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THEORETICAL AND EXPERIMENTAL RESEARCH ON THE IMPROVEMENT OF THE COOLING ON CONCAVE SEMI MOLDS FOR PLASTIC MATERIALS PROCESSING

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Abstract This paper studies the theoretical and practical issues regarding the manufacture of plastic products precision. We present a study about the influence of moulds temperature on the quality of injected plastic parts than used in the industry. It presents briefly the phenomenon that occur in the injection process and also determine a set of equations on thermal phenomenon that occur during the injection in the mould. Next we present two constructive solutions that contribute significantly to the homogenization temperature of semimoulds injected with one or more nests which increase the quality of parts. In the second part of the paper presents a case study on the size of strains according to the water used in teperature input of circuit cooling. To obtain more efficient results we use five tipes of polymers that are widely used both in automotive and in the home appliance field

Keywords**—**Plastic, injection, mould, temperature, cooling.

I. INTRODUCTION

The main process of injection involves the knowledge of work processes, chemical structure, properties, thermoplastical and mutual influence of individual factors. Therefore it is necessary for temperature regulation mould problem to be resolved taking into account the influence of these individual factors, which play an important role in the process of injection. For this reason will be explained briefly running the entire injection process, to illustrate more clearly the role of temperature regulation moulds.

The material in the form of granules, because the heat melts reaching the collection of mould. In this phase must overcome resistance and channel resistance in the way of flow matrix, which is the greater the thickness of the wall piece injection is lower. During this first phase of injection, thermoplastic give environmental heat, ie begin the process of cooling the metal near the collected heat, [1].

Since the road with increased flow, solidified layer on the inner wall of mould increases and thereby the channel with less resistance that serves to feed material to flow is diminishing, to achieve a faultless filling the moulds a even where roads flow long, this particularity of plastic flow to be taken into account through various measures:

1) - by increasing pressure and speed of injection;
2) - by increasing temperature plastic material;
3) - moldings by increasing temperature.
4) The highest efficiency is obtained by increasing pressure and speed of injection. When all adjustments are used car, improve material flow can be obtained by increasing the material temperature and increasing mould temperature or both concurrently, [2].

II. DETERMINING THE MOULD'S GENERAL THERMAL BALANCE EQUATION

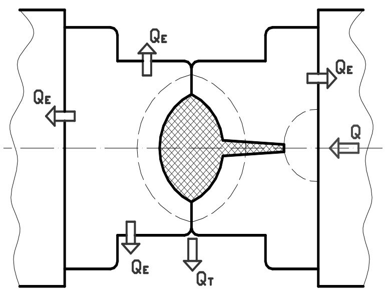

Fig. 1. Heat exchange which occurs in the case of an injecting mold [4]

The mold's temperature is the decisive factor for cooling speed and the injected reference point 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 environment of tempering QT, between the mold and the environment QE.

If we take into account the heat flows entering the positive mold, and those that come out negative, then the resulting heat balance equation:

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

III. HEAT TRANSFER BETWEEN THE PLASTICS MATERIAL AND THE MOULD

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:

$$\boldsymbol{Q = m(i_2 - i_1)}, \tag{2}$$

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:

$$\boldsymbol{Di = i_2 - i_1 = C_p(T_{Mp} - T_D)}, \tag{3}$$

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 phenomenon of conductive stationary transfer in a plane homogenous wall.

The quantity of heat Q is determined using this function:

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

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 [^{0}K];

- T_{pT} - the medium temperature to the temperature wall channel [^{0}K], [3].

IV. THE DETERMINATION OF COOLING TIME EQUATION.

Analysing the relation (1), it is observed that the time of injection (t_t) depends direction on the cooling time. (t_r). Theoretically determining t_r it is takieng into account the plastical material, which flows in the mould cavity .

They are introduced the following symplifing hypothesis:

1) *Plastical material is considered like a plane plate having the constant cooled on the both faces.*
2) *They are negletied the marginal effects;*
3) *It is negletied the anisotropies properties due to the macromolecules orientation;*
4) *It is negletied the coefficient dependence of the thermical diffusing of temperature;*
5) *The warming transfer is exclusively considered conductive.*

Genarally equation of the coordonating conducte is [4, 5]:

$$\frac{\delta T}{\delta t} = \frac{\lambda}{c_p \rho}\left(\frac{\delta^2 T}{\delta x^2} + \frac{\delta^2 T}{\delta y^2} + \frac{\delta^2 T}{\delta z^2}\right) \pm \frac{q_v}{c_p} \tag{5}$$

where:

λ – coefficient of thermical conductivity, W/mK;

c_p – specific warming to the specific presure , J/kg · K

ρ – density Kg/m^3

q_v – the warming quantity of the volume unity, W/m^3

T – temperature, K

V. PRACTICAL SOLUTIONS FOR A HOMOGENIZATION TEMPERATURE SEMIMOLDS PIECE OF INJECTION MATERIALS OF CONCAVE FORM

A. Methods of homogenization temperature moulds with more nesting

Adjust the temperature to enable a more semimould nesting can be achieved in several ways. In Fig. 2. it shows a cooling circuit in series, in which fluid

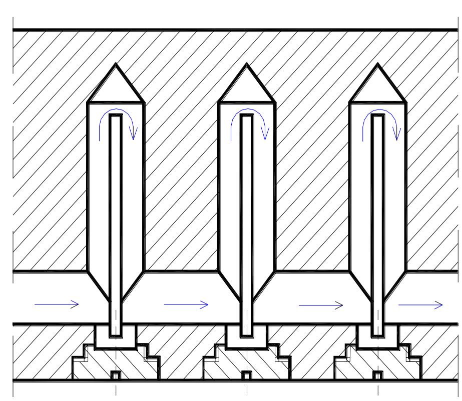

Fig. 2. Presentation merged cooling circuit in series (used

in practice) [8]

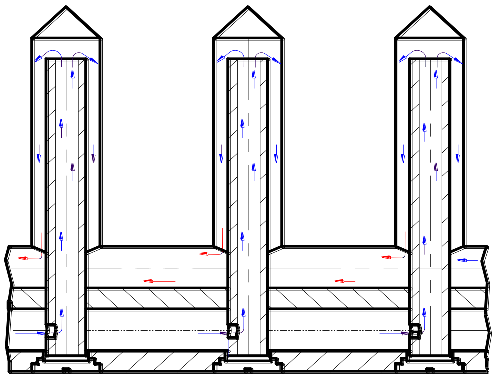

Fig. 3. Presentation merged circuit cooling efficiency education (proposed in the future) [6]

is passing successively through all the cores, this system is used frequently in practice and in Fig. 3. proposes a new variant of cooling which is proving to be more efficient cooling being made in parallel.

In the first case of cooling series, liquid cooling of each core is collected in a common channel, this method has the disadvantage that the temperature water will increase with the number of channels through which leads to the difference in temperature on each core semimoulds area.

In second method of cooling in parallel (fig 3) , liquid cooling enters in each core with the same temperature. In this way cores have constant temperatures which lead to the homogenization temperature on the whole surface semimould. There is a sewer that has the possibility to control the temperature of liquid cooling with a single device.

Cooling system in series, packing a channel of core cause discontinuation entire circuit, while the cooling in parallel, it is not possible, [7].

B. Constructive solutions of homogenisation of concave half-molds

In the figures below shows the two methods of cooling a very often used in practice (Fig.4) and another proposed by the authors, which proves to be more efficient. (fig. 5).

For ponsons cooling, liquid cooling should take a large amount of heat in the figures above, shows the two ways of cooling ponsons to mold one's nest, with ponsons large, the deep, cooling should be intense, it is generally achieved through a core binding Coiled liquid colant to continuously wash the interior walls of piston (fig. 4).

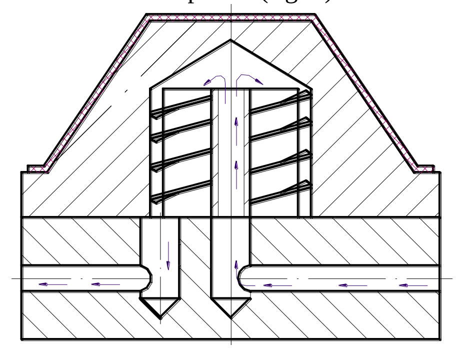

Fig. 4. Cooling circuit with a coiled middle (utilized in practice) [8]

After the finite element analysis it is found that cooling produced by a high-precision thick walled, large contractions which is recommended to use more cooling circuits, following contours of constant distance and song circuit, cooling (fig. 5). so as to fetch a large amount of heat.

Style proposed is composed of several plates with cooling channels carried on each plate at a distance equal to the outer contours of the terms gives a uniform temperature, making seal rings with "0".

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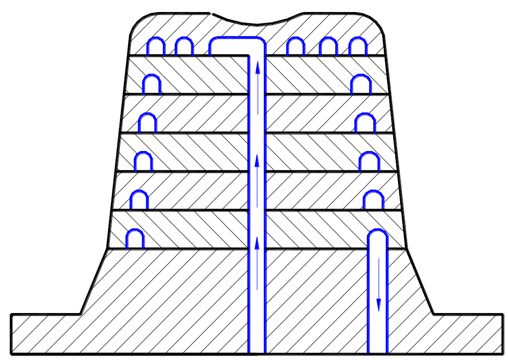

Fig. 5. Cooling circuit with multiple plates (proposed in the future)

VI. CASE STUDY

The upper figure shows a practical experiment using a matrix with an experiment wich is about the size of the study strains depending on the cooling water temperature and the input circuit, for five types of materials widely used in practice (PVC-D, PAS, PEJD, PEID, PA6).

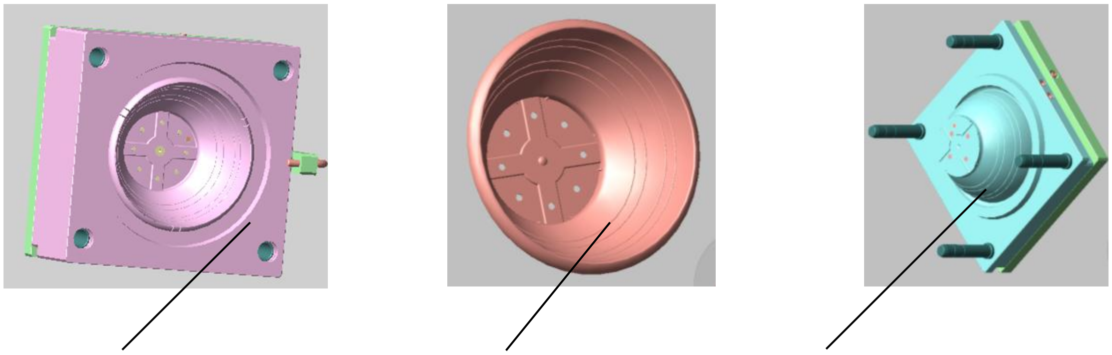

Fig. 5 Experimental injecting mold 1-Mobile semi mold, 2-piece;3 fixed semi mold.

In TABLE I, it presents the warping measurements for the materials studied depending of the cooling time is represented. Water temperature upon entry in the circuit is (28^{o}C mold center and 42^{o}C margins), [9]- [11].

TABLE I
REPRESENTATION DEFORMATIONS STUDIED PIECE, DEPENDING ON THE COOLING TIME

Material number	*Name of material*	*Maximum piece warping [mm]*				
		Mold cooling time [s]				
		5	**10**	**20**	**30**	**40**
1	**PVC-D**	**6.12**	**3.39**	**2.18**	**1.74**	**0,69**
2	**PAS**	**7.56**	**3.75**	**2.52**	**1.82**	**0,86**
3	**PEJD**	**7.72**	**3.92**	**2.56**	**1.84**	**0,93**
4	**PEID**	**7.91**	**4.25**	**2765**	**1.92**	**0,96**
5	**PA6**	**8.47**	**4.52**	**2.93**	**2.17**	**1.04**

In table 2, it presents warping measurements for the materials studied depending of the cooling time is represented. Water temperature upon entry in the circuit is (35^{o}C mold center and 42^{o}C margins).

TABLE II
REPRESENTATION DEFORMATIONS STUDIED PIECE, DEPENDING ON THE COOLING TIME

Material number	**Name of material**	**Maximum piece warping [mm]**				
		Mold cooling time [s]				
		5	**10**	**20**	**30**	**40**
1	**PVC-D**	**6.13**	**3.39**	**2.18**	**1.75**	**0,70**
2	**PAS**	**7.58**	**3.76**	**2.53**	**1.82**	**0,87**
3	**PEJD**	**7.74**	**3.93**	**2.57**	**1.85**	**0,94**
4	**PEID**	**7.93**	**4.26**	**2.75**	**1.93**	**0,97**
5	**PA6**	**8.51**	**4.53**	**2.94**	**2.18**	**1.05**

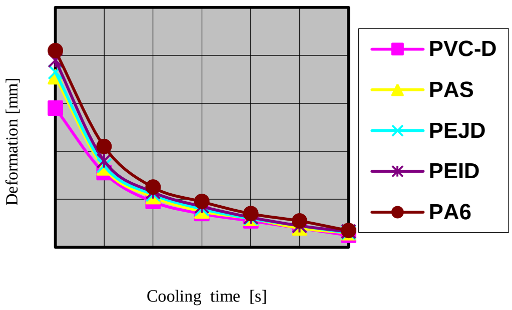

Fig.6.Graphical representation of the warping depending upon the cooling time, utilizing a circuit entry water temperature of 28 Celsius degrees in the centre and 42 Celsius degrees on the margins

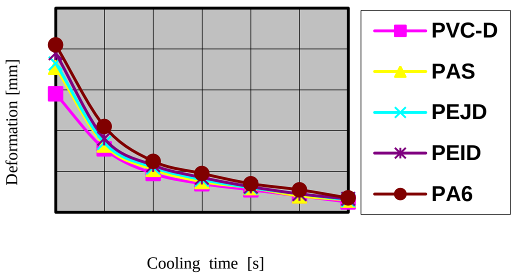

Fig. 7. Graphical representation of the warping of plane pieces depending upon the cooling time, utilizing a circuit entry water temperature of 25 Celsius degrees in the centre and 45 Celsius degrees on the margins

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