection process will be shortly explained, for a better figure out about molds temperature adjustment.

Because of the heat, grain material is melting, getting in system. In this stage it has to overcome sewer resistance and resistance of the molds drain. By the time of this first first stage, the injection, the thermoplastics material relieves the heat out, in other words cooling process is starting, the metal near the system is heating.

The heat give out can be that big, that in case of an long sliding way of the piece, the much cooled material will not be able to completely fill the mold cavity. The reasons of this thing are more than clear if we think about injecting the material in the mold, talking about an Newtonian fluid, it will immediate get to the mold wall and it is strengthening in the edges. (fig.1)

When the draining channel expands, the solidified layer of the interior wall of the mold expands too, and the channel which serves to fuel the material in the direction of the running diminishes, in order to fill up the mold and even in the case of long draining channels, several measures must be considered:

-increasing pressure and injecting speed

-increasing the temperature of the plastic material (changing viscosity)

-increasing the mold's temperature (changing viscosity)

The greatest efficiency is obtained by increasing pressure and injecting speed. When all the presets of the machine are exhausted, a better drainage of the material can be obtained by increasing the mold's temperature or the material's temperature or both at the same time.

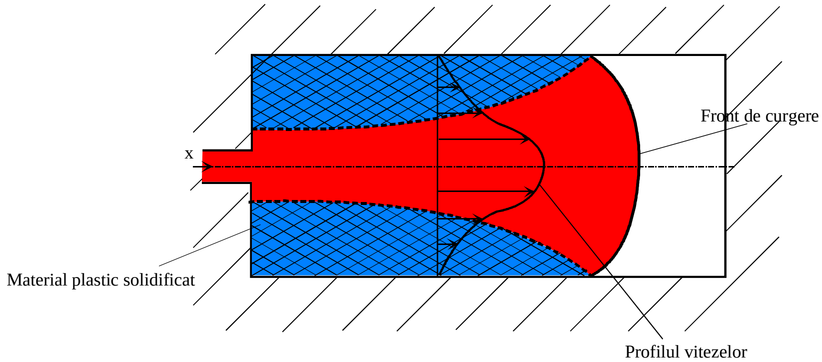

Fig 1. Representation of the cavity filling of the mold [3]

2. DETERMINING THE MOLD'S GENERAL THERMAL BALANCE EQUATION

The mold's temperature is the decisive factor for cooling speed and the injected reference point's properties. It is established according to the amount of heat that is exchanged in the mold:

-between the thermoplastic material injected into the mold and the mold's material Q;
-between the mold and the (mediul de temperare) QT;
-between the mold and the environment QE;

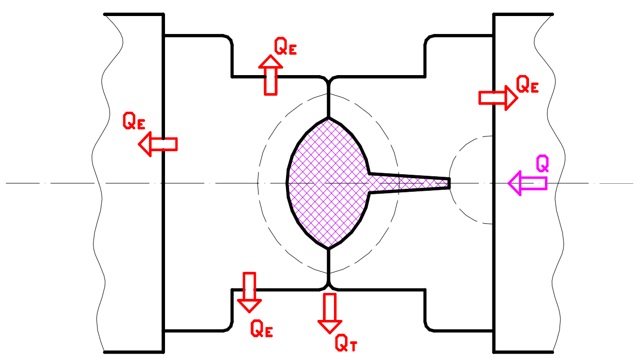

Fig 2. Heat exchange which occurs in the case of an injecting mold

If we consider the thermal fluxes that enter the mold as positive, and the fluxes that exit the mold as negative, then we can write the thermal balance equation:

$$Q = -Q_T - Q_E \,, \tag{1}$$

$$Q + Q_E + Q_T = 0 \,, \tag{2}$$

2. HEAT TRANSFER BETWEEN THE PLASTICS MATERIAL AND THE MOLD

Plastics material inserted into the mold's center, yield's , during an injecting cycle, to the mold's body, an amount of heat Q, which can be calculated using:

$$Q + Q_E + Q_T = 0 \,, \tag{2}$$

where :

m-weight of the injected piece, including the network [Kg]

i_1- the enthalpy of the plastic material upon removing [Kj/Kg]
i_2-enthalpy of the plastics material upon insertion into the mold
The enthalpy of the plastic material is calculated using this:

$$Di = i_2 - i_1 = c_p(T_{Mp} - T_D), \quad (3)$$

where:
C_p- specific heat of the plastic material
T_{mp}-the temperature of the material in the center
T_d – removing temperature [5.74]

Conduction in the mold. The quantity of heat evacuated by the piece is taken through conduction by the mold and transported into the tempering environment. We can consider the phenomena of conductive stationary transfer in a plane homogenous wall. The quantity of heat Q is determined using this function:

$$Q = \frac{\lambda_M}{\delta} S(T_{pc} - T_{pT}) \quad (4)$$

where:
- λ_M - - thermical conductibility to the mould [W/mK];
- δ - the channel distance of temperature beside the mould surfaces [m];
- S – the transversal surfaces of the mould [m^2];
- T_{pc} - the medium temperature of the wall cavity [^0K];
- T_{pT} - the medium temperature to the temperature wall channel [^0K].

4. CONSTRUCTIVE MOLD TEMPERING SOLUTIONS FOR INJECTING HIGH PRECISION THERMOPLASTIC MATERIAL PARTS.

4.1. Methods of cooling down complex high precision single centered molds

Only two methods will be presented. One used in real life (fig. 3) and the other proposed by the author which proves to be superior (fig. 4).

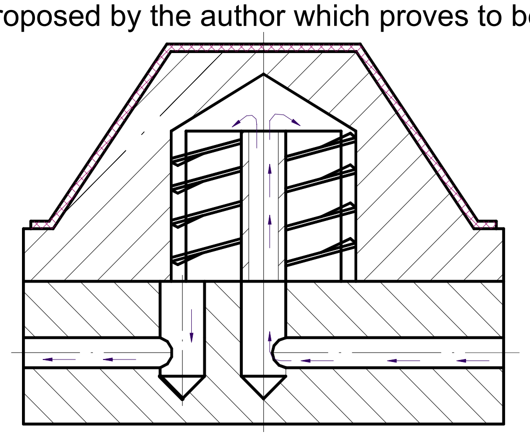

Fig 3. Cooling circuit with a coiled middle (utilized in practice)

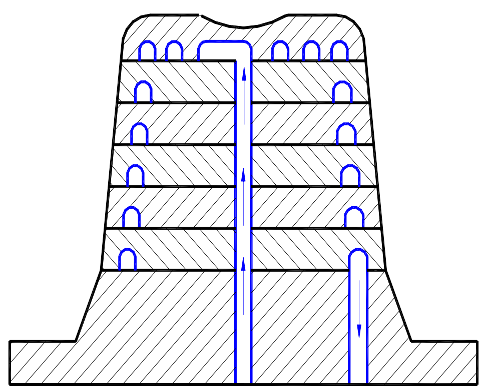

Fig 4. Cooling circuit with multiple plates (proposed in the future)

Following the analysis of a finished part, we can see that when cooling down a product of high precision, with thick walls, that have high contractions, it is recommended to use more cooling circuits, but respecting the constant distance between the outline of the part and the cooling circuit, (fig. 4) so that a higher amount of heat can be removed.

4.2 Methods of cooling complex high precision molds utilizing the thermosiphon principle

This temperature adjustment method applies in general to high complexity molds where there can be critical areas which cannot be cooled down with other methods. These solutions are based on the thermo siphon principle. (fig.5)

This concept of isobaric superconductivity is based on using a metallic tube 1 made of copper into which another metallic tube 2 of special composition with capillary structure is clamped. In tube 1's interior and between tube 1 and 2, a fluid is circulating, fluid which can be both liquid and vapor. The liquid take part of the heat from the exterior, passes through tube 2 in the interior and vaporizes. A pump effect is achieved at A end towards B end where the fluid vapors go through tube 2 and transform into liquid, giving heat to the environment. The liquid enters the circuit towards B end of the tube in order to take heat from the outside environment *[1]*

In this system's case, thermic transfer is very fast and constructive solutions that use this system become very efficient.

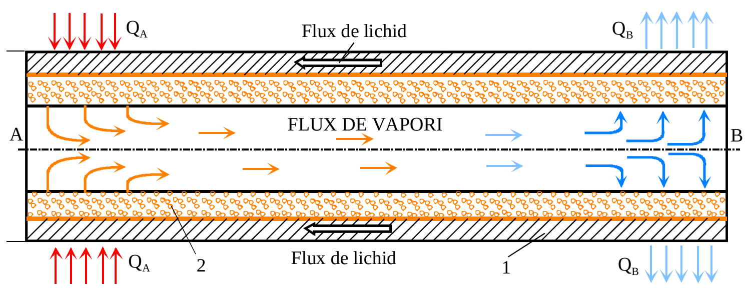

Fig 5. Presentation of a cooling concept using the isobaric system
A,B-tube's ends; Q_A absorbed heat; Q_B abstracted heat ; 1-exterior tube; 2-interior tube

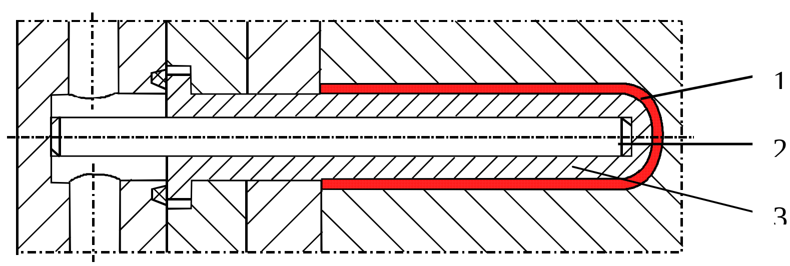

Fig 6. Cooling example of a mold using the isobaric system
1-piece; 2- isobaric tube; 3- mold;

5. CASE STUDY

Next, an practical experiment will be presented, in which the warping of a plane piece will be analyzed, depending of cooling time, and water temperature when entering the circuit, using thermoplastic materials widely utilized in practice(PS, ABS, PA, PP, PEID).

In fig.7 is presented a injecting mold on which the experiment is being conducted, and also the sample piece.

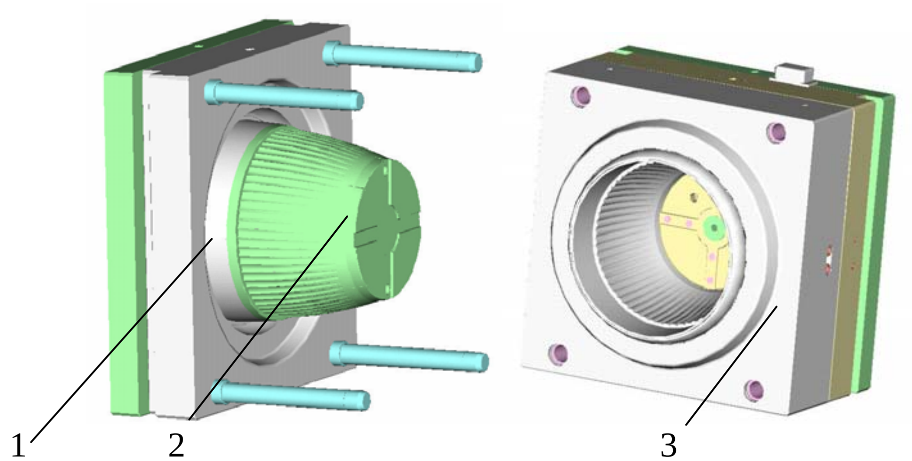

Fig 7. Experimental injecting mold
1-Mobile semi mold, 2-piece; 3 fixed semi mold

In table 1, the warping measurements for the materials studied depending of the cooling time are represented. Water temperature upon entry in the circuit is (20^{0}C mold center and 40^{0}C margins)

Table 1.

Material number	*Name of material*	*Maximum piece warping [mm]*				
		Mold cooling time [s]				
		5	**10**	**20**	**30**	**40**
1	PS	5.8	3.1	1.4	0.8	0.5
2	ABS	7.1	3.3	1.5	0.8	0.6
3	PA	7.3	3.4	1.6	0.9	0.6
4	PP	7.8	3.6	1.7	0.9	0.65
5	PEID	8.2	4.2	1.9	1.1	0.7

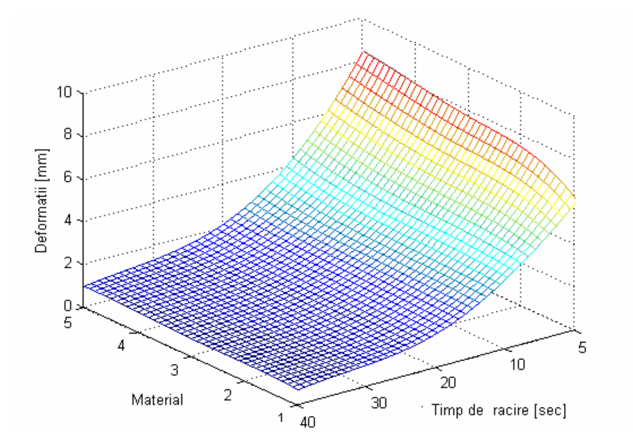

Fig 8.Graphical representation of the warping depending upon the cooling time, utilizing a circuit entry water temperature of 20 degrees C in the centre and 40 degrees C on the margins

In table 2, the warping measurements for the materials studied depending of the cooling time are represented. Water temperature upon entry in the circuit is (40^{0}C mold center and 40^{0}C margins)

Table 1.

Material Number	*Name of material*	*Maximum piece warping [mm]*				
		Cooling time in the mold [s]				
		5	**10**	**20**	**30**	**40**
1	PS	6.1	3.4	2.2	1.7	0,7
2	ABS	7.4	3.7	2.3	1.7	0,8
3	PA	7.7	3.9	2.5	1.8	0,9
4	PP	8.2	4.1	2.6	1.9	0,9
5	PEID	8.5	4.5	2.9	2.1	1.0

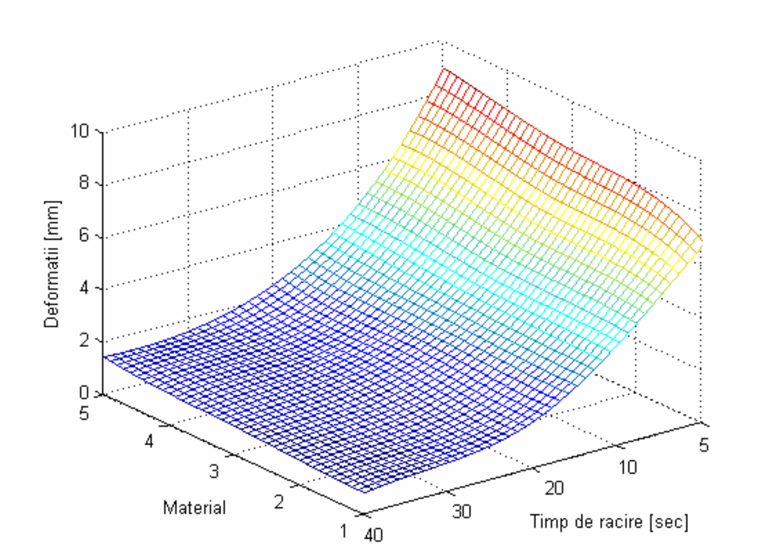

Fig 9. Graphical representation of the warping of plane pieces depending upon the cooling time, utilizing a circuit entry water temperature of 20 degrees C in the centre and 40 degrees C on the margins

6. CONCLUSIONS

Optimizing the mold's temperature has a very important role both in the future quality of the product, as in productivity.

Cooling conditions from the mold have a great influence upon injected piece warping, no matter the size and complexity .

Mold temperature influences directly cooling time, injecting cycle time, the efficiency of the product forming inside the mold, crystallinity and internal tensions.

As a conclusion, we must say that the solutions presented contribute semnificatively to optimizing temperature in the active part of the mold, particularly for products of medium size with thick walls.

REFERENCES

[1]. Losch, K. Thinwall molding: demanding bul rewarding. Modern Plastics International, 1997.
[2] Fetecău C. Injectarea materialelor plastice.Editia a doua. Ed. Didactica si Pedagogica. Bucureşti, 2007.
[3]. Mihăilă, Şt. – Teză de doctorat Universitatea Politehică Timişoara. 2005
[4].Ştefănescu, D., Marinescu, M., Danescu, A. - Transferul de căldură în tehnică, vol. 1, conducție, convecție, radiație, schimb global. Editura Tehnică, Bucureşti, 1982.
[5]. "PLASTPRACTICE" - Temperature Control by Means of Fluid Media.
[6]. Zemanski, M.W.Bazic Enginering Termodynamics - Mc. Grow Hill Book, Co New York 1985.