DOI: https://doi.org/10.24425/amm.2024.150934

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INFLUENCE OF SHAPE OF GATING SYSTEM ON POURING TIME AND FILLING OF A SPRUE WITH THE USE OF MAGMA5 OPTIMIZATION

Present hectic times do not allow the foundrymen to test various modifications of gating system in real production due to lack of time and efficiency of production phase. When testing of tens or hundreds of modifications is needed, simulation software MAGMA5 and its optimization procedure comes into place. This article deals with choosing the best design of gating system which will ensure the filling of the sprue as soon as possible together with possible shortening of pouring time on Disamatic line. Soonest filling of the sprue will ensure that no air is entraped in the molten metal which is entering the cavity of the mold and no air bubbles would occur in the final casting after pouring. With this goal achieved, foundry can secure the production of castings. There is a big chance chance to decrease the pouring time of the mold, which will make the production more effective.

Keywords: Pouring time; optimization; gating system

1. Introduction

Gating system is the essential part of the mold design. Its aim is to lead the molten metal during pouring to the cavity of future casting. The filling of the cavity should be calm and smooth, wihout any splashes, to avoid potential foundry errors. To ensure fast and smooth filling, molten metal should completely fill the sprue as soon as possible after start of the pouring. This also minimizes the risk of air bubbles in the final castings. With different shape of gating system and the sprue, various scenarios can occur during filling. Ideal state is to achieve the shortest possible pouring time (according to the technology used) with soonest complete filling of the sprue [1-2].

2. Theory section

Foundry technologists use their own sprue system design style mostly based on experience and gives better or worse results. Since the theory of sprue systems is not widely used enough, authors [3-5] dealt with the practical development of sprue systems for automated forming lines used for iron castings.

The design of sprue base has significant impact on occurrence of turbulent flow and metal splashes, which can follow with oxide pollution and problems with filtration of molten metal.

The speed of the molten metal should be equal to approximately 0.5 m/s to ensure the correct process of filling the mold cavity [6]. However, in actual operating conditions, it is very difficult and sometimes impossible to use a sipmle sprue system, and therefore the design of the sprue system is crucial, even if simple changes in the cross-section of the channels are not enough to significantly change the nature of the metal flow [7-10].

The tapering of the sprues' cross-section should change according to the hyperbolic curve, as it depicts the actual nature of the stream [11-13].

3. Materials and methods

Casting used for the simulation (Fig. 1) is a wheel with diameter 200 mm and height 106 mm, weight 8 kg and is produced from cast iron EN GJL 250. This wheel is produced on automatic molding line DISAMATIC with vertical dividing plane. Molten metal is poured into a green sand mold. There are two aluminium models on the model plate. To shorten the time needed for simulation and optimization, only filling of half of the mold has been simulated thanks to the symetrical design of the mold.

To virtually test hundreds or thousands of different gating system designs, it was needed to adequately choose the vari-

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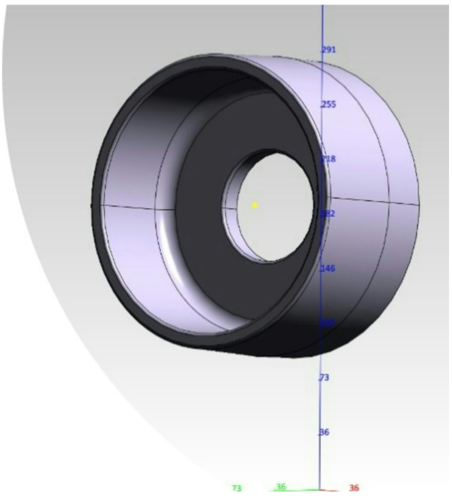

Fig. 1. Wheel casting used for simulation

ables of different parameters. Original design of gating system consisted of the gating system in shape of „rotated T“, what resulted into pouring time of 15 seconds, and the sprue had been completely filled after 13 seconds, Fig. 2. To shorten these time values, two different designs of gating systems had been proposed. The shape of gating system 1 (GS1) stayed unchanged, just the height of upper and lower part of vertical sprue had been changed in order to achieve truncated shape of trapezoid. The shape of gating system 2 (GS2) has been slightly changed – curved transition between vertical and horizontal sprue had been proposed with the aim to reduce the time needed for a sprue to be completely filled. To check if the filling time is influenced by the width and thickness of the ingate (same cross-section), variables for the thickness and width had been also implemented. The optimization variables are shown on Fig. 3 and description of optimization parameters are shown on Fig. 4.

4. Results and discussion

For Gating system 1, the height of upper section of trapezoid had been changed from 20 to 24 mm in steps of 2 mm (heights 20, 22 and 24 mm had been tested) and the height of lower section of trapezoid had been changed from 14 to 18 mm in steps of 2 mm (heights 14, 16 and 18 mm had been tested). For Gating system 2, the height of upper section of trapezoid had been changed from 18 to 24 mm in steps of 2 mm (heights 18, 20, 22 and 24 mm had been tested) and the height of lower section of trapezoid had been changed from 14 to 20 mm in steps of 2 mm (heights 14, 16,18

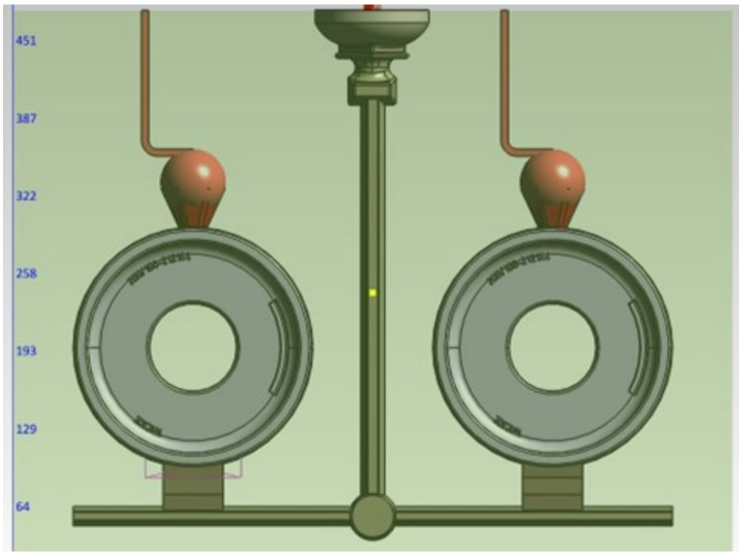

Fig. 2. Original design of gating system

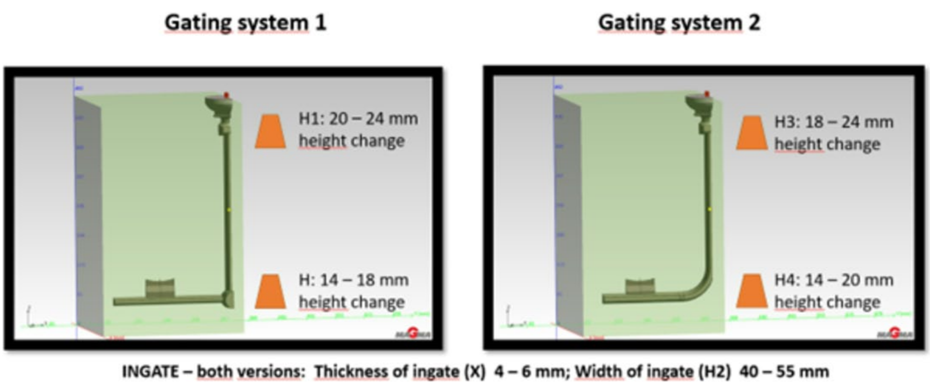

Fig. 3. Optimization variables

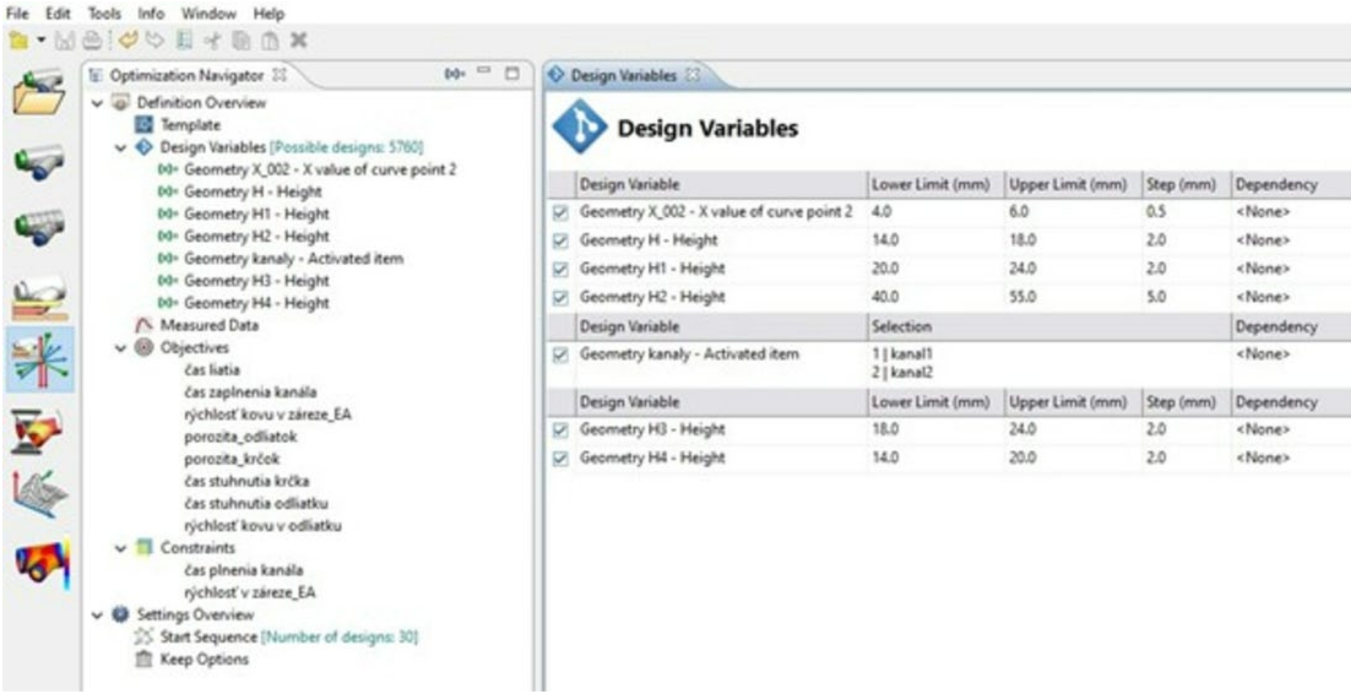

Fig. 4. Optimization parameters

and 20 mm had been tested). Thickness of the ingate had been changed from 4 to 6 mm in steps of 0.5 mm (thickness 4; 4.5; 5; 5.5; 6 mm had been tested) and width of the ingate had been changed from 40 to 55 mm in steps of 5 mm (width 40, 45, 50 and 55 mm had been tested) with keeping the same cross section.

Combination of all of these variables lead to 5760 different designs of gating system. Even simulation and optimization of such amount would take weeks, MAGMA5 offers the possibility to simulate just part of these designs (randomly chosen) in first generation of optimization (30 designs in this case were chosen). For next generations (from 2 to 5), MAGMA5 internally tries to search the best possible combination of variables (from results that were closest to main objectives of the optimization) for next generations.

After running of optimization process, 5 generations of 30 designs had been simulated. Fig. 5 shows all of simulated

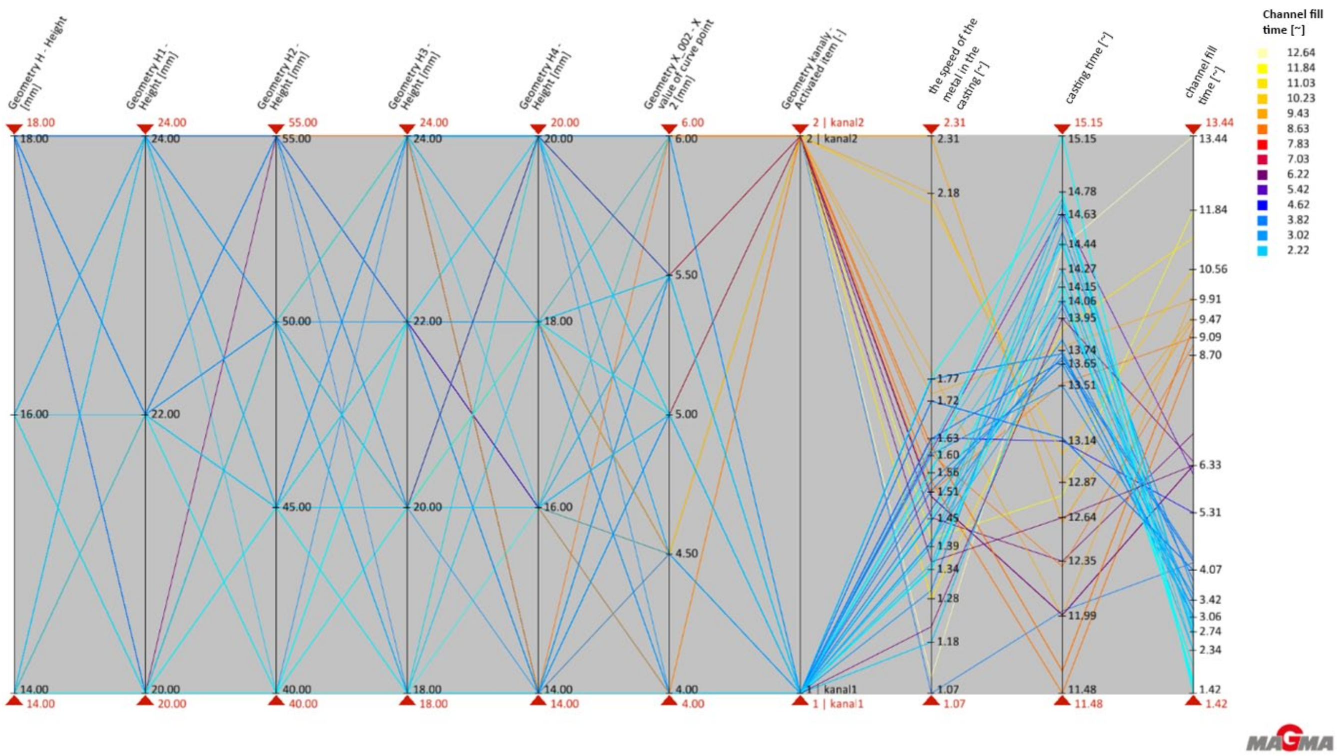

Fig. 5. All simulated designs and their results

designs and their results. Observed objectives (Pouring time and Time needed to completely fill the sprue) are showned in last two columns. As it can be seen, the results of filling time varies from 11.5 seconds to over 15 seconds and results of time needed to completely fill the sprue varies from 1.4 seconds to 13.44 seconds.

After activating only designs related to Gating system 1 (Fig. 6a) it can be seen that fastest filling of sprue can be achieved (cca 1.5 seconds), but the pouring time is around 14 seconds. On the other hand, after activating only designs related to Gating system 2 it can be seen that lowest pouring time can be achieved (12 seconds), but the time needed to completely fill the sprue is a bit higher (cca 4 seconds), Fig. 6b.

For comparison of achieved results, 3 different designs had been chosen.

The design on Fig. 7a represents original version with straight sprue (height 20 mm for both upper and lower part). Pouring time of this design is 15 seconds and the sprue will be completely filled after 13 seconds of pouring (near the end of pouring cycle).

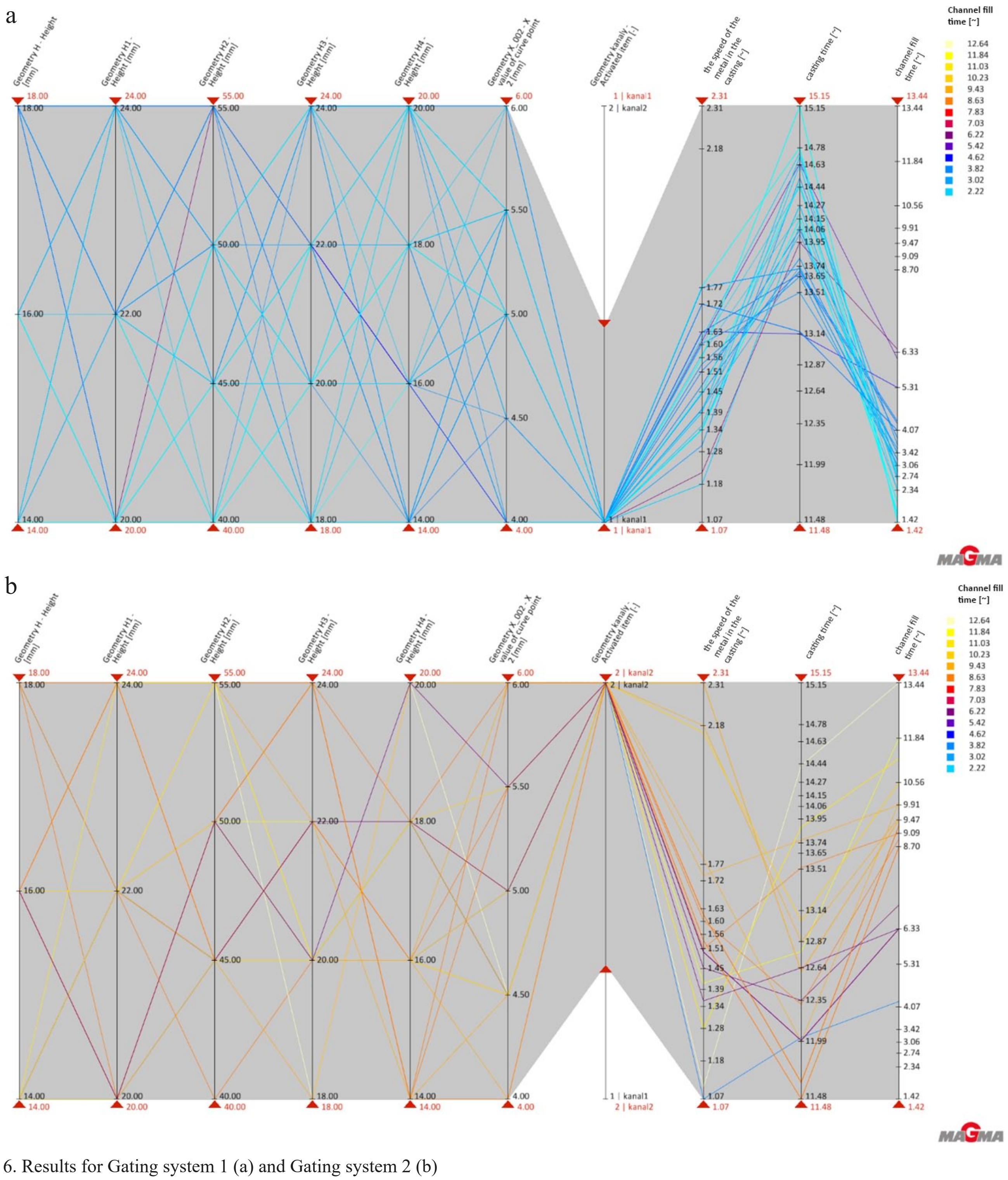

Fig. 6. Results for Gating system 1 (a) and Gating system 2 (b)

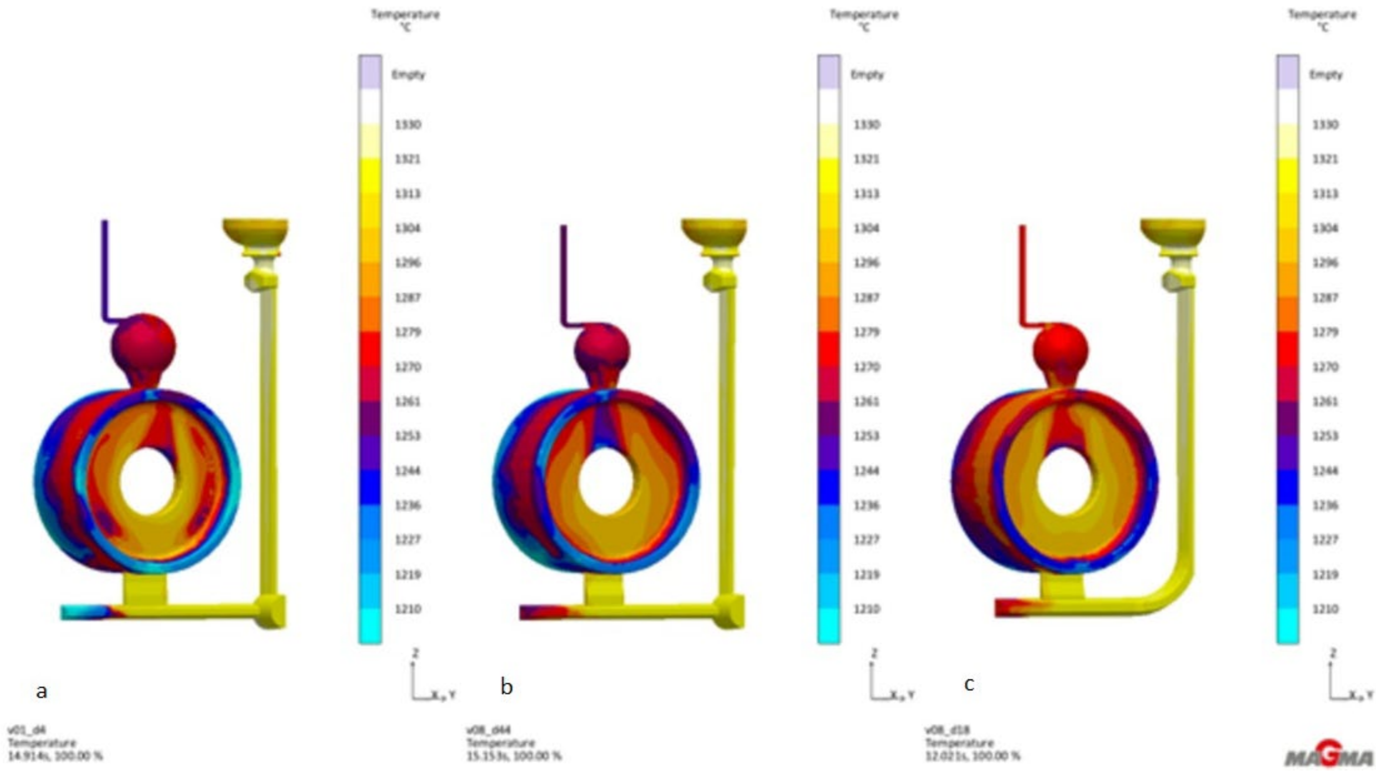

Fig. 7. Shape of gating system: Original (a), best design with Gating system 1 (b), best design with Gating system 2 (c)

The design on Fig. 7b represents version with Gating system 1 with the height of the sprue in upper part is 20 mm which decreases to 14 mm on the lower part of the sprue. Pouring time of this design is 15 seconds, but the sprue will be completely filled after 1,5 seconds of pouring.

The design on Fig. 7c represents version with Gating system 2 with the height of the sprue in upper part is 20 mm which decreases to 18 mm at the end part of the sprue. Pouring time of this design is only 12 seconds, and the sprue will be completely filled after 4 seconds of pouring.

5. Conclusion

Maximum performance of Disamatic molding line in Zlievaren SEZ Krompachy is 330 molds/hour. This performance depends on the raw weight of produced assembly. After obtaining and checking the results it can be clearly seen, that the shape of gating system has very big influence on the total pouring time of the mold. With original pouring time 15 seconds, 400 pcs of castings can be produced in one hour. When reducing the pouring time to 12 second (design on Fig. 7c), 480 pcs of castings can be produced in one hour. With such small change in gating system design (curved section of sprue instead of right-angled transition) can lead to 20% higher production rate. Even if the time needed to completely fill the sprue was 4 seconds (compared to the design with time 1.5 seconds needed to completely fill the sprue), that means not ultimately the best, foundry has chosen this version and implemented it into production stage. Produced castings are good quality and without any air bubbles.

Aknowledgement

„This work was supported by the Slovak Research and Development agency under the contract no. VEGA 1/0759/21".

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