DESIGN MODIFICATION OF THE FLOW SYSTEM OF INJECTION MOLDS FOR RUBBER IN THE ASPECT OF IMPROVING PERFORMANCE.

Jan Ziobro[1]

Abstract

The article shows problems connected with the process of injection molding of elastomers. It presents the analysis of the construction of the standard 16 cavities mold flow of injection mod to elastomers based on chloroprene rubber CR. It showed phenomena in this system. The results of the numerical simulation of injection molding have also been shown. The obtained results confirmed the possibility of the formation of defective products molded. We proposed an innovative design solution of this injection mold system. A large number of numerical simulation results for the modified flow system has been presented. Flow conditions in the channel have been improved. As a result, system volume has been reduced and a cycle of injection processing has been shortened. We eliminated the exploitation problems of mold. We reduced unit costs of manufactured products. Processing efficiency, safety and comfort have been improved.

Keywords: rubber, runner system, finite element analysis FEA, injection molds

Introduction

The economic production process forces a continuous search for newer solutions and cheaper processing operations. In the present state of technological development the key importance factors are: minimizing consumption of materials and energy, reducing time and simplifying the manufacturing process.

One of the examples meeting the above conditions is to modify flow system of injection processing tools, which are injection molds. A modern solution based on the results of various analyzes and numerical simulations allow reducing sample testing of molds to a necessary minimum [1, 2].

An adoption of correct processing conditions based on reliable material model also allows the achievement of this objective. Then it becomes multiple testing mold is unnecessary. The practical implementation of this phase is the search of the repeated of injection processing to receive the correct product, in terms of quality. As a result of multiple testing we receive a huge mass of irrevocably used material, energy and time, suggesting irrelevant selection of these conditions and receiving defective products. You can even completely block the runners. The result is a lack of filling mold cavities.

It leads to a rapid increase of the temperature and pressure, and flooding the hot vulcanizes in the parting plane of the mold. This phenomenon may be the cause of flooding the tables injection molding machine and burning the operation. The results of these burns are wounds difficult to heal because vulcanizates contain aggressive sulfur compounds [3, 4].

[1] Jan Ziobro, PhD Eng. *Technical Institute, Jan Grodek State Vocational Academy in Sanok, ul. Mickiewicza 21, 38-500 Sanok, Poland, e-mail: jziobro@pwsz-sanok.edu.pl*

The numerical simulation of the injection molding is carried out in the direction of determining the most favorable point of feeding the product and the best processing conditions. Processing conditions include factors such as: temperature ranges (plasticizing, the mold surface, curing, degradation), injection velocity profiles, pressure and clamping force, plasticizing volume, screw position, the corresponding timing diagram [5÷9].

The appropriate plasticizing capacity shall be based on the formula:

$$V_u = V_w (a_w + 1)$$

Where: V_u – plasticizing capacity, mm^3,
V_w – injection capacity, mm^3,
a_w – an experimental factor, a = 0,025÷0,035

V_w injection capacity corresponding to the total volume of the slots and mold of the flow system. It is a physical quantity which can be readily determined from the digital 3D solid model CAD software. An experimental factor a_w takes into account phenomena such as: shrinkage processing, the effect of cross-linking reaction, the possible reverse flow, the state of injection molding machines, material retention in the cylinder and the injection nozzle.

Plasticizing capacity V_u is one of the most important setting parameters. Adopting too low value results in of defective products in the form of short. An excessive value is revealed: unsealing the mold and creation of leakages in the paring plane, and the product may be of too high hardness. The appropriate plasticizing capacity value is entered in the injection molding machine controlling panel work. This main parameter is also required in softwares that simulate the injection molding process.

In order to use credible injection molding simulation it is necessary to prepare a correct 3D geometric model in CAD softwares [4, 7, 8]. On the basis of this activity discretization is performed.

This is done by covering the generated model with an appropriate type and density of the FEA mesh. It is indicated for optimal quality mesh model and its rational density, so as to minimize errors at the level of structure solution. Proper calculation model parameters should be determined on the basis of laboratory tests. The issue of the selection of models and computational geometry and required material factors goes far beyond the scope of this article. The reader may read the monograph to come across such issues [4].

The conditions presented above conducive the competitiveness of the construction office and toolmaker's shop producing mold. It is extremely important Extensive cooperation between moldmaker with technologist and leadership of laboratory preparing the data calculation. Their mutual and close relationships allow prompting and effective methods of solutions. Otherwise, the process time of design and production is significantly increased. This time factor has a direct influence on the price of mold and its operational correctness.

Description of the problem

One of the companies started manufacturing rubber molded products based on the runner system, which is shown in fig. 1.

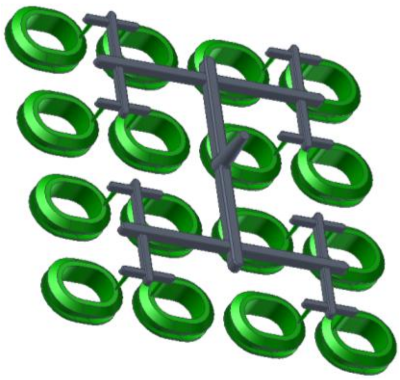


Fig. 1. The cavity system and standard the course of the runner system

In the process of exploitation of this tool, it turned out that there are problems associated with the release of the runners. This resulted in strong and frequent phenomenon sticking vulcanized rubber to the walls of the runner. This made it necessary to remove them. Then it caused cooling surfaces, which contributed in receiving defective molded products.

Diagnosed with major exploitation problems:

-vulcanizate sticking to the walls and its occur,
- difficult to release a vulcanised runner system,
- long cycle time, little economics of the process,
- receiving of defective products (patchy flexibility, surface efflorescence, visible signs of mergers, the lack of smoothness of the surface, porous of the products).

A careful analysis of the geometry also allowed to see the lack of fillets between the surfaces in the runners. Their sharp edges can result in an increase of shear stress. This may cause scorch of the flowing rubber compound. This phenomenon is normally a reason for worsening of the mechanical properties of manufactured molded products.

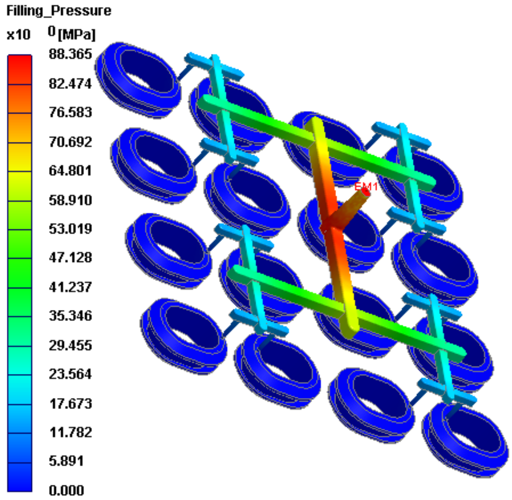
Analysis of the problem

The object of research is the geometric model of the runner system, which is shown in fig. 1. His parametric form of 3D numerical made in Inventor software. Then a discrete model to check the correctness for analysis was prepared of filling. Digitization was performed using the tetrahedron-type elements with local remeshing. It also was made generated to optimize the structure of the elements. After preparing the required input, numerical analysis ware carried out in the injection molding in Moldex3D software [4,10÷13].

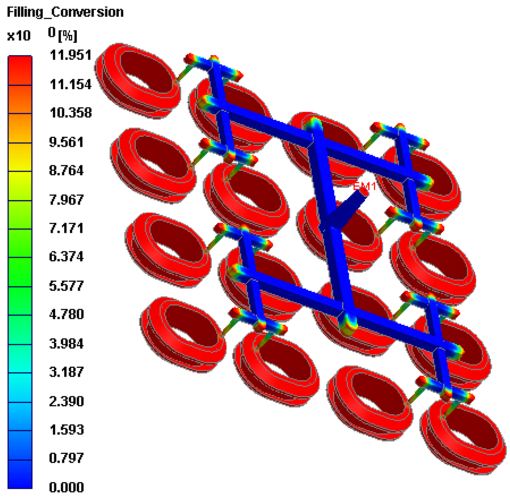
Research material is an elastomer based on chloroprene rubber CR with a density of 1.34 g/cm^3. It contains carbon black filler in an amount of 27%. In the analysis many parameters were used such as: surface temperature of the cavities T_p = 170°C sockets, injection temperature T_w = 90°C, the effect of gravity and micro-mechanics orientation of macromolecules, decreasing the injection velocity profile. In the study a kinetic-reactive rheological model of Cross-Castro-Macosco was used. The mechanism of curing reaction was carried out using a reactive model, by a kinetic Kamal-Souroura-Ryan's equation [4, 14÷20].

The results of the analyzes have been showed in fig. 2. Confirmation of a uniform distribution of the injection pressure in the cavities presented in fig. 2a. The highest value of pressure prevails in around sprue. The analysis carried out, checking the injection molding process shown in fig. 2b, it confirms the possibility of the occurrence of defective products. The analysis of simulation results can also be stated that in the final stage of filling cavities 12% of cross-linking appears in the molded article. Time course of changes in the parameters of injection pressure and the clamping force have been shown in fig. 2c. The image shear stress changes in the cross-sections of the has been reflected in fig. 2d. These stresses are the result of breakdown of the plasticized compound flux during the injection process. On the basis of fig. 2d it can be observed that there is a lack of laminar flow and significant in differences of shear stress in the sprue and the runner system. On this basis it can be concluded about the possibility of problems related to the quality of molded products.

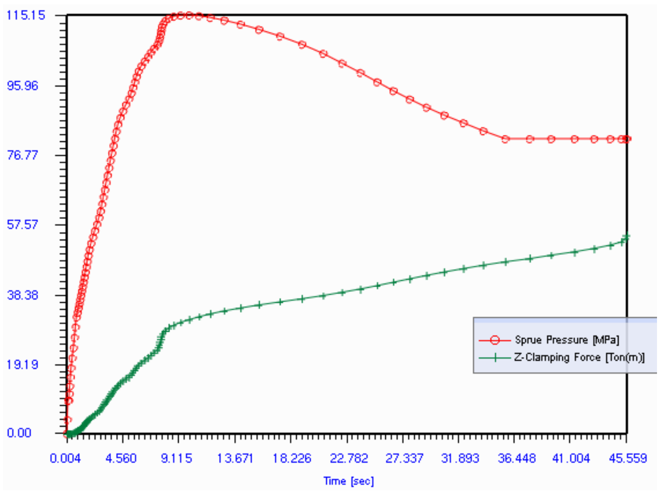
a)



b)



c)



d)

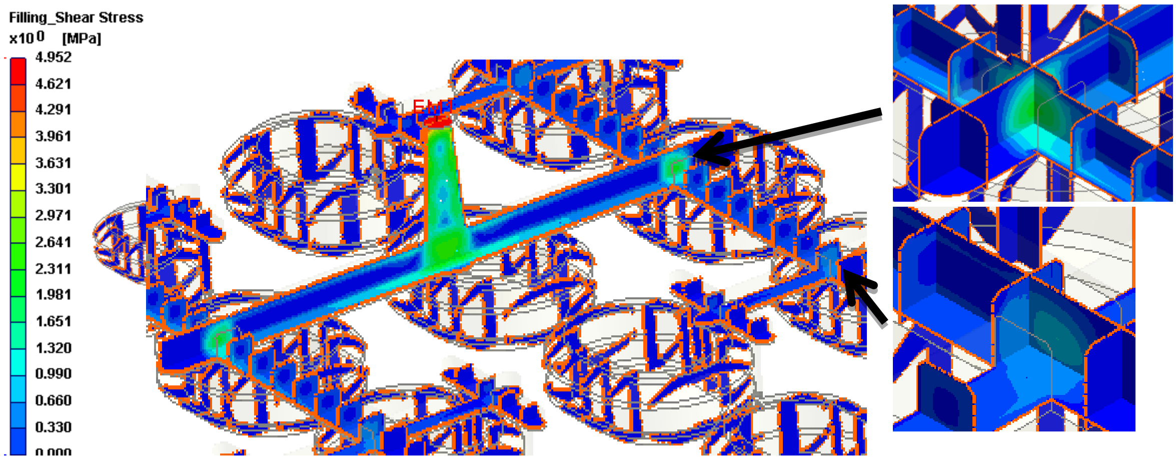


Fig. 2. The distributions for standard runner sytem: a) the injection pressure, b) crosslinking during filling, c) the injection pressure and the clamping force, d) the shear stress in the cross-sections

Solution to the problem

The innovative solution which shown in fig. 3 has been proposed. In this system the rectangular channel is replaced with fillet trapezoidal cross-section (Tab. 1). In order to ensure laminar flow in the channel of vulcanizate, a decreasing order of their respective gradation sections was applied. Also fillet transitional surfaces was introduced, which task is to eliminate the undesirable phenomenon scorch of the rubber compound flowing. It usually arises in the channels as a result of exceeding the shear stress. The recommended principles and proper parameters shaping runner system of the flow injection tools processing for such elastomeric materials as rubber, the reader will find the following in the monograph [4].

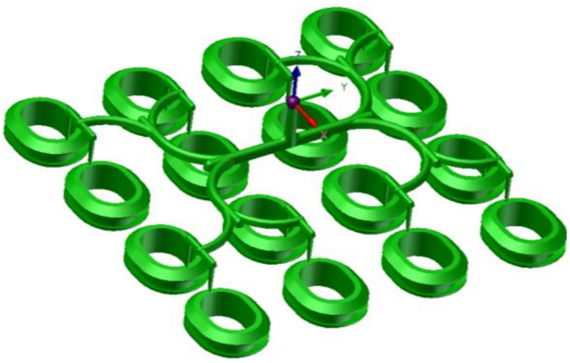


Fig. 3. The cavity system and modified the course of the runner system

The results of digital analysis have been shown in fig. 4. Confirmation of a uniform distribution of the injection pressure in the cavities presented in fig. 4a. The highest value of pressure occurs in around sprue. Obtaining uniform distributions allows to predict the value of receiving the products in repetitive manufacturing process in terms of quality. Fig. 4b presents the results of analysis of a structural solution for the modified runner system in which the cross-linking process in the mold cavities reached a safe level of about 6%. Time course of changes in parameters of the injection pressure and the clamping force has been shown in fig. 4c. A usage of a large fillet radius between the connection and the sprue channel allowed us to minimize the level of occured shear stress (Fig. 4d). A significant improvement in the conditions of flow of the vulcanizate has been achieved thanks to the introduction of specially selected the cast profile centrally under the sprue. The effect of this action has been shown in fig. 4d.

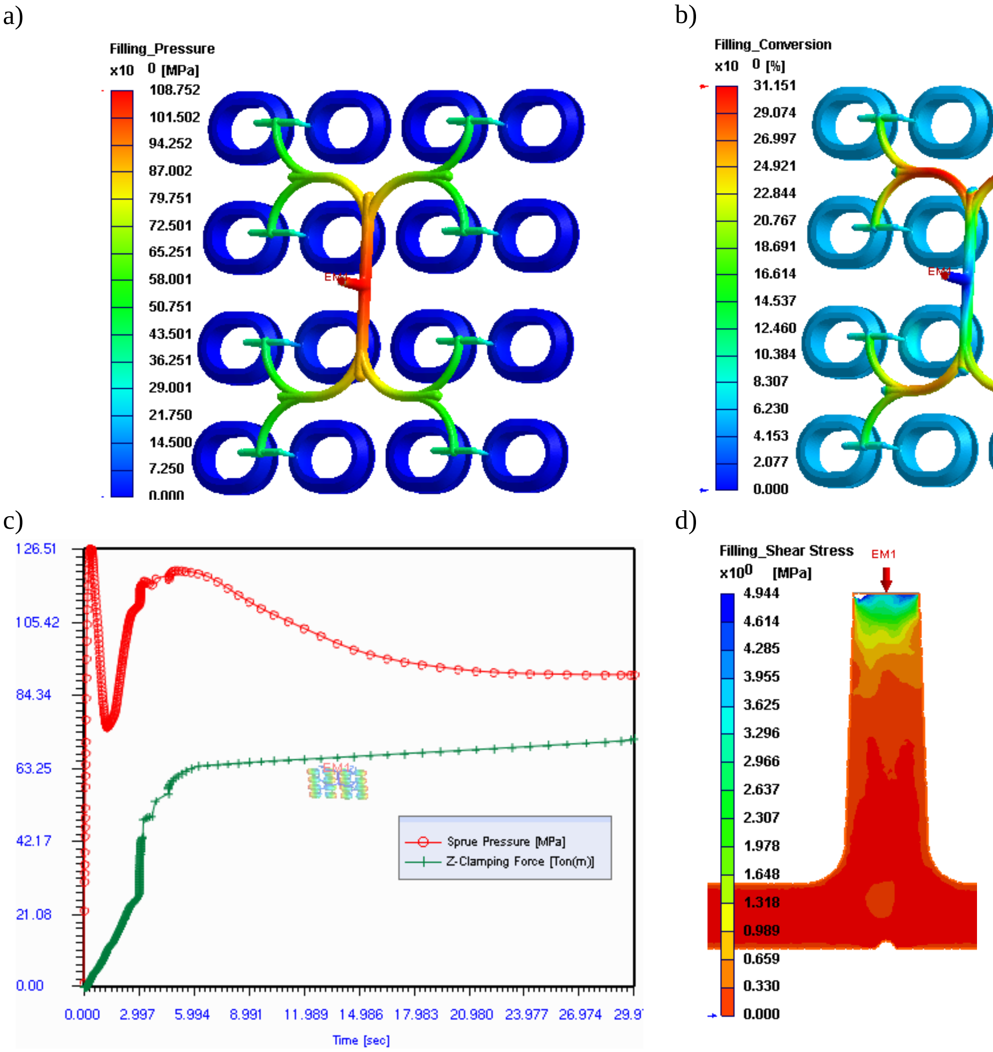


Fig. 4. The distributions for the modified system: a) the injection pressure, b) the crosslinking during filling, c) the injection pressure and the clamping force, d) shear stress in the sprue

The big improvement in the conditions of laminar flow has been achieved by introducing fillet surfaces of runner system and gate. The received effects after their introduction, have been shown in fig. 5.

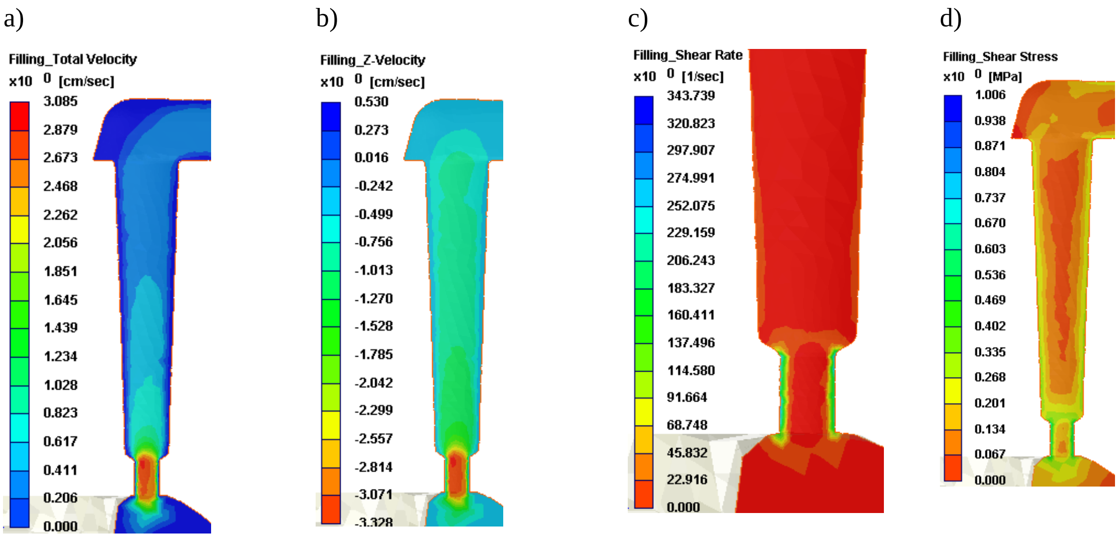
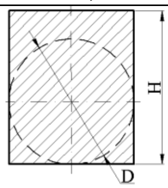
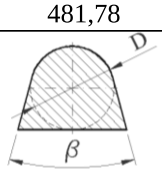


Fig. 5 Images: the flow rate, b) the vertical velocity, c) the shear rate, d) the shear stress

With course of the analysis of fig. 5a it follows that such a shape of the gate a mass flow rate is being increased of approximately 30 mm/s in the middle part. The range of changes of the vertical velocity has been shown in fig. 5b. An important parameter of the flow is checking the shear rate range. Large shear rates effects cause irreversible initiate crosslinking reaction. The shear rate in the most sensitive boundary layers of the gate (Fig. 5c) is about 320 1/s. The closer to the flow axis, the more value decreases to zero. The flow of the plasticized blend is also characterized on the basis of shear stress generated. The highest values were recorded in the gate. The image of these changes has been shown in fig. 5d.

Various analyzes carried out in the proposed construction allow us to predict a receive of molded products of the assumed and repeatable quality. That approach should help to eliminate the problems that had occurred in the standard system. Collective presentation and comparison of applied improvements and results have been presented in tab. 1.

Tab.1. Comparison of applied modifications

	Before	**After**
The volume of the runner system, cm^3	559,14	481,78
The cross-sectional shape; D – the base diameter of the channel, b – the angle channel		
Injection time, s	45,5	29,8
Cycle time, s	368	307
Operating problems	yes	no

Verification

After the mold a test sample was carried out to fulfill its cavities on vertical injection molding machine Desma. The correctness the applied solutions and the accuracy of the conditions of injection process, have been confirmed, yielding products of the required and repeatable quality. The use of fillet trapezoidal cross-section channels allowed for a smooth release of solidified runner system articles of mold workspaces. It also appeared that it is unnecessary to use a separation with a strong adhesive. The tool is currently used in the establishment to series and multi-shift production of molded accordingly to that used by the program order. Generally, these solutions allow a significant improvement in processing efficiency, safety and comfort.

Summary

On the basis of the results of numerical simulation of injection molding of elastomer based on chloroprene rubber CR, cavities with runner system and injection mold were designed. The runner system with graded cross sections fillet trapezoidal shape was made in the upper part of the movable subassembly. The proposed multiplate mold design also allows you to reduce costs during his production. Such a solution significantly improves the producibility of its implementation. Thanks to the adoption of the modified solution the volume of the runner system was reduced by approx. 14%. A smaller volume means also a significant reduction in the use of vulcanizates, which reflects in measurable cost savings. The decreased after injection waste also influences the lower mass, which is a subject of utilization. Ultimately, it offers an additional ecology aspect. The introduction of smooth radial transitions in the system allowed to reduce the value of the shear stress and shear rate. The result of this helped to achieve approx. 34.5% time reduction of injection molding vulcanize to cavities. There was also a 16.5% reduction in cycle time. It significantly improved a productivity indicator. A shorter period is at the same time saving energy demand, which is necessary for mold thermostating. These solutions also enabled to eliminate the problems associated with adhesion and releases vulcanize system from workspaces. There has been a prominent minimize in the number of defective products to an acceptable level.

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