František GREŠKOVIČ[1], Ľudmila DULEBOVÁ[1], Janusz W. SIKORA[2]
[1]Technical University of Košice, Faculty of Mechanical Engineering, Department of Automobile Processing, Mäsiarska 74, 040 01 Košice, Slovakia
e-mail: frantisek.greskovic@tuke.sk, ludmila.dulebova@tuke.sk,
[2]State Higher School of Vocational Education in Chełm, Institute of Technical Sciences, 54 Pocztowa St., 22-100 Chełm, Poland
e-mail: janusz.sikora2017@wp.pl

Application of simulation in the production of plastic mold parts

Abstract: *The aim of study is to assess the technology review of plastic mold parts and to propose the modification of its production. Analyzes were performed by simulation program Moldflow Plastic Advisor (MPA) and two alternative constructional solutions were proposed. Results of the simulation are technologically optimized mold parts and technological parameters for its production.*
Keywords: *plastic mold parts, simulation, MPA, injection mold cavity*

ZASTOSOWANIE SYMULACJI W PRODUKCJI CZĘŚCI WTRYSKOWYCH
Streszczenie: *Celem badań jest przeprowadzenie oceny przebiegu różnych sposobów otrzymywania wtryskiwanych wyprasek z tworzyw polimerowych i zaproponowanie technologii ich produkcji. Zostały przeprowadzone analizy komputerowe dwóch alternatywnych rozwiązań konstrukcyjnych wypraski za pomocą programu do symulacji Moldflow Plastic Advisor (MPA). Otrzymane wyniki symulacji optymalizują technologiczność konstrukcji wyprasek, jak i parametry technologiczne ich wytwarzania.*
Słowa kluczowe: *wypraski wtryskowe, symulacja komputerowa, MPA, gniazdo formy wtryskowej*

1. INTRODUCTION

Injection molding is one of the most variable and important technique for the mass production of complex plastic parts [1, 2]. Injection molding allows to produce precise moldings from wide range of polymeric materials with reasonable price. Injection process is carried out at the injection molding machine and uses the injection mold cavity which has the shape of a future negative molding [3, 4]. Its design and manufacturing cost raises with multiplicity of forms and complexity of the product. It is therefore appropriate, before constructing the form, to perform computer simulations which in these times are irreplaceable assistants for industries engaged in plastic processing. Basic simulation can reveal weaknesses in the design of part and also of the mold [5, 6, 7].

Design and production of injection mold is difficult and financially costly. It is therefore useful to run proper simulation before designing the mold. Computer simulation is currently irreplaceable assistant in plastics processing industry. Simulation may reveal weaknesses in the design, construction and manufacturing of the plastic molding [8, 9, 10, 11]. One of the simulation programs used in plastics processing is Moldflow Plastic Advisor (MPA), which offers a wide range of modules for different simulations, including advanced injection molding methods [8].

Plastic Moldflow Advisor is the first step of the analysis, indicating the presence of potential problems in the production process [8, 10]. Then it offers tools that will help engineers to change ~~the~~ construction of the part and adjust process parameters to ensure its manufacturability while maintaining the desired properties.

MPA is based on the analysis of the manufacturability of the specified points of the inlet, the type of material, temperature and pressure. Simulation results show the places in the part, where it will be possible to expect the molding problems during the production. By MPA, we can assume the quality of the mold part on the basis of other input information such as the internal stress of plastic, cooling time, temperature distribution, size, holding pressure [4, 6, 8].

2. EXPERIMENTAL WORK

2.1 ANALYSIS OF THE CURRENT STATE OF PRODUCTION

Assessment of technological production was done on the mold part used in the electronics industry – a switch. Mold part is produced by injection molding. The model of the considered part is in Fig. 1 with an indication of the functional areas that must be preserved. In Figure 2 the location of melt inlet to the cavity is shown.

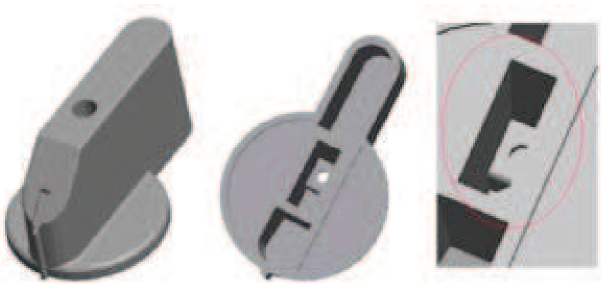

Fig. 1. 3D model of considered part
Rys. 1. Model 3D wypraski wtryskowej

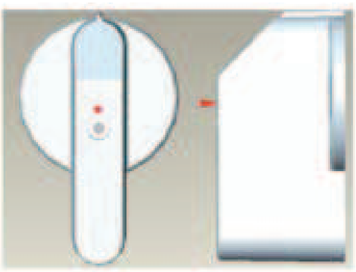

Fig. 2. Location of melt inlet
Rys. 2. Miejsce wtrysku tworzywa

For the production of mold part, polycarbonate material Makrolon®2203 produced by Bayer AG company, will be used. Selected material properties are listed in Table 1. The high-performance properties of Makrolon® polycarbonate (PC) predetermines this material for applications in diverse industries. It is UV stabilized material, extremely robust, lightweight with glass-like transparency and is impact resistant – even at extremely low temperatures. It is a good insulator, is flame-retardant, has a high dimensional stability and is easily molded.

Table 1. Properties of PC Makrolon® 2203 used in studies
Tabela 1. Właściwości tworzywa PC Makrolon® 2203 użytego do badań

Property	Value
MFI (ISO 1133)	32 g/10min
Density (ISO 1183)	1200 kg/m^3
Moisture Absorption (ISO 62A)	0.15 %
Water Absorption (ISO 62A)	0.35 %
Tensile Modulus (ISO 527)	2.3 GPa
Elongation (ISO 527)	> 50%
Vicat 50N (ISO 306)	146 ºC

Design showed non-uniform wall thickness, a sharp transition between the walls and unnecessarily complicated shapes and therefore it was necessary to propose some design adjustments. Next proposed solution will eliminate these structural deficiencies. These proposals were simulated in the simulation program, MPA and compared to the original ones.

2.2 DESIGN DRAFT WITH CONSTRUCTION CHANGES

Two different design drafts of the switch with constructional changes were analyzed.

2.2.1 DESIGN DRAFT A

Design draft A is showed in in Figure 3 and Figure 4. A uniform wall thickness of the part has been achieved by creating openings in which the ribs are proposed (elimination of walls deformation). For the smoother flow of melt several sharp bends were reduced to rounded edges. After these adjustments, molding a uniform wall thickness without significant sharp bends was possible.

2.2.2 DESIGN DRAFT B

Design draft B is showed in Figure 5 and Figure 6. The design adjustment was focused on the thick walls uniformity. On the basis of the functional dimensions of the original part, two neighboring walls thicknesses were changed. Rounded edges of the mold part are designed as proposed in the draft A. After these changes, the molding has modified sharp edges and at the same time ensures a constant thickness of the walls without any significant structural changes.

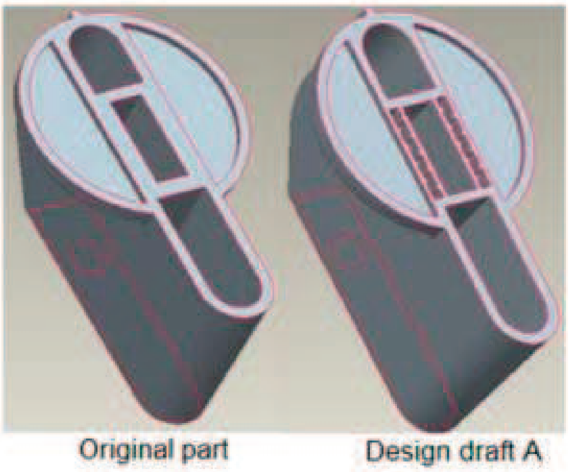

Fig. 3. Design draft A
Rys. 3. Projekt roboczy A

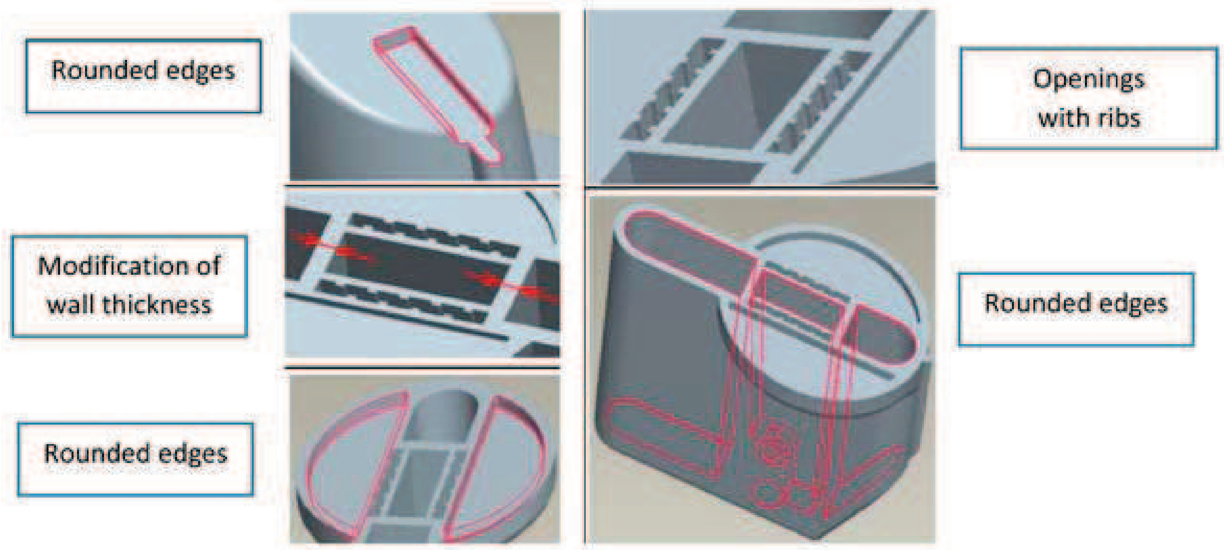

Fig. 4. Modification of part – Design draft A
Rys. 4. Modyfikacja wypraski – roboczy project A

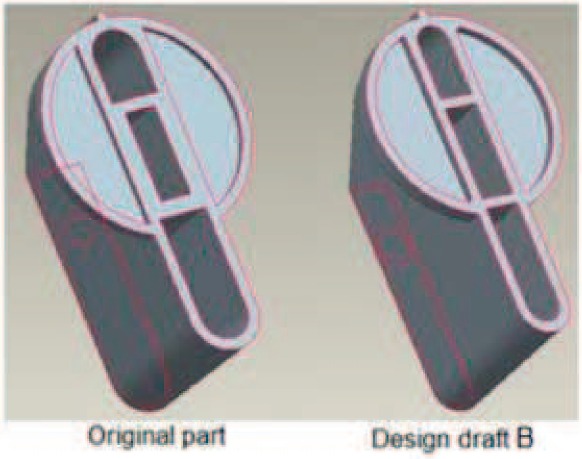

Fig. 5. Design draft B
Fig. 5. Roboczy project B

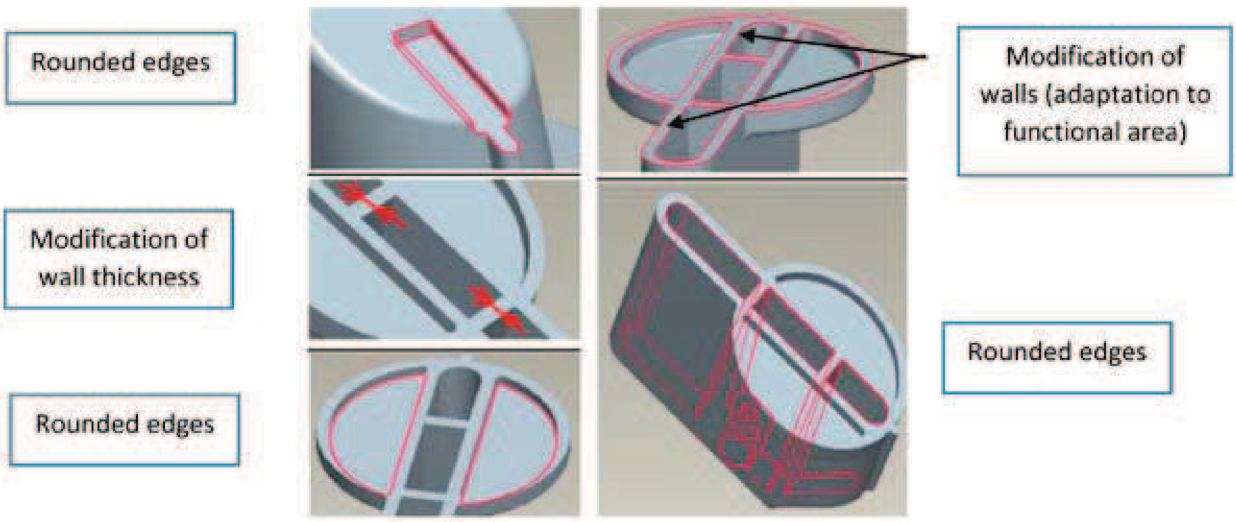

Fig. 6. Modification of part – Design draft B
Rys. 6. Modyfikacja wypraski – roboczy project B

2.3 ANALYSIS OF THE PRODUCTION OF MOLD IN THE PROGRAM MPA

For the assessment of part (Fig. 1) and the proposed modified moldings (Fig. 3 and Fig. 5) simulation was performed in the MPA software. Processed results of this simulation with the selected parameters - quality of filling, quality prediction, filling time, shrinkage, air bubbles and the quality of the cooling in the production of the molding are shown in the Figure 7.

From the results of origin mold simulation (Fig. 7) we can see, that injection filling was completed, the quality is in normal range, shrinkage is negligible in the majority, only in one place is 0.49 mm deep, the amount of air bubbles is recorded only sporadically, the quality of the cooling is in several places critical and appropriate cooling and filling time is 0.62 seconds.

Simulation of production of A - type design (Fig. 7) shows quality improvements in the areas of design at the expense of the bottom wall. Shrinkage is visibly lower, even in places where the shrinkage was largest, now it is almost zero and the filling time of 0.44 s. A major shortcoming in the design is the amount of air bubbles.

The results of the simulation - design type B (Fig. 7) show that the best results were achieved, higher quality of the mold and filling time is only 0.42 s. Isolated shrinkage did not exceed 0.17 mm.

Based on the simulation results and the complexity of the design, design type B (Fig. 5) was selected for the production. Due to the adjustments made to walls thickness in comparison to the original mold, it will in this case also save some raw material.

The molded part will be produced by injection molding technology, so four-cavity arrangement in the shape of a cross is proposed. The inlet is perpendicular to the parting plane as shown in Figure 8. Possible time and material saving can be achieved by using the hot inlet system, wherein the injection nozzle is in direct contact with the part without using distribution channels for melted plastic.

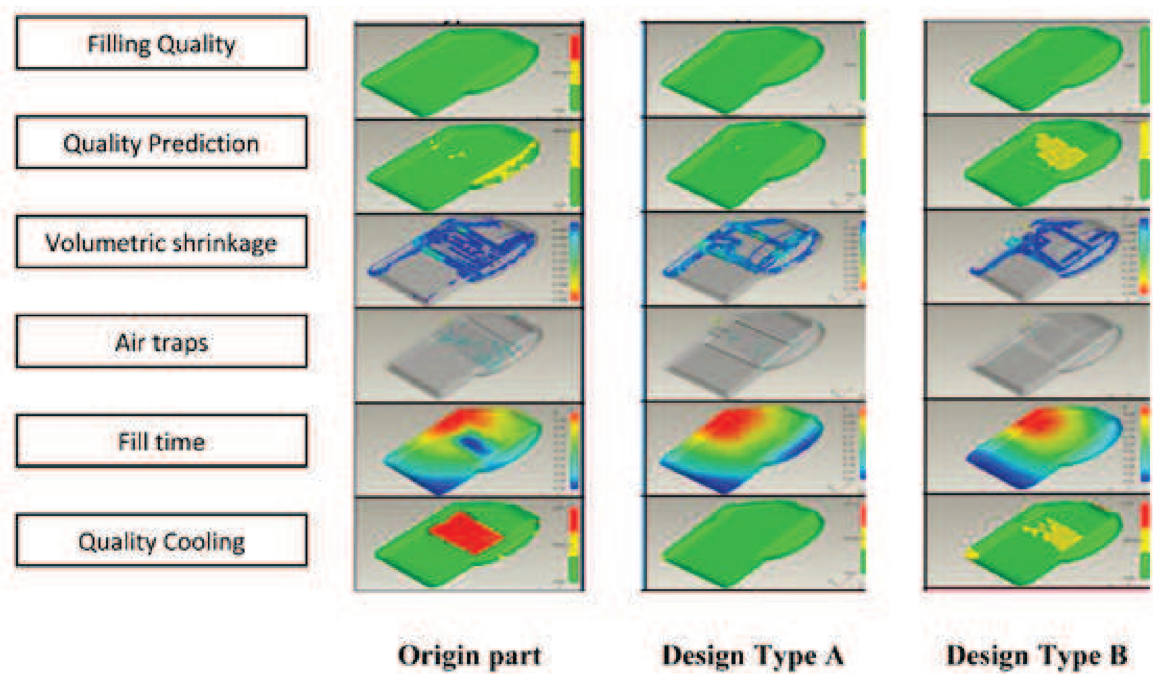

Fig. 7. Simulation results of assessed and redesigned molding

Rys. 7. Wyniki symulacji ocenianej i ponownie zaprojektowanej wypraski

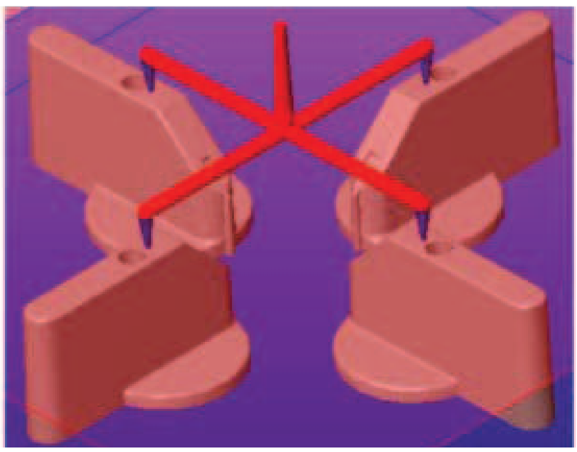

Fig. 8. Positioning of molds and injection molding channels system

Rys. 8. Usytuowanie wyprasek i układu kanałów wtryskowych

CONCLUSION

The paper was aimed to achieve the highest degree of technological suitability of plastics molding - switch - while preserving the design and material constraints. In order to eliminate potential problems during injection, two design drafts of part were proposed.

First design draft A was structurally demanding and focused on eliminating wall thickness differences with proposal of openings and ribs in the part. The other structural design B, was also directed to the reduction of wall thickness, but without creating any new shapes in the part volume. In both cases, several rounding sharp corners and transitions of wall molding were also proposed. Both design drafts were simulated in MPA software and compared to the original part. Simulation results are shown in the Figure 7.

Based on the results of the simulation, design draft B was selected. It provided not only the most suitable simulation results, but also possible material savings and simpler design. Implementation of the new design of the part was also associated with the proposal of the technology for its production. For the manufacturing of this part in mass production we would recommend injection molding to four-cavity mold with hot inlet injection system.

Moldflow simulation contributes not only to detect faults in the design of plastic parts, but also helps to determine the optimal technological parameters. Also it assists in determining optimum process parameters. Using this program, we can get information to minimize risks in the production, to reduce production cycle time and to determine the production cost much more precisely.

ACKNOWLEDGMENTS

This work is the result of the project implementation VEGA No. 1/0360/15 and VEGA No.1/0600/13.

REFERENCES

1. Dobránsky J., Běhálek L., Baron P.: *Gate location and its impact to flowing characteristics of plastic moldings.* Key Engineering Materials 2016, 669, 36-43.
2. Greškovič F., Dulebová L., Duleba B., Sikora J.W.: *Evaluation of process wear of selected tool steels for injection molds.* Advanced Materials Research 2013, 739, 171-176.
3. Kelly A.L., Mulvaney-Johnson L., Beechey R., Coates P.D.: *The effect of copper alloy mold tooling on the performance of the injection molding process.* Polymer Engineering and Science 2011, 51, 9, 1837-1847.
4. Greškovič F., Dulebová L., Duleba B., Krzyżak A.: *Criteria of maintenance for assessing the suitability of aluminum alloys for the production of interchangeable parts injection mold*. Eksploatacja i Niezawodnosc, 2013, 15, 4, 434-440.
5. Jachowicz T., Garbacz T., Tor-Świątek A., Gajdoš I., Czulak A.: *Investigation of Selected Properties of Injection-Molded Parts Subjected to Natural Aging.* International Journal of Polymer Analysis and Characterization 2015, 20, 4, 307-315.
6. Dobránsky J., Mikuš R., Ružbarský J.: *Comparison of cooling variants by simulation software.* Advanced Materials Research 2013, 801, 75-80.
7. Wong C.T., Shamsuddin S., Napsiah I., Hamouda A.M.S.: *Design and Simulation of Plastic Injection Moulding Process*. Pertanika J. Sci. & Technol. Supplement 2004, 12, 2, 85-99.
8. Stanek M., Manas D., Manas M., Navratil J., Skrobak A.: *SW and HW optimization of injection molding process.* International Journal of Mechanics 2014, 8, 1, 85-92.
9. Naumenko M., Bashtanyk P., Burmistr M.: *Technological aspect of influence on long-term constructional properties under compression of thermoplastic polymer composites*. Chemistry and Chemical Technology, 2013, 7, 2, 227-234.
10. Vishnuvarthanan M., Rajesh P., Ilangovan S. Nayak S.K.: *Optimization of Injection Molding Cycle Time Using Moldflow Analysis.* International Journal of Current Research 2012, 4, 1, 259-261.
11. Shen Ch., Wang L., Li Q.: *Optimization of Injection Molding Process Parameters Using Combination of Artificial Neural Network and Genetic Algorithm Method*, Journal of Materials Processing Technology 2007, 183, 412–418.

Data przyjęcia publikacji do druku: 22-10-16