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Direct pouring system design and optimization in steel castings

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Abstract

The aim of this study is to establish a correlation between various version direct pouring systems for steel castings in industrial conditions. In the study, a computer-aided design solid modeling program was used in the design of the kalpur direct pouring system, non-filter bottom direct pouring system, and filtered direct pouring system for steel castings. The flow and solidification simulation of the kalpur direct pouring system and the non-filter bottom direct pouring system of the casting part was made in magma flow and solidification program. The study clearly shows that the kalpur direct pouring system has revealed that it plays a significant role in preventing non-metallic casting defects in steel castings, such as sand, gas, and slag. In addition, it has been revealed in the study that the non-filter bottom direct pouring system prevents non-metallic casting defects in steel castings such as the kalpur direct pouring system. Kalpur direct pouring system is recommended to be used in ferrous based castings by FOSECO, was used for the first time in the ÇİMSATAŞ foundry in the steel castings and the appropriate result was obtained.

1. Introduction

Non-metalic inclusions are important defect in steel casting process. Inclusion defects of steel castings are defects such as slag of oxide and other substances generated in the pouring ladle by the reaction, and sand of molds and cores that flake away and are included in the molten metal, flowing into casting parts and appearing on the surfaces of parts as non-metalic inclusions. In order to reach desirable quality casting part, well design pouring system is the first step. Dimensions of the pouring system need to be calculated according to casting part geometry because of each casting part has different shape and an incorrect design is the root cause of the casting defects onto casting parts, mostly. High casting quality depends on a reasonable pouring system design. Traditionally, the foundry design and method engineers highly employ their own experience and trial and error method to design the pouring system. But this design method is time consuming and hard to get an optimal design. Today, foundry design and method engineers are experimenting different optimization methods that optimize the pouring system, including size, shape and position by using flow and solidification programs [1-6].

In recent years, foundry metal filtration technology has been rising popularity in casting system for casting processes of many metals such as cast irons, steel and aluminum. Filtration technology is evolving as the demand for clean, quality castings with high yield, low scrap rates, and low process costs increases. The benefit of filters, especially reticulated foam filters, besides their turbulence-reducing effect, is to prevent non-metallic inclusions such as sand and slag from entering the casting part during pouring the liquid metal into the sand mold [7-10]. This study presents the results of filtered pouring system known as kalpur direct pouring system (developed by FOSECO) and the non-filter bottom direct pouring system (ÇİMSATAŞ casting practice) studies.

1.1. Kalpur direct pouring system

Kalpur direct pouring system developed by FOSECO for foundries is used in green sand moulding lines and resin moulding lines to obtain high part efficiency and clean casting parts. Kalpur direct pouring system includes many critical components within its own structure; exothermic feeder, ceramic foam filter, and collapsible breaker core etc. The main purpose of the kalpur direct pouring system is; reduced fettling cost, reduced non-metallic inclusions, lower turbulence related defects, improved directional solidification, good surface finish optimized yield, and increased space on the pattern plate. Parts molded with the kalpur direct pouring system can be poured with lip pouring ladle or bottom pouring ladle [10-13].

1.2. Non-filter bottom direct pouring system

Non-filter bottom direct pouring system is one of the casting practices of the ÇİMSATAŞ foundry. Non-filter bottom direct pouring system is used in resin moulding line in ÇİMSATAŞ foundry to obtain high part efficiency and clean casting parts. The basic components of the non-filter bottom direct pouring system designed by ÇİMSATAŞ are the exothermic feeder, pouring basin, and sand cap. The main purpose of the non-filter bottom direct pouring system is; reduced fettling cost, reduced non-metallic inclusions, lower turbulence related defects, improved directional solidification, good surface finish optimised yield, and increased space on the pattern plate. Parts molded with the kalpur direct pouring system can be poured only with bottom pouring ladle.

1.3. Filtered direct pouring system

In the steel casting process, the filtered direct pouring system is known as the casting practice based on placing a ceramic foam filter in a feeder. The basic components of filtered direct pouring system is feeder and ceramic foam filter. Filtered direct pouring system is used in resin moulding lines and green sand moulding lines. Main purposes of the filtered direct pouring system are; reduced non-metallic inclusions, lower turbulence related defects, improved directional solidification, good surface finish, optimized yield, and increased space on the pattern plate. Parts molded with filtered direct pouring system can be poured with bottom pouring ladle or lip pouring ladle [13-14].

2. Material and Method

In this study, it is aimed to develop direct pouring systems for steel castings by using a computer-aided solid modeling program. The direct pouring system designs of the bearing casting part are based on the modulus and geometry of the casting part. In the study, the material of the part was determined according to the EN 10293 standard and material of the casting part was selected G20Mn6N. The part with three different direct filling systems was molded in the flaskless resin moulding system and cast in the ÇİMSATAŞ foundry. The nominal chemical composition of the casting part was selected as shown in Table 1 and the image of the bearing casting part is shown in Figure 1.

Table 1. Chemical composition of the bearing casting part

Content	**% C**	**% Mn**	**% Si**	**% P**	**% S**	**% Cr**	**% Ni**	**% Mo**	**% V**
	0,199	1,593	0,432	0,014	0,007	0,191	0,065	0,035	0,013
Content	**% Cu**	**% B**	**% Ti**	**% Sn**	**% Al**	**% Zr**	**% Nb**	**% Pb**	**% Sb**
	0,071	0,00018	0,001	0,003	0,048	0,002	0,008	0,001	0,000
Content	**% Fe**	**% CEQ**	**% Zn**	**% Ce**	**% Bi**	**% W**	**% As**	**% Co**	**% N**
	97,264	0,528	0,002	0,001	0,000	0,000	0,007	0,008	0,008

Figure 1. Schematic representation of the bearing casting part

In the first direct pouring system study, filtered direct pouring system was designed by placing a dimension of Stelex Pro Ø150x30 mm 10 PPI graphite-based filter was placed inside the BGK6 exothermic feeder in the cope side of the part solid data. Then, the flow and solidification simulation of the part was made at 1600 °C by choosing lip pouring ladle. According to simulation results, filtered direct pouring system was assembled to the casting part model. Images of the simulation results of the casting part are shown in Figure 2, and filtered direct pouring system is shown in Figure 3.

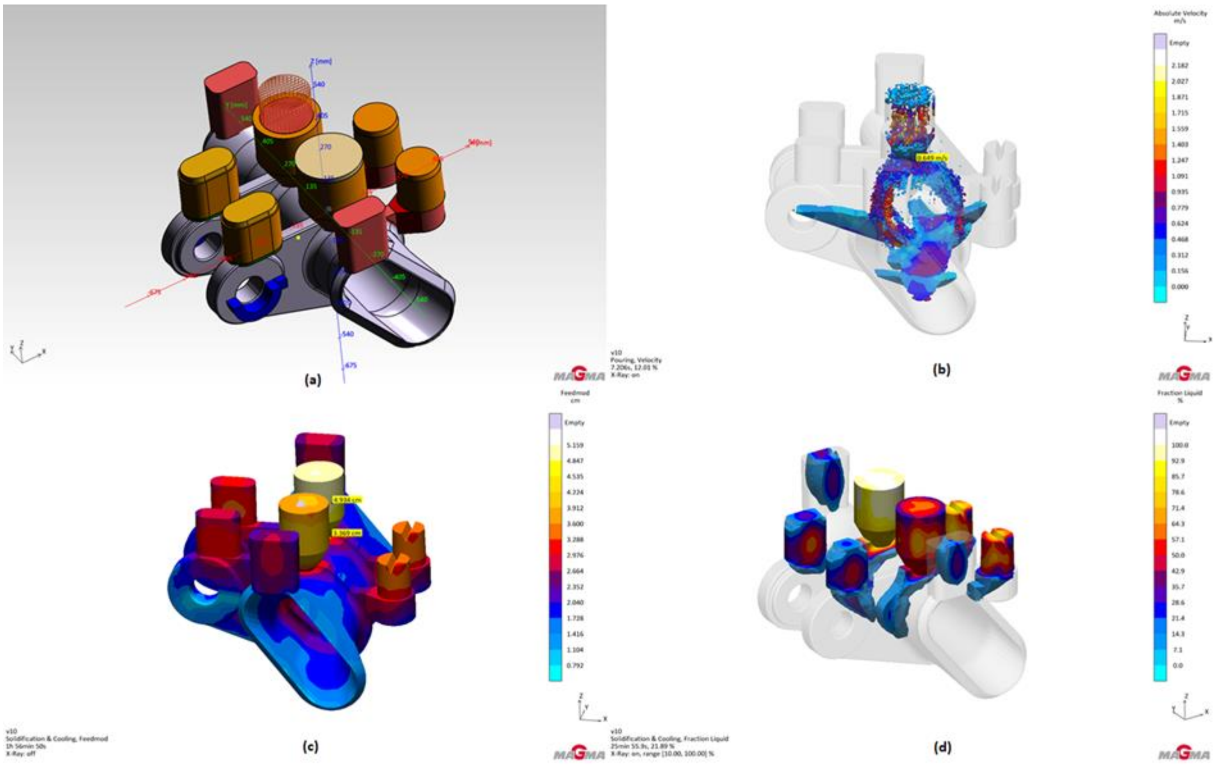

Figure 2. a); The image of the casting part geometry, (b); The image of the metal flow and filling simulation of the casting part, **(c);** The image of the feeding mod of the casting part, **(d);** The image of the friction liquid mod of the casting part

Figure 3. Schematic representation of the filtered direct pouring system

After simulation results, one part was molded in the flaskless resin moulding system in the ÇİMSATAŞ foundry and the casting was carried out with a lip pouring ladle at 1600 °C and 38 second. Total weight of the casting part is 590 kg. Image of poured part with the filtered direct pouring system is shown in Figure 4.

Figure 4. The image of poured casting part with the filtered direct pouring system

The part that was poured with the filtered direct pouring system was examined and then a design change was made in the part. In the casting part design, Stelex Pro Ø150x30 mm 10 PPI graphite-based filter was placed inside the Kalminex ZTAE PPE 18/20 exothermic feeder and the filling point of the casting part was revised as kalpur direct pouring system. Kalpur direct pouring system was placed at the lowest point of the cope side in the casting part solid data and flow and solidification simulation was made at 1600 °C by choosing bottom pouring ladle. According to simulation results, kalpur direct pouring system was assembled to the casting part model. Images of the simulation results of the casting part are shown in Figure 5, and kalpur direct pouring system is shown in Figure 6.

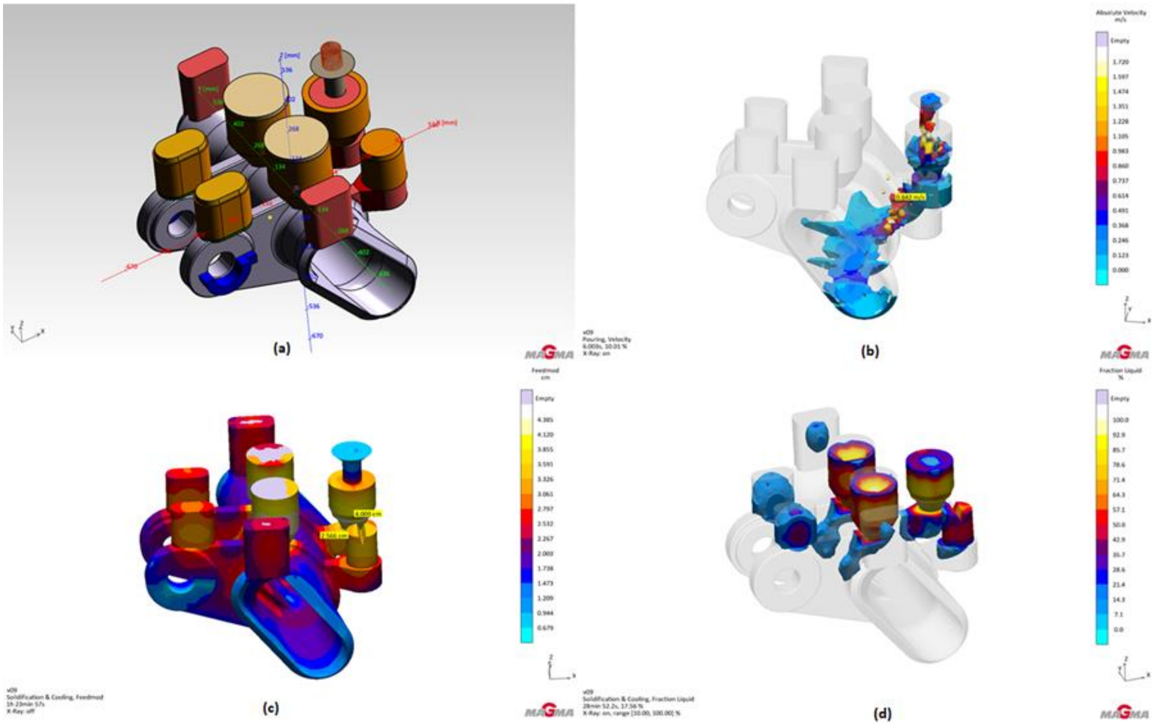

Figure 5. (a); The image of the casting part geometry**, (b);** The image of the metal flow and filling simulation of the casting part, **(c);** The image of the feeding mod of the casting part, **(d);** The image of the friction liquid mod of the casting part

Figure 6. The Image of the kalpur direct pouring system

After simulation results, one part was molded in the flaskless resin moulding system in the ÇİMSATAŞ foundry and the casting was carried out with bottom pouring ladle at 1609 °C and 32 second. Total weight of the casting part is 613 kg. Image of poured part with the kalpur direct pouring system is shown in Figure 7.

Figure 7. The image of poured casting part with the kalpur direct pouring system

After examining the poured part with the Kalpur direct casting system, the part design was revised as non-filter bottom direct pouring system. In the casting part design, Stelex Pro Ø150x30 mm 10 PPI graphite-based filter was not placed inside Kalminex ZTAE PPE 18/20 exothermic feeder as the casting practice of the ÇİMSATAŞ foundry. The filling point of the casting part was chosen as the same region as the kalpur direct pouring system. Flow and solidification simulation of the casting part was made at 1600 °C by choosing bottom pouring ladle. According to simulation results, non-filter bottom direct pouring system was assembled to the casting part model. Images of the simulation results of the casting part are shown in Figure 8, and non-filter bottom direct pouring system is shown Figure 9.

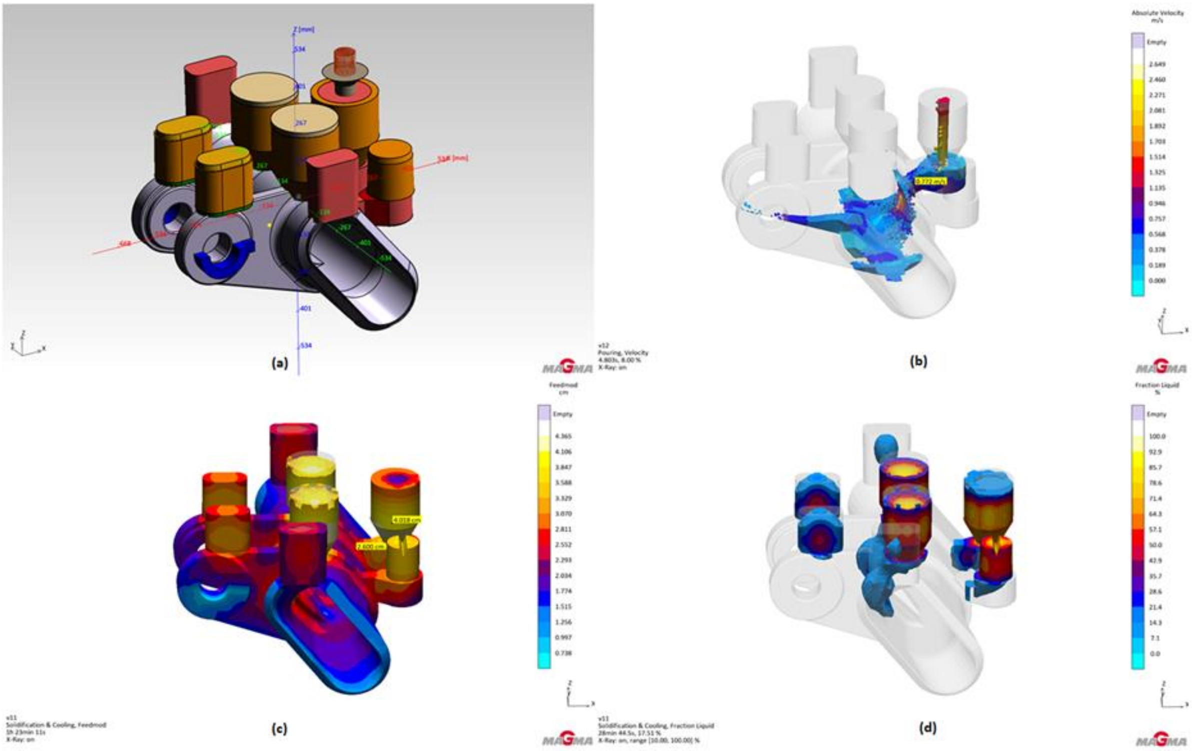

Figure 8. (a); The image of the casting part geometry**, (b);** The image of the metal flow and filling simulation of the casting part, **(c);** The image of the feeding mod of the casting part, **(d);** The image of the friction liquid mod of the casting part

Figure 9. The image of the non-filter bottom direct pouring system

After simulation results, one part was molded in the flaskless resin moulding system in the ÇİMSATAŞ foundry and the casting was carried out with bottom pouring ladle at 1582 °C and 20 second. Total weight of the casting part is 613 kg. Image of poured part with the non-filter direct pouring system is shown in Figure 10.

Figure 10. The image of poured casting part with the non-filter bottom direct pouring system

3. Results and Discussion

In this study, casting parts were designed according to the simulation results with different direct pouring system versions in steel castings. The findings were obtained from the simulation and casting results of the parts.

- It is found that the simulation results highly represent the actual casting results.
- Cold shut defects were detected as well as non-metallic inclusions on the surface of the part poured with the filtered direct pouring system. And filling time of the casting part is 38 second.
- Poured with kalpur direct pouring system and non-filter bottom direct pouring system, the gross weight of the casting parts has increased from 590 kg to 613 kg. In total, gross weight of the casting parts have increased by 23 kg.
- It has been revealed that pouring design of the casting part and the selection of the pouring region is very important for the surface quality of the casting part.
- With the kalpur direct pouring system, a remarkable improvement has occurred on the surface quality of the casting part.
- With the non-filter bottom direct pouring system, the need for Stelex Pro Ø150x30 mm filter used in the moulding of the part has been eliminated. It has been observed that clean parts can be poured with this system by using bottom pouring ladle too.
- While the filling time of the poured part with the kalpur direct pouring system is 32 seconds, the filling time of the poured part with the non-filter bottom direct pouring system is 20 seconds.
- It has been observed that the surface qualities of the poured parts are close to each other with the kalpur direct pouring system and the non-filter bottom direct pouring system.
- It has been observed that the surface qualities of the poured part are worst with filtered direct pouring system.

4. Conclusion

Although non-filter bottom direct pouring system for steel castings minimizes the escape of non-metallic inclusions from ladle into the casting part during sand mould filling, the use of ceramic foam filter inside the non-filter bottom direct pouring systems are very important for the scrap rate of the foundries.

With the design of the different version of the direct pouring systems in the ÇİMSATAŞ foundry, the surface quality of the casting part has improved positively by design of the kalpur direct pouring system and non-filter bottom direct pouring system. Ceramic foam filters are cost-effective and efficient way to reduce casting defects. The improvement in the casting part surfaces which get obtained by using direct pouring system was reduced the rework needed (such as cosmetic welding, grinding, etc.).

The results of the study show that the kalpur direct pouring system and non-filter bottom direct pouring system have best given positive and reliable results in the steel casting process.

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Author contributions

Mustafa Murat Zor: Conceptualization, Methodology, Software, Data curation, Writing-Original draft preparation, Software, **Serdar Kesim:** Validation. **Buğra Erbakan:** Visualization. **Ferhat Tülüce:** Validation, Editing, **Alper Yoloğlu:** Data curation, Editing, **Kazım Çakır:** Editing

Conflicts of interest

The authors declare no conflicts of interest.

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