Study on strain analysis as a function of cooling time for plastics commonly used in the automotive industry.

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Abstract: Given the fact that plastics are found in an increasing percentage in the automotive industry, with a tendency to expand in the future, it is obvious that all auto parts manufacturers are trying to increase productivity and quality of parts. One of the important parameters influencing productivity and part quality is the cooling time as well as the cooling mode of the part or mould.

The paper studies some important aspects of the influence of cooling time on the quality of engineering polymers used in the automotive industry. In the paper, a series of mathematical calculations were carried out to determine the cooling time equation, analysing the conductive heat transfer, in the case of plastic plate, between the cooled walls of the mould. Practical studies are carried out for four types of polymers very important in the automotive industry, the part used for the test having flat surfaces. Deformation magnitudes were determined as a function of cooling time, using the same mould cooling temperature.

1. Introduction

Cooling time has a great influence on the total processing time of a plastic product obtained by injection regardless of size and properties of the material the piece is made of, the greater the cooling time the greater the processing time .

Cooling time is influenced by a number of factors like : the properties of the plastic material, heat transmission coefficient, wall thickness as well as technical condition imposed upon the part.

Generally most manufacturers are increasingly pursuing productivity growth so that economic efficiency is high. According to research, it is very clear that with decreased cooling time, we see an increase in part deformations. This is somewhat worrying given that most products in this category have very strict technical requirements, which does not allow cooling times to be reduced.

In order to diminish these problems, a very important role is given to the way the cooling circuit of the mold is designed, the diameter of the cooling channel, the shape, lenght and localization of the cooling channels as well as calculating the flowing liquid's debit.

This paper deals with a number of calculations related to these issues, but also comes up with some proposals on optimal processing parameters especially related to the ideal setting of cooling times for the most common materials used in the automotive industry.

2 . Determination of cooling time.

The efficiency of injection machine depends on the time of injection cycle.
Generally simplifying the injection cycle, the total injection time is:

$t_t = t_u + t_r + t_m$ [1] (1)

where: t_u – fulling time of the mould
t_r – cooling time

tm– mold closing and opening times

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

They are introduced the following symplifing hypothesis:

Plastical material is considered like a plane plate having the constant cooled on the both faces

They are negletied the marginal effects;

It is negletied the anizotropia properties due to the macromolecules orientation;

It is negletied the coefficient dependence of the thermical diffusing of temperature; The warming transfer is exclusively considered conductive.

Genarally equation of the coordonating conducte is [1]:

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

where: [1]:

λ – coefficient of thermical conductivity, W/m · K;

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

t – time, s.

It is noted:

$$\frac{\lambda}{c_p \rho} = a\left[\frac{m^2}{s}\right] \text{, which is called thermal diffusi} \quad (3)$$

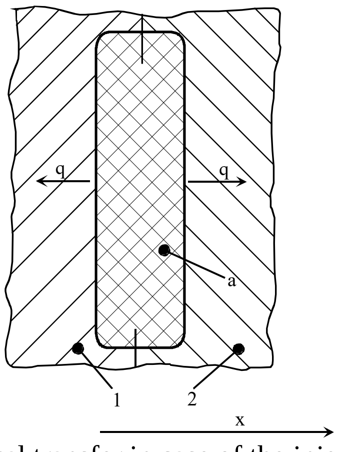

Figure 1. The thermical transfer in case of the injection pieces in mould: 1,2-forming plates; a- injected pieces; q-thermical high tide unitary on x direction [2]

Analisying the thermical conductive transfer ,in case of material plastic plate, between the cooling walls of the moulds (fig.1), general shape of the equation (2) symplifies , considering that:

The transitory transfer (interval time dt the izoterm position is modified temporaly and in space:

There is no inside sources of heating, $q_v = 0$;

The heating trasfer is done perpendicular on the plate surfaces (unidirectional transfer in x axes). So: $q_y = 0$, $q_z = 0$

where: qy – thermical high tide unit on y direction;

qz – thermical high tide unit on z direction;

Due to the fact that the thermical fluxes on direction y and z are null, it results:

$$\frac{\delta^2 T}{\delta x^2} = \frac{\delta^2 T}{\delta y^2} = 0 \quad (4)$$

Taking into account the proposed simplifications, equation becomes

$$\frac{\delta T}{\delta t} = a\frac{\delta^2 T}{\delta x^2} \quad (5)$$

which represents the unidirectional conduction equation in trajectory mode without internal heat sources. It is assumed that the solutions of equation (5) are given in the expression
where:
A, B, C, m are integration constants;
x – the position of the temperature point after the time interval t has passed since the beginning of cooling.
In order to solve these equations, the boundary conditions that specify the contour criteria of the body (its shape and dimensions) are necessary.

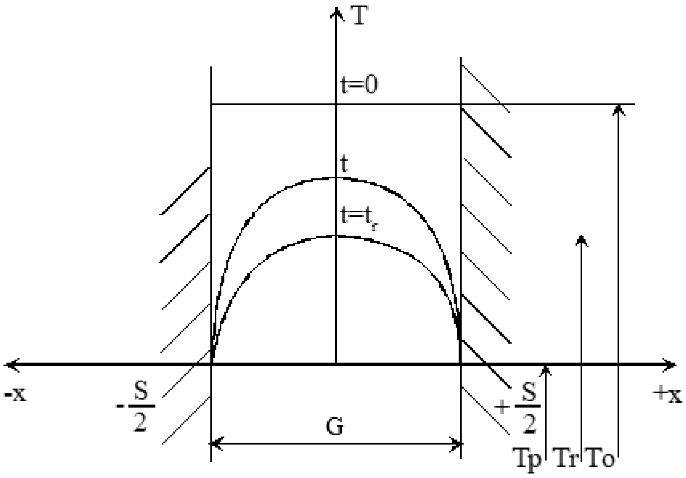

Figure. 2. Cooling of the plastic material in the mold:
G-thickness of the injected part; T0-temperature of the plastic material at t= 0; Tp- temperature of the mold walls; Tr- cooling temperature.

Consider the material plate with the median plane corresponding to the coordinate x = 0 (figure. 2). Denoting the thickness of the plate with G, the median plane corresponds to the coordinate x = 0, and the lateral surfaces to the abscissas: $x = \pm\frac{G}{2}$

It is considered that the plate made of homogeneous plastic material, with initial temperature T0, is suddenly introduced, at time t = 0, into a cooling medium with temperature Tp (temperature of the mold walls).

For T =T_p şi $x = \pm\frac{G}{2}$ and equations becomes: (6)

$$x = \frac{G}{2} \cdot T_p = A + B\cdot\frac{G}{2} + Ce^{-am^2 t}\cos\left(m\frac{G}{2}\right) \quad (7)$$

$$x = -\frac{G}{2} \cdot T_p = A - B\cdot\frac{G}{2} + Ce^{-am^2 t}\cos\left(m\frac{G}{2}\right) \quad (8)$$

Since the temperature of the outer surfaces T_p to $x = \pm \frac{G}{2}$ la is constant over time, it follows that equations (7) and (8) must not depend on time and, therefore, the condition must be fulfilled:

$$\cos\left(\pm m \frac{G}{2}\right) = 0 \qquad (9)$$

With relation (9), equations (7) and (8) become:

$$T_p = A + B \cdot \frac{G}{2} \qquad A = T_p \qquad (10)$$

$$T_p = A - B \cdot \frac{G}{2} \qquad B = 0 \qquad (11)$$

3. Determining the deformations depending on the cooling time

In the following, the results obtained in the form of tables and graphs are presented with regard to studies carried out on four types of materials widely used in the manufacture of automotive parts, materials which have relatively different properties.

For the analysis, forty samples were taken for each material, ten samples for the four values of cooling time, so that the maximum deformation values for each material can be determined as a function of cooling time.

In order to carry out the samples a Demag injection moulding machine was used, the mould used is a single nest injection mould, the injection system is direct injection with heated nozzle.

Figure.4. Presentation of the injection machine for processing the studied samples.

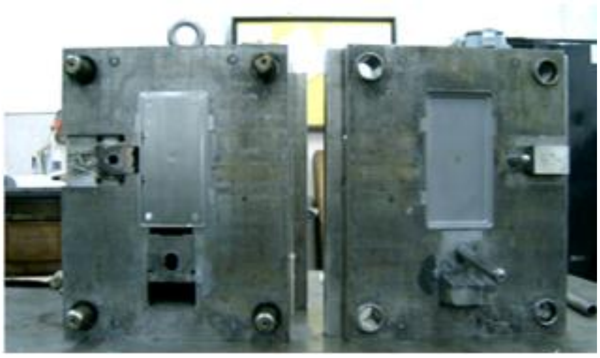

Figure.5. Presentation of the injection mould for processing the studied samples.

Figure.6. Representation of the model of the piece, for testing.

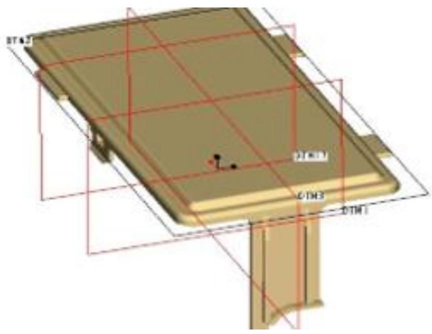

Figure.7. 3D model representation.

Table 1. Representation of maximum deformations as a function of cooling time, for polymers used in the automotive field

Name of material	Material number	Maximum deformation of the piece [mm]			
		Cooling time of the piece [s]			
		15	20	25	30
PC	1	1.2	0.8	0.06	0.02
PA6.6.	2	1.3	0.9	0.07	0.025
POM	3	1.4	1.2	0.15	0.041
PBT	4	1.5	1.3	0.25	0.043

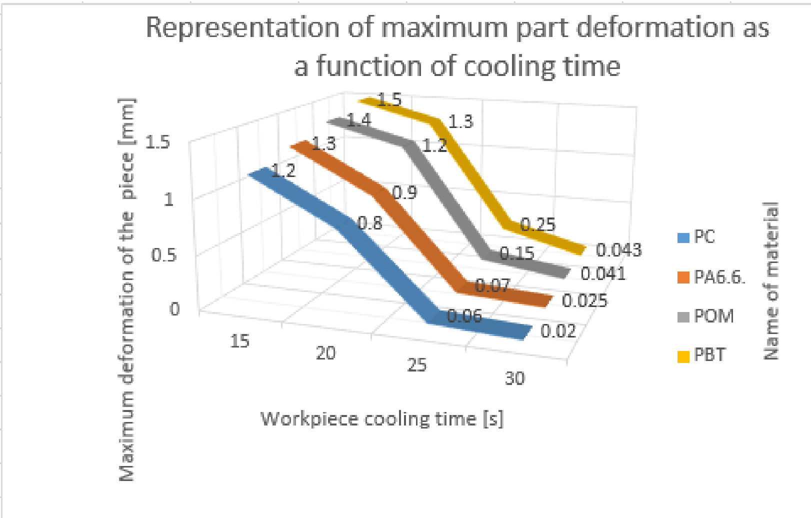

Figure.8. Representation of maximum part deformation as a function of cooling time , for polymers used in the automotive field

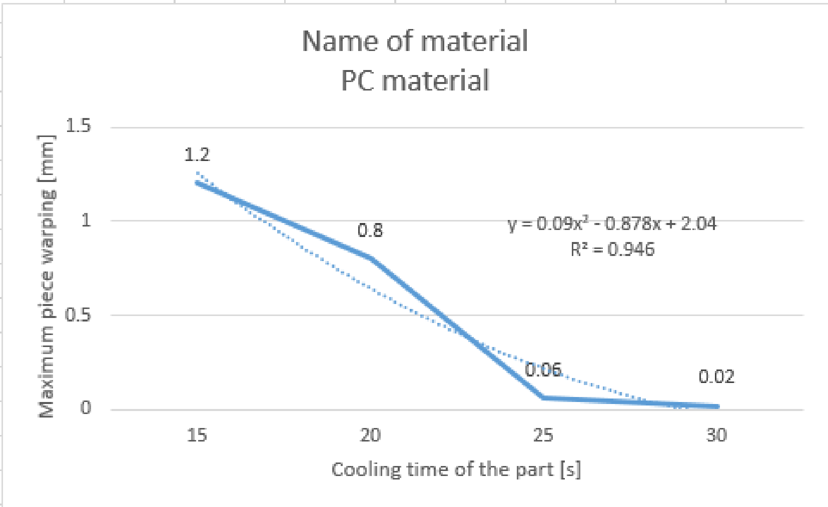

Figure.9. Representation of maximum part deformation as a function of cooling time for PC

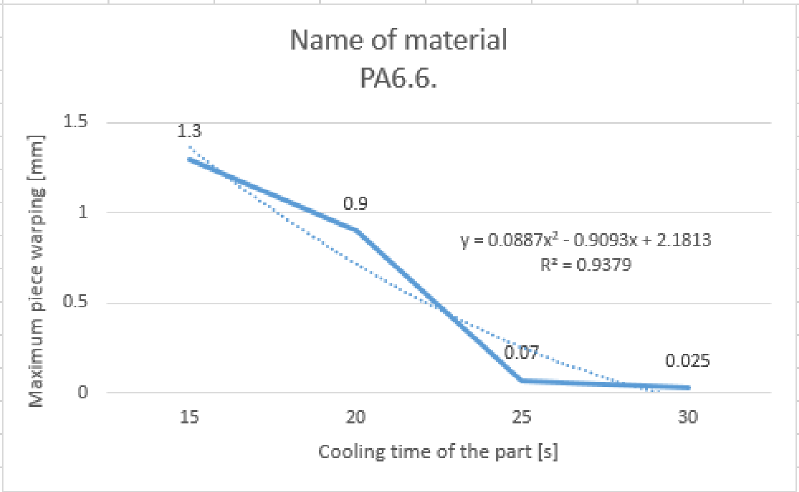

Figure.10. Representation of maximum part deformation as a function of cooling time for PA 6.6.

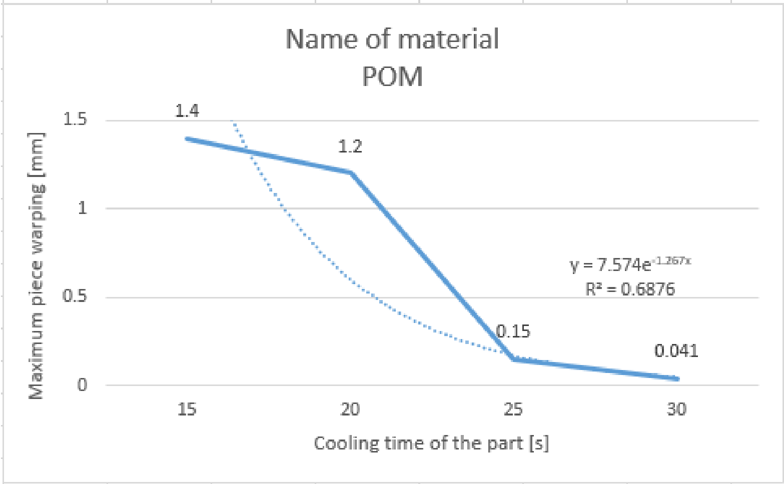

Figure.11. Representation of maximum part deformation as a function of cooling time for POM.

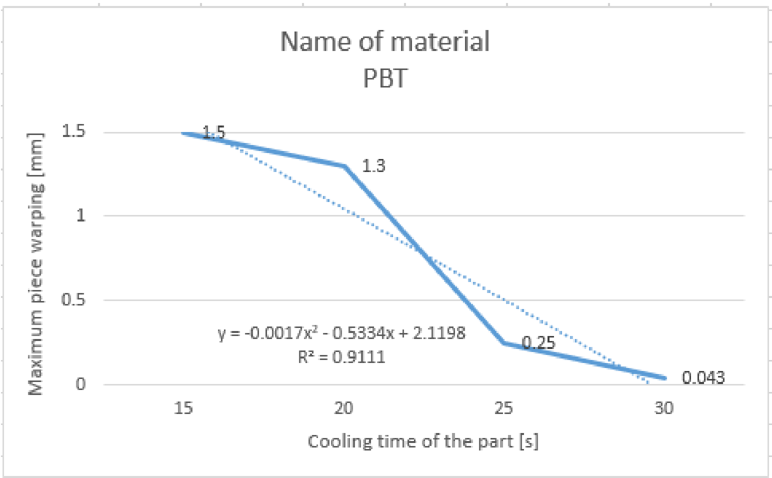

Figure.12. Representation of maximum part deformation as a function of cooling time for PBT.

4. Concluzion

Considering that cooling time is the most important parameter on the total time to obtain a part, manufacturers are increasingly looking for technical solutions to reduce processing time in order to increase productivity.

This paper tries to solve some of the problems related to the optimization of processing time especially for the plastics most used in automotive manufacturing.

The results obtained from the studies carried out on the four polymer dips, we believe are useful for all manufacturers of injected parts, especially those in the technopolymer category, so that they help a lot in determining the type of material used for certain parts, depending on the technical conditions imposed respectively the functional role in the assembly of which they are part.

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