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Variation of Cavity Pressure Depending on Processing Temperature at Injection Moulding of the Polymers Used for Manufacturing of Sport Products

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Abstract: This paper is establishing the influence of the processing temperature on the in-mould (cavity) pressure at injection moulding of the polymers used for manufacturing of sport products. The processed polymers were: polyoxymethylene (POM, polyacetal), polyamide 6,6 (PA 6,6), polycarbonate (PC), thermoplastic polyurethane (TPU) and polypropylene (PP). The injection machine employed was an horizontal ENGEL G/11/10/116/3, model VC 500/110 TECH, made in 2002. The temperature in the injection cylinder nozzle was measured through a DYNISCO Ti422J thermocouple. The cavity temperature was determined by means of a thermocouple temperature probe, model 2024T, produced by Digitron Instrumentation Ltd. and the cavity pressure was measured with a transducer, model IDA, made by Dynisco Europe GmbH.

Key words: injection moulding , pressure, temperature

1. Introduction

The injection moulding is a cyclical process, each cycle comprising several operations: feeding, melting and homogenization of polymer grains inside the plasticizing cylinder, mould closing, injection under pressure of melt in mould's cavities, solidification and cooling of polymer inside the mould, mould opening and ejection of moulded piece [1].

The process is influenced by several parameters. The main factors which determine the moulding process of thermoplastic materials are: the chemical, physical and flowing properties of polymer in the specific conditions of the injection process, temperature, pressure and time required for moulding the product [2].

The melting of thermoplastic material is realized by the thermal energy transmitted from the heated wall of plasticizing cylinder to material and by the thermal energy resulted as a frictional transformation of the mechanical energy.

The pressure exerted by screw conveys the flowing state polymer from the cylinder chamber - through sprue and mould runners – inside the mould cavity. The mould cavity pressure reaches the maximum values at the end of screw stroke and depends on the force exerted by piston-screw, polymer viscosity and the hydraulic resistance of flow path. In injection process, the following types of pressure are defined: external pressure, inner pressure, holding pressure, sealing pressure and remanent inner pressure [3].

The injection moulded products have to satisfy specific requirements related to their properties and dimensional stability in use.

The conformity with such requirements is checked through analysis of product properties with consideration of the source-material and the processing conditions. Also there are considered the measurement technics suitable for determination of macromolecules orientation, residual stress, possible density alteration and other characteristics as well [4, 5].

The residual stress in injection moulded products are induced by two main sources: the first are the stress induced by cooling of material which flows into mould and the second, the stress induced by the processing parameters, temperature and pressure. The first are caused by the viscoelastic flow of polymers during the mould filling and the others are due to the different shrinkage. In absolute figures, the stress induced by temperature is greater than the stress induced by flow. However the macromolecular orientation generated by the cooling of flowing melt determines the anizotropy of the mechanical, thermal and optical properties and it influences the long-termed dimensional stability of the moulded products too [6].

For sport products, it is advisable to have low residual stress since these products are subject to high strains and an eventual deterioration of one of the product's components can put in danger the life of sportsman.

The present study aims to analyze the variation of pressure required for filling the mould cavity depending on the temperature of injected material, for some of technical polymers used at production of sport products.

The polymers used were :

- polyoxymethylene (POM, polyacetal),
- polyamide 6,6 (PA 6,6),
- polycarbonate (PC),
- thermoplastic polyurethane (TPU),
- polypropylene (PP).

2. Experimental part

The polymers used for determinations were:

- polyoxymethylene, grade TENAC 2013 A,
- polyamide 6,6, grade TECHNYL A 221,
- polycarbonate, grade XANTAR 18 UR,
- thermoplastic polyurethane, grade DESMOPAN KA 8377
- polypropylene, grade INNOVENE 100- GB06.

All these polymers are used for manufacturing of sport products.

The test-pieces were moulded using an ENGEL injection moulding machine, type G/11/10/116/3, model VC 500/110 TECH, made in 2002. The temperature of the flowing-state polymer was measured with a thermocouple DYNISCO, type Ti422J fit in the nozzle of plasticizing cylinder in order to get the real temperature within the central stream of the polymer melt flow (Fig.1).

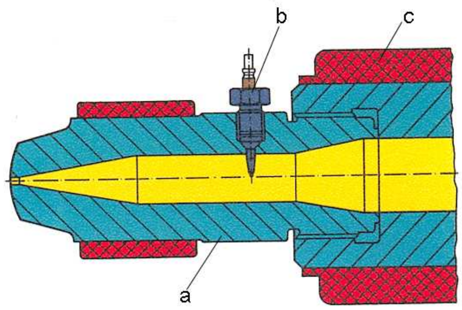

Figure 1. The thermocouple fit in the nozzle of plasticizing cylinder:
a) nozzle ;
b) thermocouple DYNISCO, type Ti422J ;
c) plasticizing cylinder.

The mould inner (cavity) parameters - temperature and pressure - were determined by means of a thermocouple temperature probe (i.e., supplier Digitron Instrumentation Ltd., model 2024T) and a pressure transducer (i.e., supplier Dynisco Europe GmbH, model IDA).

Depending on the type of material processed, different feeding time values have resulted for each material as presented. These differences originated in the materials features : the rate of thermal transfer, shape and dimemsion of polymer grains and - the last, but not the least - the melt viscosity is different for each material.

Different temperatures were set for different moulds. These values were required by the type of material processed, on one hand and by the dimensions and complexity of moulded product, on another.

For the performance of injection experiments, the temperature intervals recommended by the material producers were generally set (Tab. 1).

TABLE 1. Temperature intervals recommended by the material producers

Technopolymer	Temperature interval recommended
TENAC 2013 A	180 - 240˚C
TECHNYL A 221	270 - 345˚C
XANTAR 18 UR	280 - 340˚C
DESMOPAN KA 8377	200 - 240˚C
INNOVENE 100- GB06	220 - 300˚C.

3. Results and discussion

For injection of polyoxymethylene (POM), grade TENAC 2013 A the following conditions were set:

- injection pressure = 1900 bar,
- feeding time = 8 s,
- mould temperature (fixed plate and moving plate) = 80°C,
- real temperature of the mould cavity = 65°C.

The results obtained are presented in Table 2.

TABLE 2. The variation of peak pressure depending on the injection temperature (POM, grade TENAC 2013 A)

Real injection temperature [˚C]	180	190	200	210	220	230	240
In-mould peak pressure (bar)	1900	1900	1900	1900	1850	1800	1700

At increasing the injection temperature, the in-mould pressure peak, (i.e., the maximum pressure needed to compact the material into the cavity) is decreasing till 1700 bar at 240˚C temperature. This decrease of the cavity pressure is the result of the lower melt viscosity as the processing temperature is higher.

For injection of polyamide 6,6, grade TECHNYL A 221, the following conditions were set:

- injection pressure at 1200 bar,
- feeding time at 9 s,
- mould temperature (fixed plate and moving plate) = 80°C,
- real temperature of the mould cavity = 65°C.

The injections were done between 270 – 345°C and the pressure peak is significantly modified. In Figure 2 is presented the variation of in-mould peak pressure depending on the injection temperature (PA 6,6, grade TECHNYL A 221).

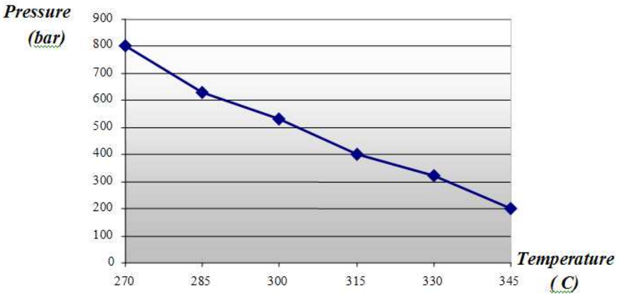

Figure 2. The variation of peak pressure depending on the injection temperature (PA 6,6, grade TECHNYL A 221)

From Figure 2 can be noticed that a major decrease in pressure from 800 bar to 200 bar occurs for a temperature rise from 270°C to 345°C, meaning that using at higher processing temperatures an external pressures of 1200 bar is not justified. This fact leads to important energy savings and reducing the wear of machine's hydraulic system.

For injection of polycarbonate, grade XANTAR 18 UR, the following conditions were set:
- injection pressure = 1600 bar,
- feeding time = 11 s,
- mould temperature (fixed plate and moving plate) = 80°C,
- real temperature of the mould cavity at 65°C.

The injections were done between 280 – 340°C and modification of the in-mould pressure peak occured. The variation of in-mould peak pressure depending on the injection temperature is presented in Table 3.

It can be noticed for PC as well, a major decrease in pressure at increase of injected material temperature, meaning that using at higher processing temperatures an external pressures of 1600 bar is not justified.

TABLE 3. The variation of peak pressure depending on the injection temperature (PC , grade XANTAR 18 UR)

Real injection temperature [˚C]	280	295	310	325	340
In-mould peak pressure (bar)	1500	1200	1000	860	720

For injection of the thermoplastic polyurethane (TPU), grade DESMOPAN KA 8377, the following conditions were set:
- injection pressure = 1600 bar,
- feeding time = 12 s,
- mould temperature (fixed plate and moving plate) = 80°C,
- real temperature of the mould cavity = 67°C.

The injections were done between 200 – 240°C and the temperature of flowing state material significantly influenced the in-mould pressure peak and the production of moulded piece. In Fig. 3 is presented the variation of peak pressure depending on the injection temperature (TPU, grade DESMOPAN KA 8377).

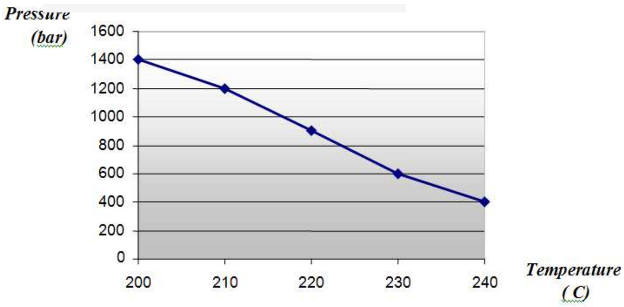

Figure 3. The variation of peak pressure depending on the injection temperature (TPU, grade DESMOPAN KA 8377)

For injection of polypropylene (PP), grade INNOVENE 100- GB06 the following conditions were set:
- injection pressure = 1900 bar,
- feeding time = 11,5 s,
- mould temperature (fixed plate and moving plate) = 40°C,
- real temperature of the mould cavity = 35°C.

The results obtained are presented în Tab 4 and shows that the in-mould pressure decreases as the material temperature increases.

According to these data related to the tested polymers, it is noticed that the real in-mould pressure is lower than the external pressure, excepting the processing of POM at temperatures below 210ºC where the cavity pressure is equal with the external pressure. This fact can be explained by the considerable decrease in viscosity of flowing-state polymer which automatically implies important pressure losses in the cylinder–screw assembly.

The results obtained are compliant with the specialty literature data [7, 8], which indicate important changes of melt flow rate for these polymers within the analyzed temperature ranges. In injection moulding, the polymers viscosity is one of the most important characteristics of the flowing process and this depends mainly on temperature, shear and molar mass. For the moulded pieces with the chosen polymers, the results obtained are concordant with the presented information.

TABLE 4. The variation of peak pressure depending on the injection temperature (PP, grade INNOVENE 100- GB06)

Real injection temperature [˚C]	220	240	260	280	300
In-mould peak pressure (bar)	610	610	590	560	530

The production of parts having qualitative characteristics and time-stable dimensions is conditioned by the processing and formation of polymers within the domain of viscoelastic deformations. All the polymers used - excepting POM – in flow-state have low viscosity and their viscosity decreases as the temperature rises, which implies increasing of pressure losses. Due to the polymer's chemical structure, the viscosity of melted POM is high, reason why the pressure losses are much lower in cylinder–screw assembly.

4. Conclusions

There were established correlations between the injection temperature, external pressure and the real cavity pressure for the following polymers:
- polyoxymethylene, grade TENAC 2013 A,
- polyamide 6,6, grade TECHNYL A 221,
- polycarbonate, grade XANTAR 18 UR,
- thermoplastic polyurethane, grade DESMOPAN KA 8377
- polypropylene, grade INNOVENE 100- GB06.

The test-pieces were moulded using an ENGEL injection moulding machine, type G/11/10/116/3, model VC 500/110 TECH, made in 2002.

The accurate temperature measurement of the flowing-state polymer into the nozzle of plasticizing cylinder was realized by means of a thermocouple DYNISCO, type Ti422J and by using a thermocouple temperature probe Digitron Instrumentation Ltd., model 2024T for the in-mould cavity temperature.

For fitting the DYNISCO thermocouple in cylindre's nozzle, it was realized a port in order to get the real temperature of the flow-state polymer within the middle of the melt flow .

The in-mould pressure (cavity pressure) was determined with an IDA model transducer, made by Dynisco Europe GmbH.

For all the analyzed polymers, it was determined a significant decrease of material pressure inside the mould cavity as the real injection temperature increases, in condition of maintaining the external pressure at the same value.

This would permit a decrease of the external pressure too, meaning energy saving and reducing of machine wear.

However, over certain values of the real temperature, thermal degradation occurs affecting the characteristics of these materials used for producing of sport products.

For this reason, there must be established an optimum of pressure and temperature, specific for each sort of material.

A study of a specific pair polymer – product allows the establishing of optimum conditions both for product properties and economical considerations.

REFERENCES

1. Mărieş, Gh., R., E., Elemente de ştiinţa prelucrării termoplastelor, Editura Universităţii din Oradea, Oradea, **2004**, pp. 33.
2. Şereş, I., Injectarea materialelor plastice, Editura Imprimeriei de Vest, Oradea, **1996**, pp. 94-99.
3. Tudose, R., Z., Procese şi utilaje în industria de prelucrare a compuşilor macromoleculari, Editura Tehnică, Bucureşti, **1976**, pp. 35-46, pp. 486-487.
4. Douven, L.,F.,A., Baaijens, F., P., T., Meijer, H., E., H., Prog.Polym.Sci., 20, nr.3, **1995**, pp. 403.
5. Postawa, P., Koszkul, J., J.Mater.Process.Technol.,162-163, **2005**, pp.109.
6. Mărieş, Gh., R., E., Manoviciu, I., Bandur, G., Rusu, G., Pode, V., The Influence of Pressure and Temperature on the Injection Moulding of Thermoplastic Materials used for High Performance Sport Products, Materiale Plastice, Vol.44, nr.4, Bucureşti, **2007**, pp. 289-293.
7. ***, Polymer Handbook, 3th Edition, John Wiley & Sons, J. Brandrup and H. Immergut, New York, **1989**, pp. V.1-V.108.
8. Tudose, R., Z., Volintiru, T., Asandei, N., Lungu, M., Merica, E., Ivan, Gh., Reologia compuşilor macromoleculari, Reologia stării lichide, vol. II, Editura Tehnică, Bucureşti,**1983**, pp. 84-99.