# EXPERIMENTAL APPROACH FOR OPTIMIZATION OF GATING SYSTEM IN CASTINGS

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**Abstract**

To achieve a sound casting of at least acceptable quality many production process parameters must be concerned. One of the most important is a casting design with the particular focus on the gating system. The better the gating system the better casting quality and this is a well-known statement. But in many cases it is very difficult and sometimes even impossible to design and make the gating system according to all theoretical and practical rules. So the issue of the gating system optimization is still interesting both from the scientific and practical point of view. In the paper the authors approach for the problem of gating system optimization was presented. The experimental casting was equipped with the typical gating system and with the optimized gating system based on professor John Campbell's considerations and theories. Then a computer modeling was performed, the research stand was created and the real mold pouring process was captured by high speed camera. All results were analyzed and compared and some preliminary conclusions were formulated.

**Keywords:** Cast iron, gating system, mold pouring modelling, sound casting, pouring process

## 1. INTRODUCTION

Every foundry plant must keep the quality standards at the highest possible level alongside with the low prices of produced castings. This is the only way to stay competitive on the more and more demanding market. That is why the problem of casting defects and the idea to create the castings completely free of them is still one of the most important issues [1, 2]. Of course it is possible to repair the castings with even major defects using for example the specific welding methods [3, 4] but the best idea is to design the whole manufacturing process as a defect-free one. It is widely known that on the final casting quality a lot of parameters have a significant impact. We can divide them into several groups including these connected to molding sand and mold quality [5-8] or these connected to molten alloy being poured into mold [9-12]. But for many foundry engineers and researchers the most important issue is a proper casting mold making especially the gating system design [1, 2, 13]. The pouring process when the liquid alloy is about to be introduced into mold cavity and then finally reaches it is the crucial moment of casting manufacturing process of the best engineered castings [1,2]. Obviously a primary and secondary metallurgy, including alloy additions introduction [14], recarburization process [15], and the overall quality standards inside the foundry plant [16] are all important, too, but the final internal cleanness and soundness depends on the quality of the gating system, as was proven by many scientists [2, 13].

There is a lot of methods and different approaches to make the best possible gating system for any casting technology and each one can bring the good results. One of them is John Campbell's theory of the slim gating system for optimization of the pouring process to achieve right (small enough) metal flow inside mold velocity and to protect the metal stream against the air suction inside the runner and finally to lower the percentage of internal non-metallic inclusions. His very thorough researches finally proved the relationship between the gating system design, liquid alloy cleanness level and final casting soundness [1, 2, 17]. He proposed 'the ten rules to make a good casting' and some of them are directly connected to the proper gating system design [1]. Only that can ensure the right (not to high) velocity of the liquid metal entering the cavity without excessive turbulences because they can result in mold damages and/or in non-metallic inclusions (mostly oxides) called by professor Campbell "bi-films" [2, 17]. Even though this knowledge seems to be well-known the further researches are still necessary because the foundries still have problems with the castings defects caused by the wrong gating system design. That is why the authors had targeted this issue as an important not only from the academic by from the industrial practice point of view, too.

## 2. RESEARCH DESCRIPTION AND RESULTS DISCUSSION

The experiment was divided into several parts obviously based on the state-of-the-art in the gating system design. According to our best knowledge there have not been similar research in Poland so far therefore we had based mostly on professor Campbell's and his continuators results [1, 2, 17]. The first step was designing the two different gating systems for the same model casting: the first accordingly to the typical rules and the second following professor Campbell's remarks. After the gating system calculation the two experimental molds were created and they are shown in the **Figure 1**. The molds were built as a half-molds with the transparent wall made of the high temperature resistant glass. In the traditional approach the mold cavity was fed by the ingate situated in the half of the casting while in the optimized case the siphon (promoted by Professor Campbell in most cases) system was designed. Additionally the typical pouring cup was used in the first and the special one in the second case. The precise description of the molds preparation as well as the whole hot experiment (with the liquid alloy) was included in the unpublished Master of Science thesis.

**Figure 1** The experimental molds; left - traditional gating system, right - optimized gating system according to Professor Campbell's rules

The molds pouring experiments were carried out with the tin as model alloy because of its low melting point. However, the problems occurred because of the tin high wettability so the glass surface was quickly and completely covered by it making the observations quite difficult (even though the special non-adhesive substance was used to spray the glass). The pouring process was captured by the high speed camera Phantom v210 by Vision Research (1000 fps) to give the possibility to analyze the liquid alloy flow inside the mold cavity. The **Figure 2** shows the selected screenshots for only one gating system design - the optimized one because of the article volume limits. Then the captured videos were thoroughly checked and analyzed showing the differences between these two design approaches. In the case of traditional gating system the big turbulence was observed as well as higher (too high) liquid alloy flow velocity. In the second case - the optimized one - the mold cavity filling was calm and uniform.

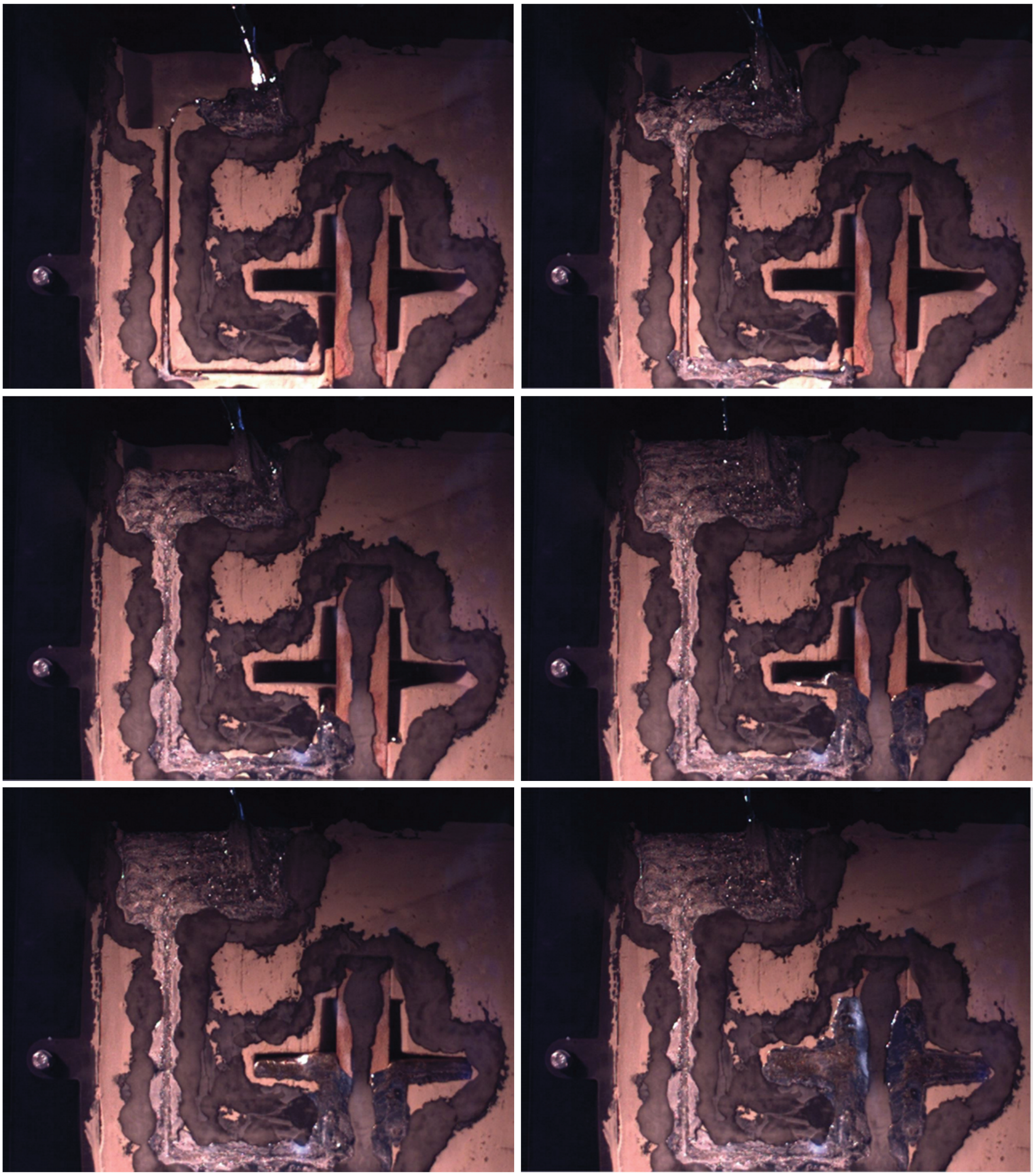

**Figure 2** The sequence of the photographs showing the mold pouring process for the optimized gating system according to Professor Campbell's rules

The next step of the research was the computer modelling. Two simulations reflecting the previous hot metal experiment captured with high speed camera were made in MAGMASOFT® MAGMA5 in order to highlight the differences between two presented gating systems. **Figures 3** and **Figure 4** present absolute velocity of molten metal filling mould cavity. In classic gating system the velocity of metal entering the mould cavity is between 1.264 and 1.965 m / s, the velocity of metal inside the mould cavity is between 0.135 and 1.211 m / s. In gating system made according to recommendations of professor Campbell the velocity of metal entering the mould cavity is between 0.911 and 0.920 m / s and the velocity of metal inside the mould cavity is between

0.114 and 0.569 m / s. It can be noticed that in prof. Campbell's gating system the velocity of metal is not only lower but also the metal flow is more uniform which is a vital thing considering processes stability and repeatability. Also it can be noticed that in classic gating system distribution of metal velocity in bends is uneven, there are large areas where the velocity is up to 10 times lower than the maximum, which might cause cavitation damage to the mould. In prof. Campbell's gating system distribution of the metal velocity is much more coherent, only a small area presents up to 4 times lower velocity than the maximum and rounded bends are much less prone to chipping off than ones present in classical gating system. In prof. Campbell's gating system the spatter is much smaller, almost non-existent in comparison to the classic gating system, it is a vital thing considering the possibility of oxide bi-films formation.

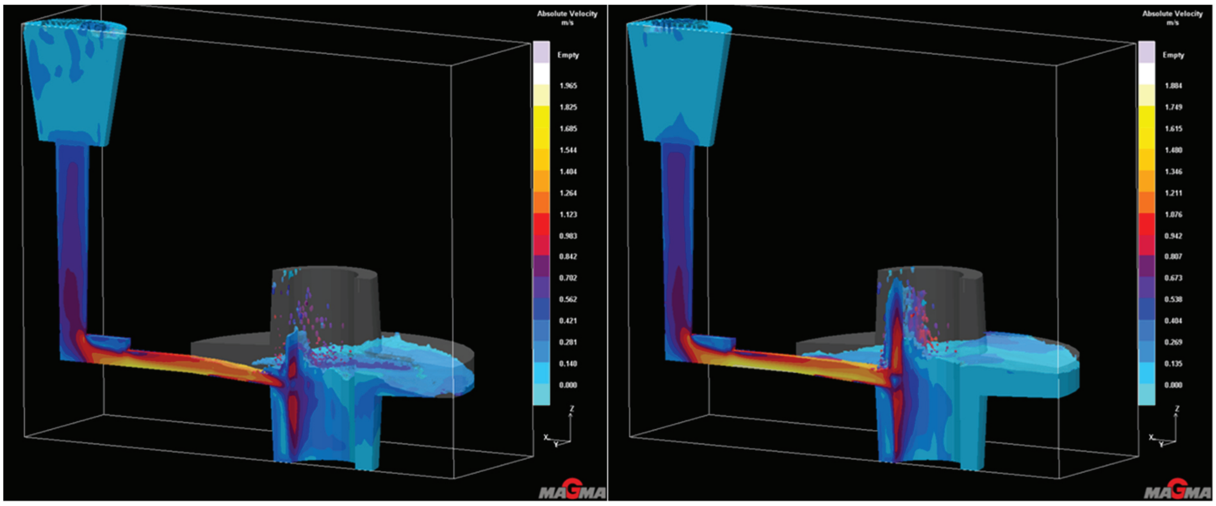


**Figure 3** Absolute velocity of molten metal in classic gating system, on the left side 50 % fill, on the right side 70 % fill

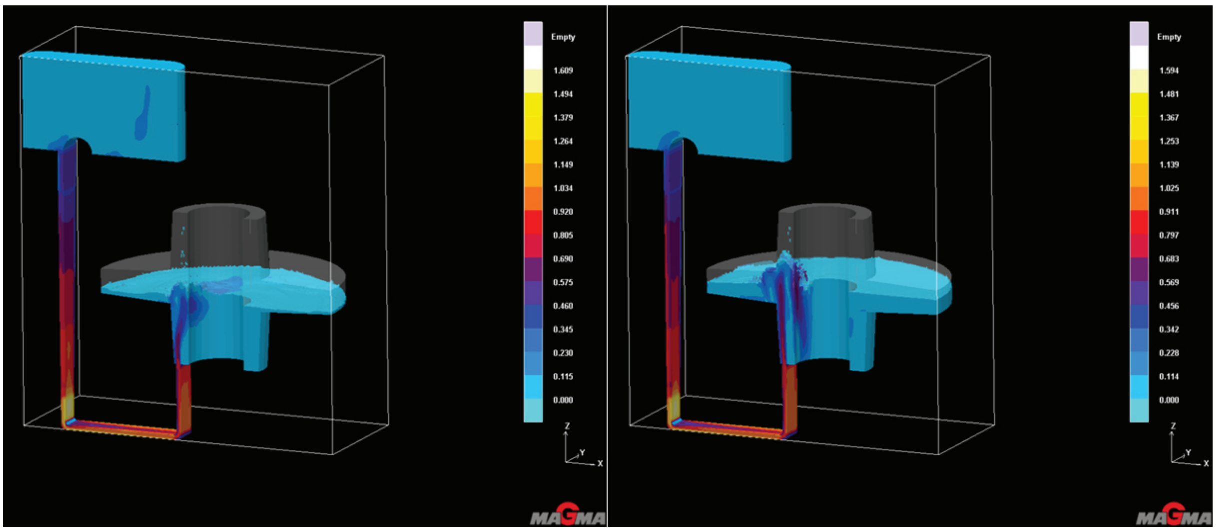


**Figure 4** Absolute velocity of molten metal in prof. Campbell's gating system, on the left side 50 % fill, on the right side 70 % fill

**Figures 5** and **Figure 6** present the fill tracers view. It can be noticed that in prof. Campbell's gating system neighbouring areas of the casting have similar markers feature which proves that the flow is much less turbulent, mixing of metal inside the moulds cavity is low, so the potential of casting defects occurrence decreases.

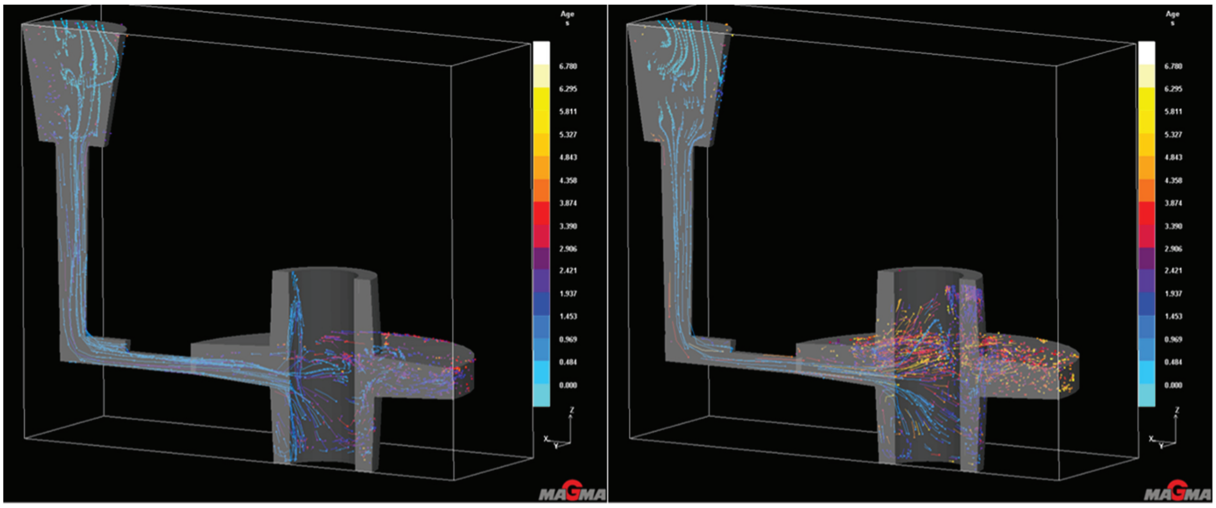


**Figure 5** Fill tracers in classic gating system, on the left side 70 % fill, on the right side 100 % fill

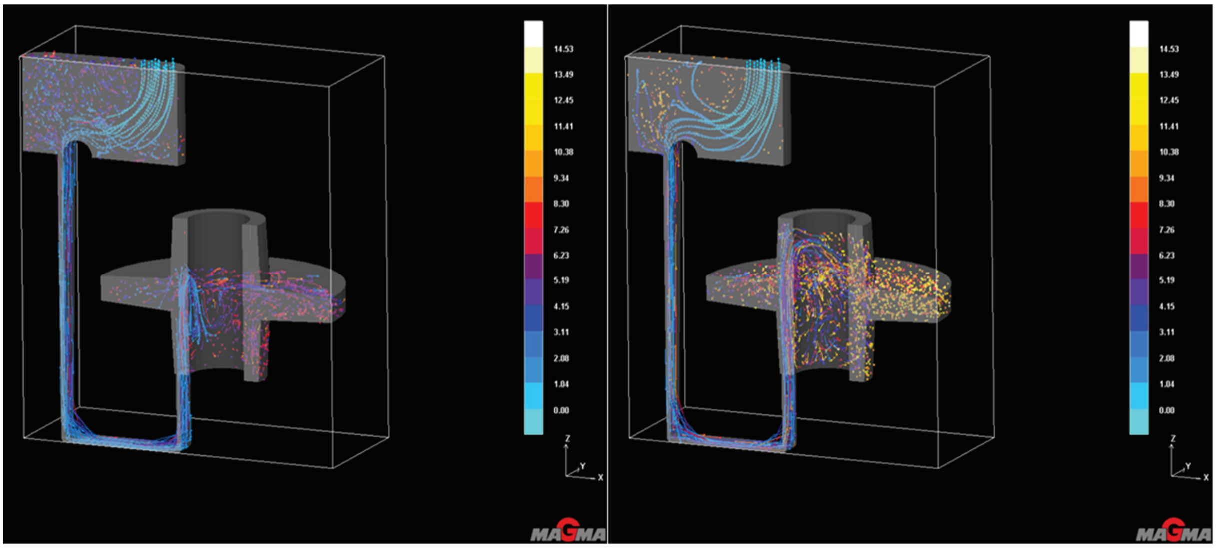


**Figure 6** Fill tracers in prof. Campbell's gating system, on the left side 70 % fill, on the right side 100 % fill

## 3. CONCLUSIONS

The analysis of the real hot metal experiments jointly with the computer modelling results have shown the advantages of the optimized gating system designed according to the Campbell's rules. The presented results are only the preliminary ones because their aim was to develop the research stand and the conditions of the experiment. Therefore from that point of view the research has been successful so far, however, some modifications must be implemented to make the experimental molds easier to produce (to fast repeat the experiments under various conditions) and captured videos easier to analyze. So to the next step (has been just launched) the following changes were applied:

- the molten alloy to be poured into the mold was changed into zinc-aluminum alloy ZnAl4 because of its excellent fluidity and accepted melting point,
- the mold is produced in different way (compacted on the glass sheet as a pattern plate) to make it more leak-proof without the use of sealant,
- the pouring cup (the optimized one) is going to be equipped with the stopper to make possible to completely fill it out and then to start the cavity pouring process with the full cup, ending with less air volume sucked into the down sprue,

- the mold and core vents are added to make the filling process faster and more similar to the real foundry conditions. There were no vents in original design to make it faster to prepare - one of the final results is to create the quick and repeatable method to show the gating system design issue to the students and foundry engineers as practical exercise,
- after the method and tools are developed the next experiments will be extended with the final casting produced internal quality check to find how much the gating system design influences that.

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