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Influence of processing conditions on changing of shrinkage and mass POM injection molding parts

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Abstract: The conditions of injection molding which are result of working of many factors connected with injection molding machine, design of mould, received processing conditions and processed polymer affect on physical state formed molding. All this decides about mechanical, thermal and useful properties. The results of experiment, which had in view the estimation of influence of parameters of processing on shrinkage (longitudinal and perpendicular) injection molding parts made from semi crystalline polymer POM.

The investigations was realized using prepared design of experiment, which consisted with 27 arrangements and 5 entrance volumes: mold temperature, injection temperature, cooling time, hold pressure, injection speed. Differentiation of perpendicular shrinkage across injection cavity was shown. The analysis of received results hugged the search (estimation) of the equations of regression, which describe the changeability researches volumes in function of processing conditions

Keywords: Injection moulding, Moulding shrinkage, Processing conditions, Statistic analysis

1. INTRODUCTION

The conditions of injection which are a result of many factors connected with the injection moulding machine, mould, the processed plastic and the assumed injection process conditions affect the physical state and the structure of the injection moulding piece. These, on their part, decide on its mechanical, thermal, usable and other properties [1, 2, 3].

2. EMPIRICAL PART

The purpose of the investigations was to determine the influence of chosen input parameters (injection moulding conditions) on the output quantities (such as shrinkage and mass of the injection moulding piece) and further, using experimental techniques and statistical methods for the data analysis, to present the relation between them in the form of function. The investigations have been led for partly crystalline copolymer POM of M8 type with the commercial name Santial, manufactured by Rhodia Engineering Plastics (France). Samples for investigations have been made using injection method by means of Krauss Maffei KM 65-160 C1 machine which was equipped with special mould for manufacturing samples for thermoplastics shrinkage investigations. The shape and the dimensions for the mould cavity of the injection moulded piece has been adjusted to the requirements of the ISO standards. The shape of the injection moulded piece used for the investigations with range of variability of parameters are presented in the Fig. 1.

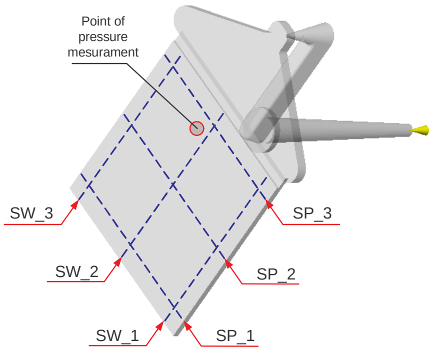

Figure 1. Injection molding with marked lines of determinations of longitudinal shrinkage (SW_1, SW_2, SW_3) and perpendicular one (SP_1, SP_2, SP_3)

3. STATISTICAL ANALYSES METHODOLOGY

The plan according to which the samples have been prepared has been worked out on the basis of the literature on theory of design of experiments [4, 5] and the module (DoE – Design of Experiment) of STATISTICA software for statistical data analysis by StatSoft.

3.1. Regress equation (model equation)

The variable (characteristic) which is described by the model is called a dependent (investigated) variable. However, the variable which appear in the model, which explain the regularity of the tested variable are called the independent (explanatory) variables.

First stage to build the model is to specify the scope of the investigations and to specify dependent and independent variables. Another stage is to gather the data and to select them properly on the basis of which it becomes possible to estimate model parameters. In the analysed process of injection each input data are described as following:

$$\begin{aligned} z = & \beta_0 + \beta_1 T_f + \beta_2 T_t + \beta_3 t_{ch} + \beta_4 v_v + \beta_5 p_d + \\ & + \beta_{11} T_f^2 + \beta_{22} T_t^2 + \beta_{33} t_{ch}^2 + \beta_{44} v_w^2 + \beta_{55} p_d^2 + \\ & + \beta_{12} T_f T_t + \beta_{13} T_f t_{ch} + \beta_{14} T_f v_w + \beta_{15} T_f p_d + \beta_{23} T_t t_{ch} + \\ & + \beta_{24} T_t v_w + \beta_{25} T_t p_d + \beta_{34} t_{ch} v_w + \beta_{35} t_{ch} p_d + \beta_{45} v_w p_d + e \end{aligned}$$

Next stage of an analysis is estimation, i.e. looking for the model parameters. On the basis of its results one can take measures to limit the number of factors describing investigated variable, which leads to simplification of the model. The value of the adjustment coefficient R^2 should be checked every time. If its value, as a result of the simplification of the model, shows significant drop, one should give up introducing further simplifications.

3.2. Investigations results and analysis

In the beginning, the analysis of correlations of each variables, both dependent and independent ones for both polymers have been performed. The results have been presented in table 1.

Table 1.
Matrix of correlation for POM

POM	m, g	$\overline{S_w}$, %	$\overline{S_p}$, %
T_f, °C	-0,044	0,078	-0,026
T_t, °C	0,239	-0,171	-0,156
t_{ch}, s	0,004	-0,066	0,010
v_w, mm/s	0,038	-0,128	-0,100
p_d, MPa	0,935	-0,918	-0,956

While analysing data gathered in correlation tables, one can come to a few conclusions. In case of POM, the change in mass of injection moulded piece is strongly correlated with the value of the clamp pressure. Its positive value shows that the increase in clamp pressure causes the increase in moulded piece mass. On the other hand, the mould temperature is of little influence on moulded piece mass. The value of both longitudinal and transverse processing shrinkage depends significantly on the clamp pressure value – in this case – the values of the correlation coefficient reach even the value of 0,956. Hence, the crucial influence on the mass and processing shrinkage change is exerted only by one value – clamp pressure. One can notice at the same time that all dependent variables are very strongly correlated with each other. Their correlation coefficients exceed the value of 0,95.

3.3. Diversity of the processing shrinkage

While analysing the value of the longitudinal shrinkage in the places marked as SW_1, SW_2 and SW_3 (Fig. 1) no significant differences between them have been noticed. However, the significant differences have been found between values of transverse shrinkage measured close by the nozzle (SP_3), in the middle of the moulded piece (SP_2) and at the end of plastic flow way (SP_1). In the Figure 2 showing the values of transverse shrinkage in two places of the moulded piece i.e. SP_1 and SP_3 for the whole population of the samples have been presented. One should mention the fact of appearance of stronger transverse shrinkage in the part of the moulded piece which is at the farthest distance from the nozzle (SP_1 point). The regularity appears for all the investigated samples.

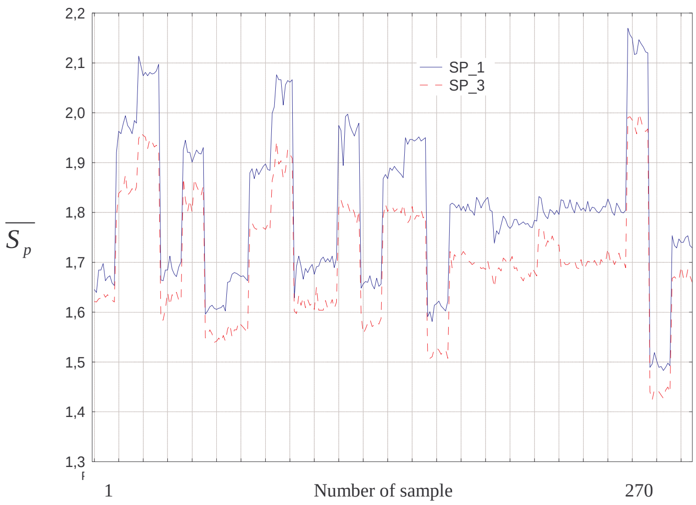

Figure 2. Perpendicular shrinkage changes of all POM samples investigated

The absolute differences of the shrinkage in each place on moulded piece are 8 – 10%. Taking small size of the moulded piece into consideration, the value is a considerable one. It should be expected that for the bigger moulded pieces and long distances of plastic flow, the differences may appear even bigger. The 7%-drop in value of transverse shrinkage has been noticed between points SP_1 and SP_3. The distinct differences in the values of transverse shrinkage in the individual regions of the moulded pieces prove diverse conditions of their solidification which appears during filling in the mould cavity, clamp phase and during cooling.

The drop in the pressure of clamp and the pressure of injected plastic which appears during flow causes different density for different regions of the injection moulded piece. In the places of higher pressure the plastic density is also higher and vice versa, which results in the diversity of the transverse shrinkage.

4. CONCLUSIONS

Applying the statistical analyses, the dependencies (model equations) which describe the investigated properties of the moulded pieces as a function of five the most significant input parameters have been determined. The appearance of the significant differences between dependencies of the investigated values on the changing injection parameters for these plastics have been found. The change in mass and processing shrinkage of the injection moulded pieces made of polyoxymethylen, which belongs to the group of crystalline plastics, depends much on the clamp pressure and less on the injection temperature [6].

It has been also found that the most important parameters on which the processing shrinkage and mass value depend are, in case of POM the clamp pressure and the injection temperature. Hence, in manufacturing practice, in order to control the values of the shrinkage and mass of the moulded piece the most profitable way is to change the value of the clamp pressure as a parameter which can be changed quickly (the possibility to change the value within a cycle).

Moreover, the investigations show the appearance of the diversity for the shrinkage in the individual regions of the moulded pieces. The transverse shrinkage is higher for the points situated farther from the nozzle than for the closer points. The reason may be the fact of the appearance of different values of the plastic temperature and pressure along the way of its flow in mould cavity.

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