Technological Devices Design Using Simulation Tool

Peter Pastucha[1,a], Andrea Cizikova[1,b], Anna Smeringaiova[1,c], Romana Hricova[1,d], Slavomir Hric[1,e]

[1]TU Kosice, Faculty of Manufacturing Technologies with the seat in Presov, Sturova 31, 080 01 Presov, Slovakia

[e]peter.pastucha007@gmail.com; [b]andrea.cizikova@tuke.sk; [c]anna.smeringaiova@tuke.sk; [d]romana.hricova@tuke.sk; [e]slavomirhric@gmail.com

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Abstract. The article deals with the research of the pressures originate inside the cooling system and also in the mould cavity during the injection moulding process. The reason for this research is the fact that the wear on the injection device reduces with the decreasing of pressure in the mould cavity during the injection process what increases its lifetime. The simulations were realized for three designed types of running system and for four versions of cooling system. 3D model of the mould was created in Autodesk Inventor Professional software and then solidification of material was simulated in Autodesk Moldflow Insight software. The most significant decreasing of the pressure has shown the fourth alternative, at which the inlet system was heated in its entirety and trajectory of cooling channels have ensured better heat removal. The results were compared and the best version from the view of pressure was manufactured and placed into the injection moulding machine Arburg Allrounder 320 C.

Introduction

Plastic has become the cornerstone of our society. So many things from plastic are made that it is hard to imagine what our lives would be like if it was never invented. With so many of our everyday products being made of plastic, it is easy to understand why plastic injection moulding is such a huge industry.

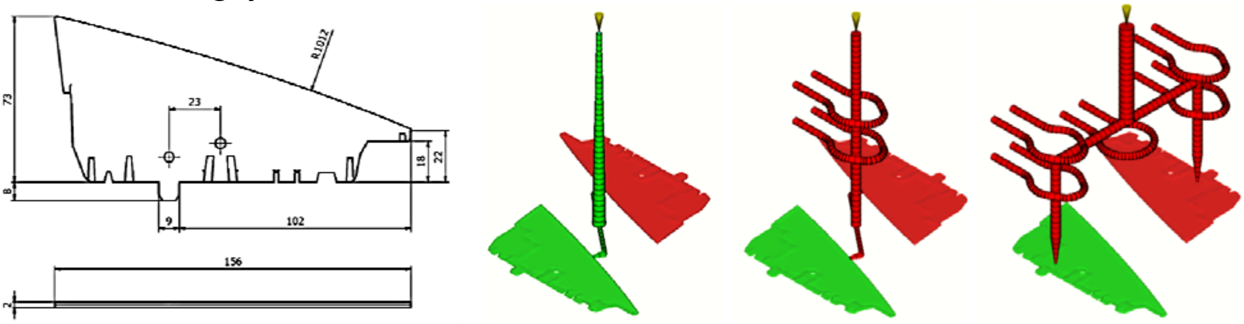
Injection moulding is a complex technology with possible production problems. It has seen steady growth since its beginnings in the late 1800's. The technique has evolved from the production of combs and buttons to major consumer, industrial, medical, and aerospace products. In 1868, perhaps in response to a request by billiard ballmaker Phelan and Collander, John Wesley Hyatt invented a way to make billiard balls by injecting celluloid into a mould. By 1872, John and his brother Isaiah Hyatt patented the injection moulding machine. The machine was primitive yet, but it was quite suitable for their purposes. It contained a basic plunger to inject the plastic into a mould through a heated cylinder. Revolutionizing the plastics industry in 1946, James Hendry built the first screw injection moulding machine with an auger design to replace Hyatt's plunger. The auger is placed inside the cylinder and mixes the injection material before pushing forward and injecting the material into the mould. Once cooled, the mould can be removed. This principle is commonly used up today in mass-production or prototyping of a product. [1,2]

Problem definition

The primary aspects attracting current research involve lowering the cycle times and improving the quality of parts. Pressurization techniques offer some hope in lowering the cycle times as applying a small pressure at the right point in the heating phase may speed the coal essence of polymer particles. This will produce parts will less bubbles in a shorter amount of time than at atmospheric pressure. So, the optimal setting of the production process is a crucial factor that affects the quality, cost and productivity of injection moulding. [3]

Studied component for injection moulding was intended to serve as a stopper in the automotive spotlight and it should be made from material Dyblend from German company Hoffmann + Voss. To the thermoplastic material of the ABS + PC glass fibbers, mainly used in the automotive industry. This material should be dried before the injection at 80 °C dry air. The parts should be produced in plant´s conditions by means of injection moulding machine Arburg Allrounder 320 C. The product with its basic dimensions is shown in the Fig. 1a.

On the base of its closing force and maximal injection pressure, and on the base of requirements for high surface quality and flatness compliance, there was specified multiplicity of cavity “2”. [4,5,6] Based on the principles of mould making and due to uniform heat dissipation, the components should be placed inside the form in a mirror position against each other. For cavities organization mentioned about, it was designed three alternatives of running system. The first one (Fig. 1b) is a cold running system; the second and the third systems are heated (Fig. 1c,d). The second version in the Fig. 1c includes two heating spirals that heat only main sprue; at the third alternative (Fig. 1d) five spirals heat whole running system. [6]



a) b) c) d)

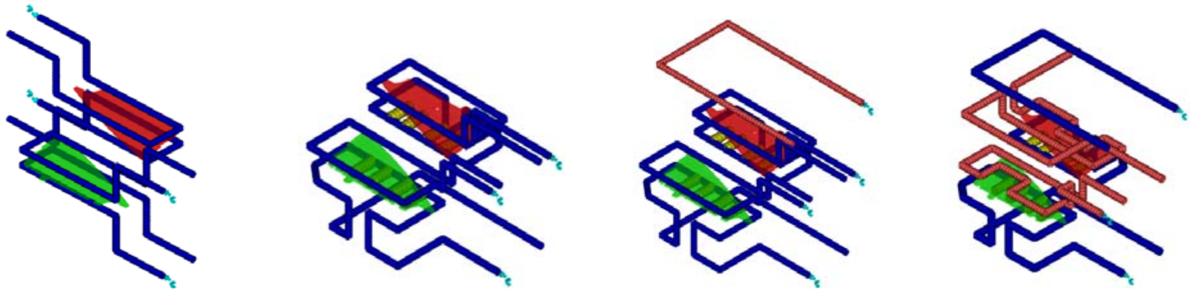
Fig. 1 The product and three versions of running system [6]

Alternatives of cooling system

The next step of injection process optimization was the designing of cooling system. There were considered four types of cooling system displayed in Fig. 2.

1. The concept of the cooling system in the first alternative (Fig. 2a), designed for cold running system showed in Fig. 1b, was the simplest among all proposed. It consists of four separate cooling circuits. Diameter ϕ 8mm of cooling channels was specified based on rules for their designing. This follows from the weight of components, which is 16 grams and from the dimensional capacity of injection moulding machine, at which the maximum size of form plate is 446 x 446 mm. For used material DYBLEND the form has to be malleable to a temperature 50-80°C. Based on this criterion, the coolant temperature was selected 65 °C and as the cooling medium was used water.
2. The second version (Fig. 2b), designed also for cold running system showed in Fig. 1b, better follows the shape of part; in addition there are the flat segments. They were used for regulating and directing the flow of coolant, which thus gets to the harder reach areas. Thereby a higher cooling efficiency can be achieved. The segments were placed only in the moving parts of form because the runners could be cooled too much. It could cause various errors of injection. [7,8] Diameters of cooling channels remained at ϕ 8 mm, diameters of segments were ϕ 12 mm and coolant temperature was 65 °C.
3. The third version of cooling system (Fig. 2c) was prepared for heated running system with two spirals that is shown in Fig. 1c. Because of heated main sprue, the cooling system in the fixed part of the mould is added by a further circuit. Diameter of this fifth cooling channel is ϕ 8 mm. Through the use of the heated inlet system, the coolant temperature in tempering channels was changed in this alternative. The coolant temperature of the headings in the mobile part of the mould is 60 °C, and for circuits in the fixed part of the mould is 70 °C. The reason for the rise in coolant temperature for circuits in fixed part of the mould is to increase the efficiency of heated running system.
4. Due to changes in the running system with added heating spirals (Fig. 1d), it was necessary to change the cooling system in the fixed part of the mould. Trajectory of cooling channels was therefore chosen so to run around the gates and thus better copy the shape of the component, ensuring better heat removal. The newly designed cooling system in the fixed part of the mould is

shown in Fig. 2d. Diameter of cooling channels and coolant temperature were the same as in the third alternative.



a) b) c) d)

Fig. 2 Alternatives of cooling system

After designing of running and cooling system, the simulations of pressure in the cooling system and also in the mould cavity were activated in software Autodesk Moldflow Insight. The pressures achieved by simulation for all types of cooling system (Fig. 2) are shown in the Figures 3 and 4.

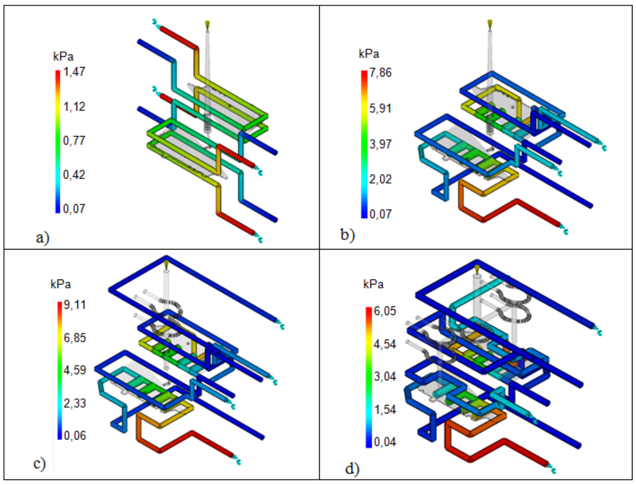


Fig. 3 Pressure in the cooling system

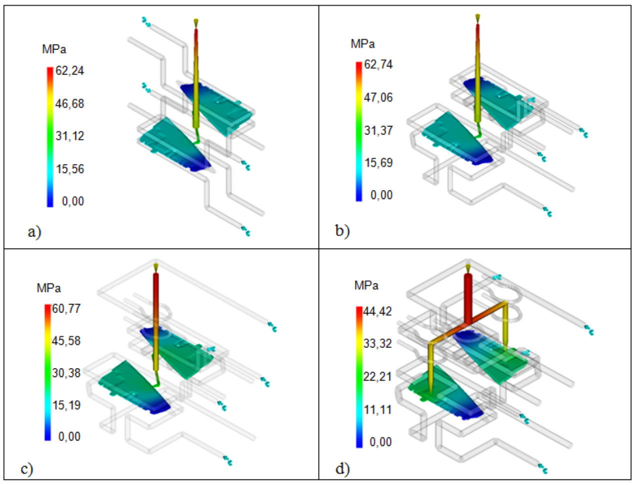


Fig. 4 Pressure in the mould cavity

The easiest cooling system was designed at the first alternative, so it is reflected on the pressure which operates in this system. The achieved value is 1.471 kPa and it is the smallest of all the alternatives. On the contrary, highest pressure in the cooling system shows the third alternative, at which a value of up to 9,112 kPa was reached. This high pressure is caused by complex cooling system with complicated trajectory and lower temperature of form. Slightly lower pressure 7,863 kPa acted in the second alternative and 6,047 kPa in the fourth one. The last two mentioned alternatives have almost identical trajectory of cooling system, but form at the fourth version is malleable at a lower temperature.

The wear on the injection device reduces with the decreasing of pressure in the mould cavity during the injection process what increases its lifetime. For the first two alternatives of cooling system, pressure in the mould cavity was growing during the filling process at approximately the same value 62.24 MPa and 62.74 MPa. Slight pressure drop occurred in the third alternative, where the trajectory of runner system was identical to the first two alternatives, but the main sprue was heated and its cross-section was also enlarged. This had a positive impact by reducing the pressure in the mould cavity to 60.77 MPa. The most significant pressure drop analysis showed the fourth option, at which inlet system was heated in its entirety and its trajectory was changed. It was the reason why pressure in the cavity decreased on the level of 44.42 MPa.

Summary

The cost of manufacturing moulds depends on a very large set of factors ranging from number of cavities, size of the parts (and therefore the mould), complexity of the pieces, expected tool longevity, surface finishes and many others. The initial cost is great; however the per-piece cost is low, so with greater quantities the unit price decreases. It can be said that it is ideal for producing high volumes of the same object. [8]

Achieved results show that from view of pressure the most suitable type of cooling system is the fourth alternative that is shown in the Fig. 2d. This version was also specified as optimal from the view of minimum waste, mould filling time and product cooling time at the additional simulations. On the base of the best alternative, the final version of 3D model of the mould was prepared and consequently manufactured in company conditions. The form was placed into the injection moulding machine Arburg Allrounder 320 C. (Fig. 5)

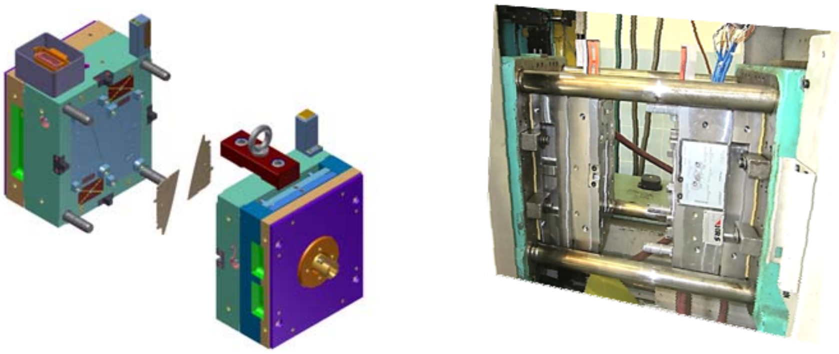


Fig.5 3D model and real mould form manufactured for studied component

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