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THE USE OF INJECTION MOULDING PROCESS SIMULATION SOFTWARE CADMOULD FOR INJECTION MOULD DESIGNING

Dariusz Sykutera, Marek Bieliński

University of Technology and Life Sciences
ul. S. Kaliskiego 7, 85-796 Bydgoszcz, Poland
tel.: +48 52 3408224, fax: +48 52 3408222
e-mail: sykutera@utp.edu.pl

Abstract

The work shows the use of simulation software for aiding the design of forming elements of injection moulds and for the analysis of the phenomena occurring while the injection mould cavities are filled with polymer material. The digital analysis was used for the design work of a research modular injection mould equipped with a hot runner system. The use of the injection moulding process simulation software significantly simplifies the analysis of the appropriateness of the assumptions concerning the plastic part shape, the location of the gating points, the gaiting geometry as well as facilitates the recognition of the phenomena taking place inside the mould cavity while polymer freezes. The use of the simulation software results from the necessity to adopt the right assumptions concerning the simulation model and the knowledge of the process parameters used for processing a particular plastic material. In addition to injection mould design aiding, simulation programs constitute a tool to define advantageous plastic material processing parameters.

Keywords: *polymer, simulation, injection mould, injection moulding, molded part,*

1. Introduction

New construction plastic materials, thermoplastic material structure modifications, adopting new control systems in injection machines and process automation are the most visible symptoms of the development of polymer material processing. The aim of injection moulding is to achieve plastic parts of specified geometrical characteristics and physical-chemical properties. Obtaining a part characterised by the required utilitarian properties depends on a number of factors connected both with the process settings and injection mould design (e.g. the melt feeding into the cavities, gating type or the number of cavities) [1-5, 7, 8, 10-13]. The influence of many variables, remaining in mutual interaction, causes that digital programs describing the injection process progress become a substantial tool used for injection mould design verification as well as for the injection moulding process optimisation. According to DSM Engineering Plastics, the introduction of CAE (Computer-Aided Engineering) into the plastic product development caused the reduction of the total manufacturing costs, saving of the time related to the product design and processing as well as the final product quality increase. The results of simulation are not only used for product design work concerning its geometry and the geometry of the injection mould, but also as an important tool for the processing optimisation [1, 2, 5, 11]. Consequently, applying the simulation software may significantly support even an experienced designer, especially in cases, where work connected with the realisation of the tool design for processing reinforced plastic materials (shrinkage anisotropy) and for processing innovative construction thermoplastic materials. The result suitability depends on the mathematical model algorithm assumed by the program, which describes the basic melting and filling processes as well as the polymer material properties, and are, in addition, the derivative of the quality of the plastic part model. The value of the results depends also on the correct assumption concerning the part model, the processing settings and gate geometry [1-4, 6-8, 9-13]. The next approximation of the real injection moulding conditions is introduction into the calculations the correct rheological plastic material model, which will take into account the viscosity changes depending on other inputs. [6, 7, 10, 11, 13]. If one aims at the absolute imaging of the real process conditions, the simulation project should also take into account the position and sizes of the mould cooling or heating channels, but as well the materials used for manufacturing the particular mould elements [1, 2, 5, 6, 11, 13]. The implementation of the new product is accompanied by the necessity of injection mould trial shooting, whose aim is to eliminate the injection mould design errors and defining the optimum processing parameter setting.

One of the most popular simulation programs aiding the polymer injection moulding process is Cadmould by the company Simcon (Germany). The program also allows to read momentary injection process parameter values at a required moment of the process at a required section and point of the moulded part. The analysed course of the melt filling the cavity can be presented in the animated form. The course is obviously, realised until the moulding is removed from the cavity, and, consequently, it takes into account the material volume change during the holding and cooling phases. In addition to the results of the filling and holding pressure distribution, the moulded part temperature distribution during filling and cooling, the shear stress values, the shrinkage and shear velocity distribution, the melt filling and freezing times, it is also possible to define the location of the gating points, the sizes and types of gating, as well as the weld line positions, air traps and fibre orientation. The shrinkage distribution and melt flow analysis allow to describe the maximum values of shape deformations. The simulation model, which is used by Cadmould, is a surface model, which allows to conduct the analysis on 25 independent layers of the moulded part, where only the neighbouring nods influence the final results in particular model points.

2. Exemplary self-conducted digital research conducted in Cadmould

2.1. Defining of the polypropylene freezing time in a pinpoint gate

Pinpoint gate is a significant element of an injection mould flow system. In case, where semi-crystalline polypropylene is injected, due to its high value of the volume shrinkage, the holding time should on average amount to about 8 seconds for 1 mm of the part thickness (for a moulded part of the wall thickness between 3 and 4 mm). Filling up the mould cavity with the melt resulting from volume counteraction while the moulded part freezes will be effectively realised in the assumed time only if the viscoplastic polymer will not freeze earlier in the gate. As a result, the gating point should have the appropriate diameter. For the research work, a geometrical model of the gate was prepared and its sections assigned to test the freezing time (Fig. 1).
It was established that the size of the pinpoint gate diameter significantly influences the polypropylene freezing time. What is worth mentioning, is that the melt material freezes the fastest in section 3 (Fig. 1) for the channel diameter over 1.5 mm (Fig. 2). It is the consequence of the fact that a considerable amount of heat is generated during the melt flow through the small-diameter narrowing, which causes an additional polypropylene temperature rise in this area.

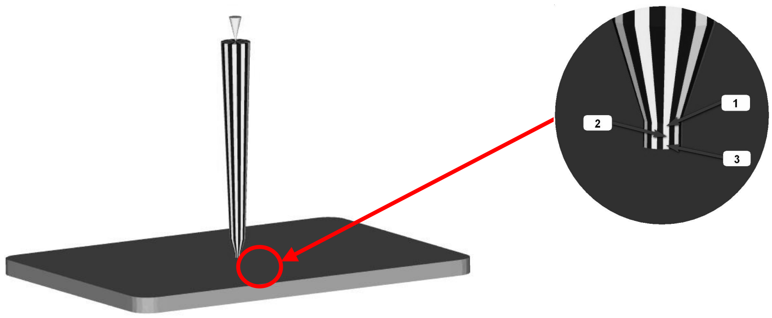


Fig. 1. Pinpoint gate model with characteristic freezing time measurement diameters

The influence of the analysed gate lengths on the freezing time of PP is less significant, and the differences amount maximally 0.2 s. For channels of the diameter above 1.5 mm the length increase causes the delay in polypropylene freezing.

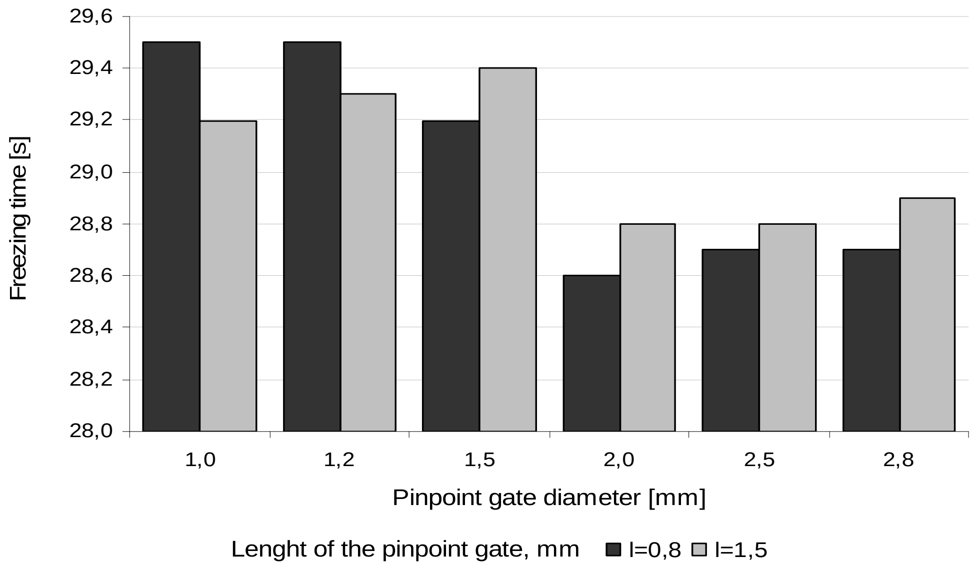


Fig. 2. The influence of the pinpoint gate cross-section and its length on the PP freezing time in a narrowed feeding channel

2.2. Defining the conditions of ABS/PMMA blend injection moulding for a large-size thin-walled part. Selected results.

A large-size plastic part characterised by a complex geometry and thin walls with construction latch elements usually generates many problems during injection moulding process realisation (Fig. 3). During the filling and holding phases, the melt of a specific viscosity must fill the thin-walled volume located the furthest from the gaiting point, which is usually connected with the necessity of applying very high injection and holding pressures. The conducted analysis of the real part surface quality proved that a minor wall thickness (from 1.6 up to 2.3 mm) and a number of construction latch elements generates problems with filling the cavity with the melt plastic. The part was produced of a ABS/PMMA polymer blend of the company Evonik of the trade name of Plexalloy NTA-4. The use of polymer blends is one of the observed manners of polymer property modification. The use of PC/ABS and ABS/PA blends for manufacturing the white and brown household product housings might be the evidence. Due to the high melt flow rate of PC/ABS, it is used for mobile phone housing production. Digital research was preceded by generating a 3D model, which was the exact image of the shape and dimensions of the real plastic part. In the digital program the rheological model of the ABS/PMMA melt worked out by the company Simcon was applied.

The realised simulation research indicates the possibility of the proper mould cavity filling with the ABS/PMMA polymer blend through combining the high injection velocity with the appropriate polymer melt temperature and the temperature of the injection mould cavity (Fig. 4a).

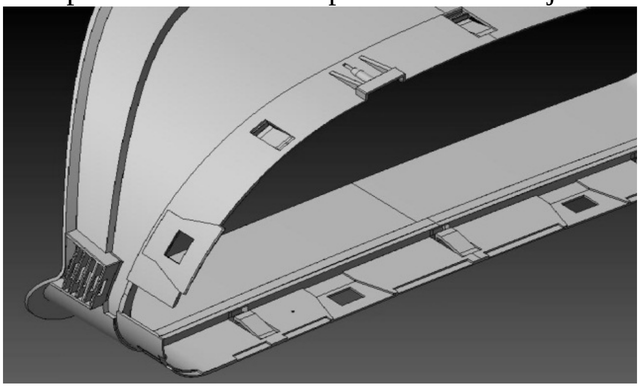


Fig. 3. A fragment of a digital model of a thin-walled part of the wall thicknesses between 1.6 mm and 2.3 mm

In case of large-size thin-walled parts, ABS/PPMA blend processing should be realized at high temperatures of the cavity and processed melt (close to the upper limit suggested by the producer). The high temperature settings should be accompanied by high cavity filling velocity, which, however, should not exceed the value of 200 mm/s. In case of the analysed thin-walled part, injecting the blend into the cold injection mould (temperature of 30 and 50 °C) causes that the polymer melt freezes too fast, which, in turn, causes that the fragments of the part that are the furthest from the gating point as well as the fragments of complex geometry and very thin walls are not filled or filled with difficulty (Fig. 4b). The complete stop or slow-down of the melt front movement means its temperature decrease resulting from the prolonged contact with cold walls of the mould. A high dynamics of the melt polymer movement causes faster cavity filling with the plastic material of a lower viscosity and higher temperature (Fig. 4c). However, one should remember that this may cause a sudden melt pressure decrease in the cavity, which requires the use of an injection machine of a very high nominal injection pressure. Due to this reason, the estimated maximal injection velocity was of the value of 200 mm/s.

a) b) c)

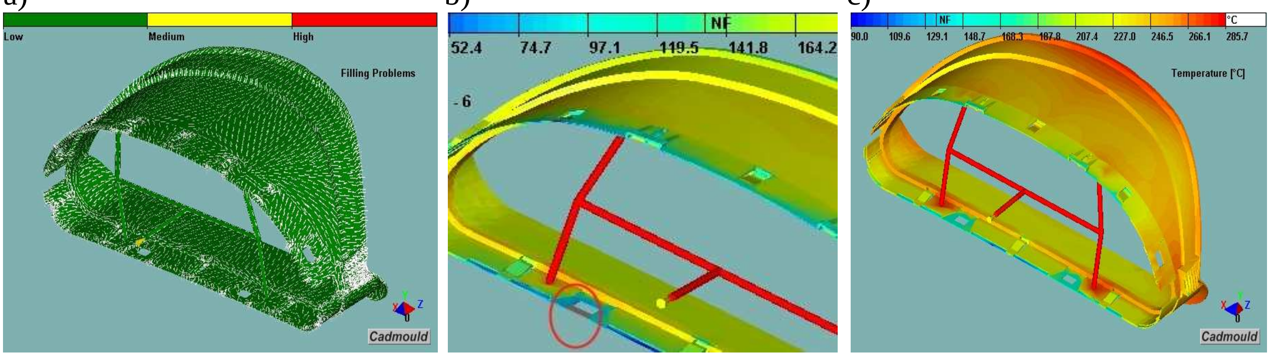
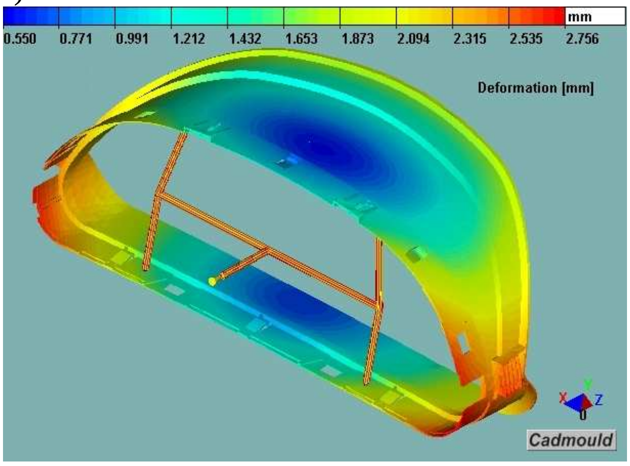


Fig. 4. Examples of the test results: a) the melt flow direction in the cavity, b)unfilled fragment resulting from the too fast melt freezing (simulation realised at a low cavity temperature of 30 °C and low injection velocity of 30 mm/s), c) temperature distribution in the mould cavity after the filling phase for the appropriately produced plastic part (injection velocity of 145 mm/s and cavity temperature of 70 °C)

The injection process realisation with a long cavity filling time at simultaneously low temperatures of the plastic material and tool cavity, caused the greatest shape distortions, especially on the surfaces with the greatest curvature, significantly remote to the gating points (Fig. 5a). Increasing the temperature and reduction the cavity filling time considerably decreased the warpage differences in the particular part fragments, with the greatest deformation not bigger than 1 mm (Fig 5b). Consequently, applying the appropriate injection settings may significantly influence the plastic part quality.

a)



b)

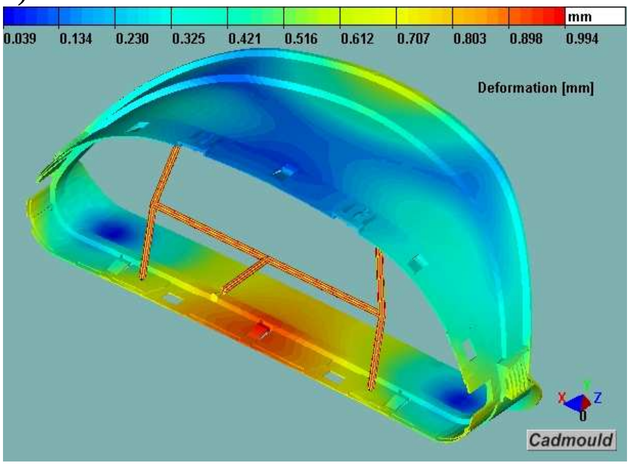


Fig. 5. Examples of deformation distribution: a) for a sample realised at the injection velocity of 30 mm/s and low values of temperatures of the melt and mould cavity, b) for a moulding produced in a hot injection mould (70 °C) at the injection velocity of 145 mm/s and the melt temperature of 250 °C

2.3. Research injection mould design with the use of the simulation program

The experience gained in the area of simulation research, caused that the research on designing and manufacturing a research injection mould for standard research mouldings (dumbbells) was started. Considering the numerous conditions concerning the research samples described in standards, it was decided that the injection mould would be modular with the possibility of fast exchange of forming elements. The design and tool shop work was preceded with the simulation research analysis, which was conducted on different research sample models and with a group of plastic materials. The example of mould cavity pressure distribution for a strength research dumbbell is presented in Fig. 6a. As a result, a modular two-cavity mould with interchangeable inserts equipped with a modern hot runner nozzle by the company HASCO (Germany) was designed and manufactured (Fig. 6b).

a) b)

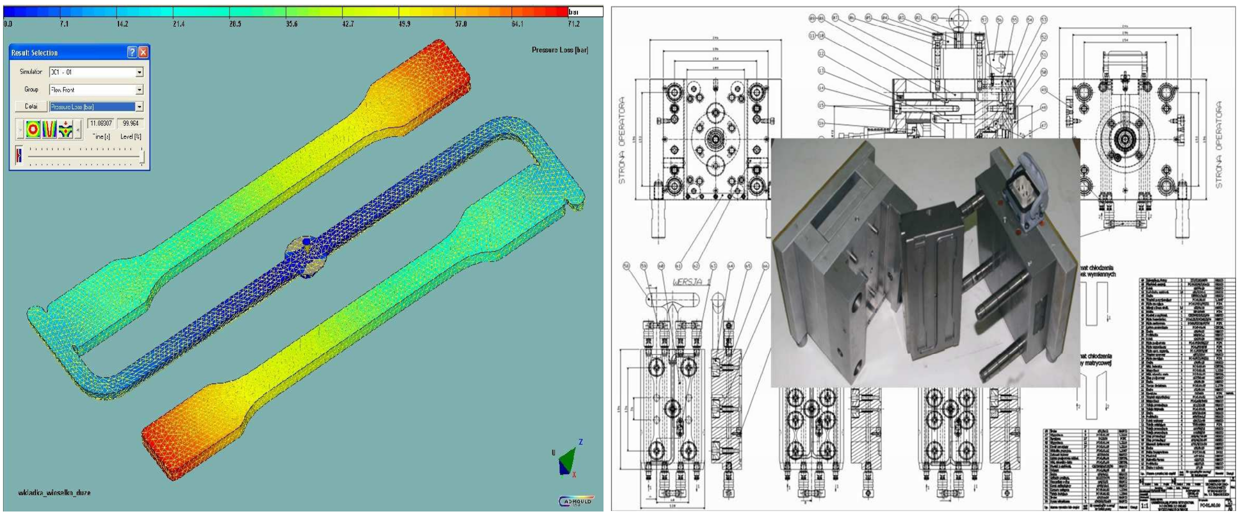


Fig. 6. a) Selected results of PP injection process simulation – gradient of pressure changes in the mould cavity after the filling phase, b) the design and manufacturing of the two-cavity research injection mould

3. Conclusions

Digital software significantly aids the work connected with the injection mould design, especially in the area of final cavity shape forming, as well as the cooling elements and gating points, considerably decreasing the time needed for the project implementation. With the proper initial assumptions and a well-prepared digital model it is possible to achieve the simulation results close to the results obtained in real conditions.

Injection mould design basing only on the designer's experience and intuition or on the practical testing becomes insufficient in today's plastic processing.

The use of a digital software for the filling and holding phase realisation allows to correct the possible mould designer's errors at the stage of the design. The analysis of the melt flow and the kinetics of the part constitution in the mould cavity allows to better understand the phenomena taking place in the melt during the freezing phase in the injection mould.

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