NUMERICAL SIMULATION AND PROCESS OPTIMIZATION ON CAST STEEL BEARING SLEEVE

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Abstract:

A three-dimensional Computer Aided Design (CAD) model of the bearing sleeve casting is established by Pro/E software. The ViewCast program is utilized for studying casting processes of solidification and mould-filling in order to optimize the casting technology. Based on the solidification simulation, the casting shrinkage and porosity as well as solidification processes are forecast visually in diagrams with the help of ViewCast. The mould-filling simulation results verify whether the fluid/liquid metal fills gates and the mould smoothly. The simulation results of an initial casting scheme show that this scheme is improper. Two optimization schemes have been completed based on the filling simulation so that a modified casting technology is obtained. The simulation results of optimized schemes indicate that the metal fluid fills the mold smoothly and the shrinkage is eliminated effectively. The optimized scheme II is preferred to scheme I. Experimentally, the casting confirms that these optimized methods are very useful in reducing the casting defects and improving the product quality.

1 Introduction

As an important component of a coal mining machine, the bearing sleeve should have good comprehensive mechanical properties and behaviors by a suitable casting technique. No casting defects such as shrinkage porosity, cavity, cold-shut and crack should exist in the bearing sleeve.

Numerical simulation and its optimization are proved to be cost-effective approaches to improve the traditional casting technology. The mould-filling and solidification process are two basic components in casting numerical simulation. By solidification simulation, shrinkage defects of steel and iron castings could be forecast, while mould-filling simulation could be used to verify whether the fluid melt fills the mould smoothly and steadily. With the fast development of novel technique, the casting simulation shows significant advantage of low cost and time efficiency [1-5] over the traditional "trial and error" method, while the latter could not fulfill the development requirement anymore [1]. The structure of a gating system and casting technology play some important roles in the stability during

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solidification and a mould pouring process [6-8]. For example, when the mould-filling is in the condition of physical instability, it can result in splashing, spatter, slag and porosity and so on [7-10]. The formations of casting defects include sand burning, pore, oxidation and slag [4, 11]. These above mentioned defects reduce strength, toughness and quality of the cast steel of the bearing sleeve.

Commercial software ViewCast is employed in the casting process. This software is mainly used for predicting casting defects and designing the gating systems. ViewCast is composed of three modules as following: preprocessing, numerical calculating and post processing [12]. In this paper, solidification simulation is conducted by virtue of ViewCast. The gating system and the riser are designed based on the simulation results. Two optimization schemes aiming at reducing the casting defects and assuring the smooth gating are presented. The technological parameters of the casting are tested and verified by mould filling.

2 Implement of Numerical Simulation

2.1 Structure and material

Fig.1 shows a casting structure of the bearing sleeve using cast-steel serial ZG270-500. The chemical composition of it is shown in Table 1. The boundary dimension of the bearing sleeve are 178 mm × 366 mm × 366 mm, the thinnest size of the sleeve casting is 13mm, the thickest size of the bearing sleeve casting is 41 mm, and the average thickness of the casting is 37 mm. The bearing sleeve is a circular cylindrical shell and the gross weight of it is 73 kg. The mould material is sodium silicate sand.

2.2 Solidification Process

The solid model of the casting is generated by Pro/E software and saved as *.STL file. The part of the bearing sleeve is shown in Fig. 1. Grid subdivision is implemented by the preprocessing of ViewCast. Although the grid refinement could enhance the accuracy of results, it would require a very long computation time [12]. So, the minimum dimension of grid cell is set at 4 mm. The filling temperature is 1580 °C and the initial temperature of mould is 20 °C. The parameters of cast are set before the calculation.

Figure 1. Three dimensional solid model of the bearing sleeve.

The solidification simulation of the cast-steel is calculated by ViewCast. The simulation results of the vertical and the horizontal positions are shown in Fig. 2 and consequently, severe shrinkage, caused by the solidification contraction, can be seen from the pictures. The scale of shrinkage in casting technology of horizontal position is smaller than that of the vertical position. The transparent locations in the figure illustrate where the metal content is above 97 percent, hence, these locations are deemed as non-defective. The riser is calculated by ViewCast and the gating system is planned.

a) b)

Figure 2. Defect forecast map of the sleeve: a) vertical position, b) horizontal position.

Table 1. Chemical composition of cast-steel ZG270-500.

Element	C	Mn	Si	S	P	Fe
Content (wt.%)	0.31-0.40	0.49-0.79	0.20-0.69	0.009-0.056	0.011-0.049	Balance

The simulation results shown in Fig. 3 demonstrate that the shrinkage is largely transferred to the riser so that a small scale of shrinkage exists in the cast. Defects existing on the surface of mechanical processed trail-production and predicted by the simulation results are shown in Fig. 4.

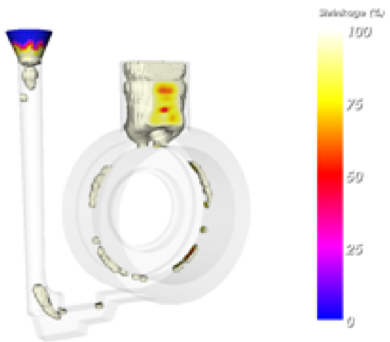
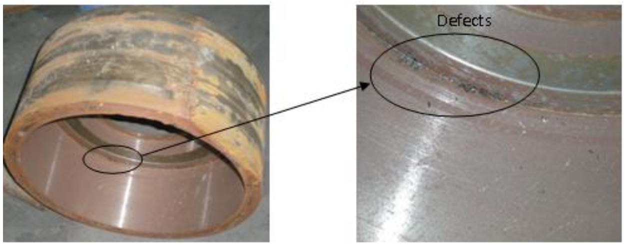


Figure 3. Defect forecast of casting technology.

The solidification process is shown in Fig. 5 and the six diagrams illustrate the representative stages of the solidification. When the solidification time was at 17 s, the casting began to solidify. The solidification of the bearing sleeve has been completed at 896 s. The simulation results show that the riser cannot feed casting completely.



(a) *(b)*

Figure 4. Defects exist on the surface of casting with mechanical processing: a) trial-production, b) detail with enlarged scale.

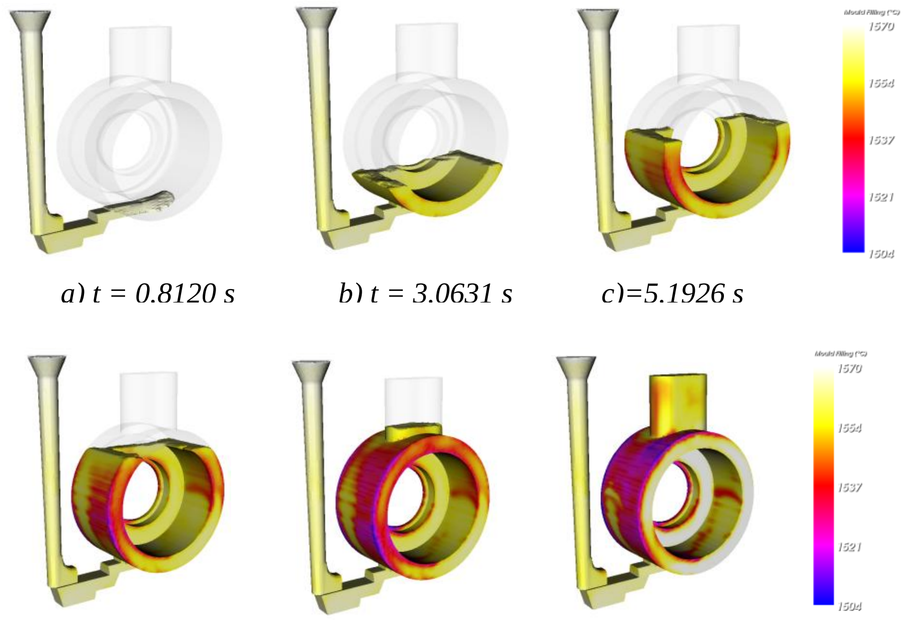
2.3 Mould Filling Process

The gating system was tested and verified with mould-filling simulation using ViewCast. The gating simulation can examine the behavior of liquid flow visually and validate the process of mould filling. The mould-filling simulation results are shown in Fig. 6 and the different color indicates the different temperature of the metal.

a) t = 17 s *b) t = 112 s* *c) t =206 s*

d) t = 310 s *e) t = 520 s* *f) t = 730 s*

Figure 5. The solidification process of the casting.



a) t = 0.8120 s b) t = 3.0631 s c)=5.1926 s

d) t = 7.1493 s e) t = 9.4618 s f) t = 11.9159 s

Figure 6. Mould-filling process of the casting technology.

The diagrams demonstrate that the filling process is smooth and no turbulence exists in the pouring process.

3 Technology Optimization

In order to solve the problem of the initial scheme, two schemes were carried out to optimize the cast technology. The parting gate system is designed to fill the casting and one riser is used to feed the cast on the top of the part in the optimized scheme *I*. The axis is in a horizontal position and a bottom gating system is planned in an optimized scheme *II*. Two risers are projected on the top of the casting to feed the casting simultaneously. In addition, risers used in the scheme *I* and scheme *II* are both insulting risers, which can increase the feeding ability and also reduce the volume of the riser. The defect forecast maps for the optimized technology schemes are shown in Fig. 7. And the yield of metal for the optimized scheme *II* is 69.3 %.

3.1 Optimized Scheme *I*

The simulation result shown in Fig. 7 a) demonstrates that the shrinkage and porosities are largely eliminated but small scales of shrinkage exist in the cast. The solidification process is shown in Fig. 8. The six images show that the riser cannot feed the casting effectively during the solidification. The mould-filling process (Fig. 9), however, shows that the metal liquid fills the cast gates smoothly.

(a) (b)

Figure 7. Defect forecast of two optimized schemes: a) optimized scheme I, b) optimized scheme II.

3.2 Optimized Scheme *II*

The simulation result of scheme *II* shown in Fig. 7 b) demonstrates that this casting technology is effective in eliminating the casting defects. The solidification process of scheme *II* is shown in Fig. 10. Two risers can effectively feed the casting and the cast has achieved progressive solidification. The mould-filling process of the scheme *II* is shown in Fig. 11.

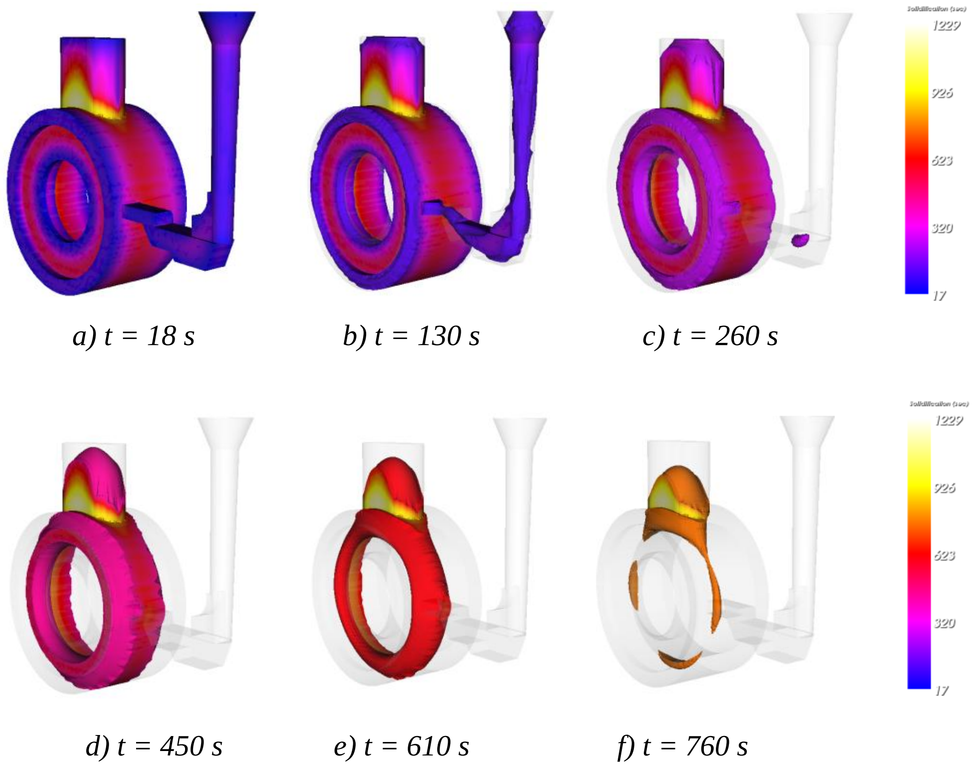


Figure 8. The solidification process of optimized scheme I.

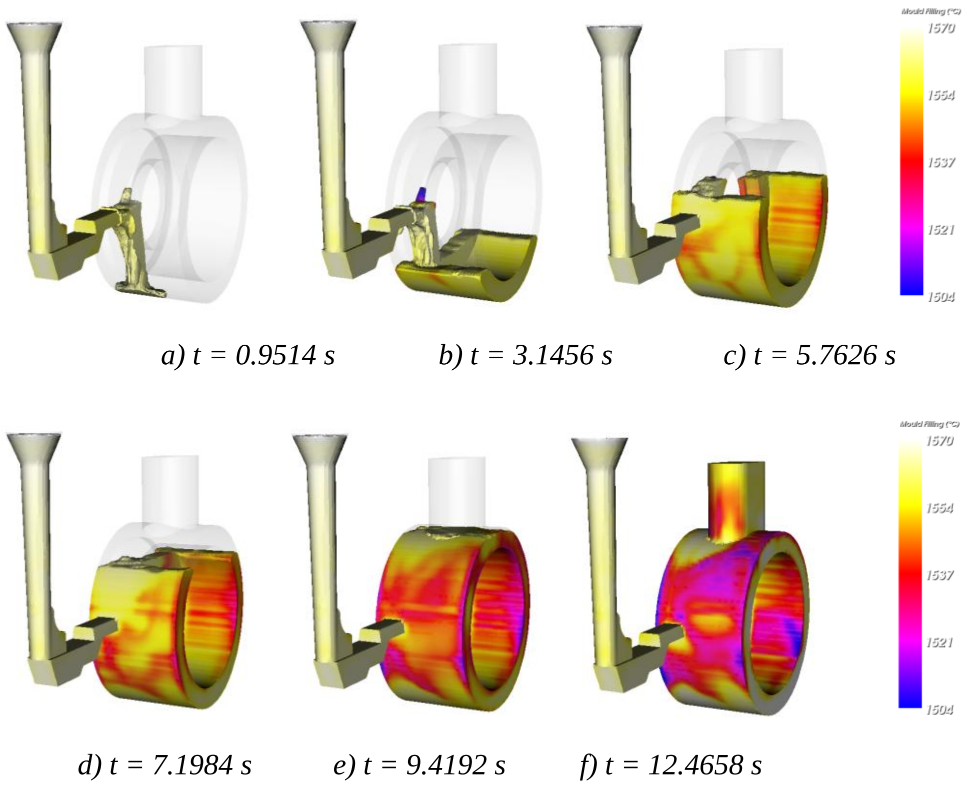


Figure 9. Mould-filling process of optimized scheme I.

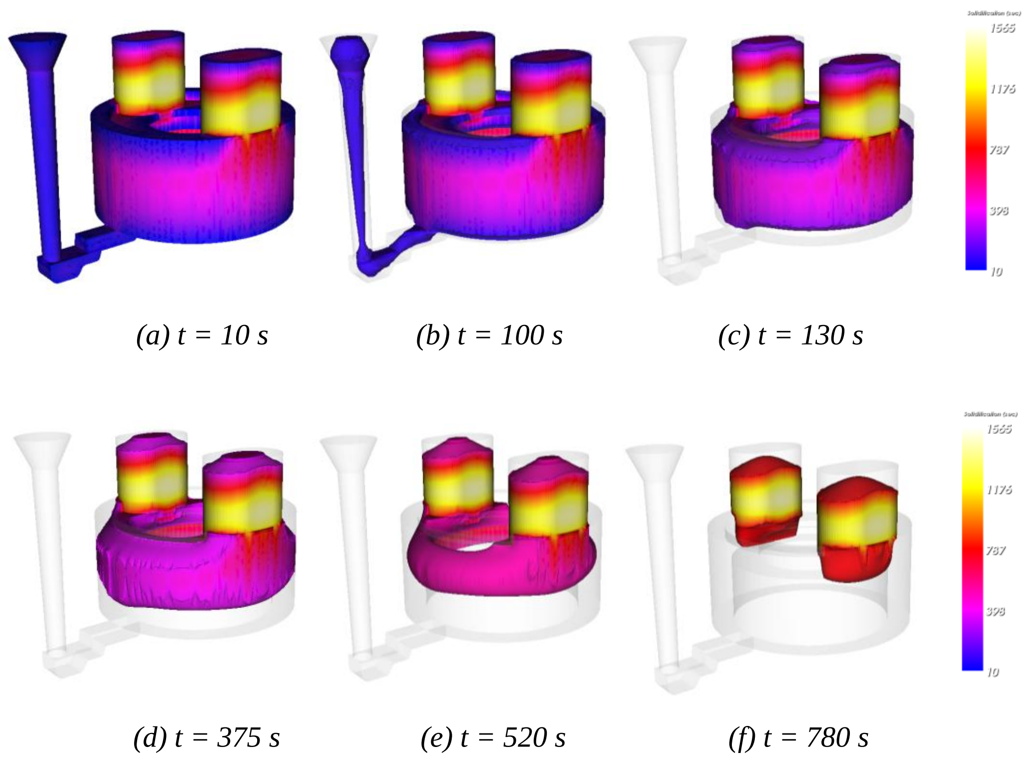


Figure 10. The solidification process of optimized scheme II.

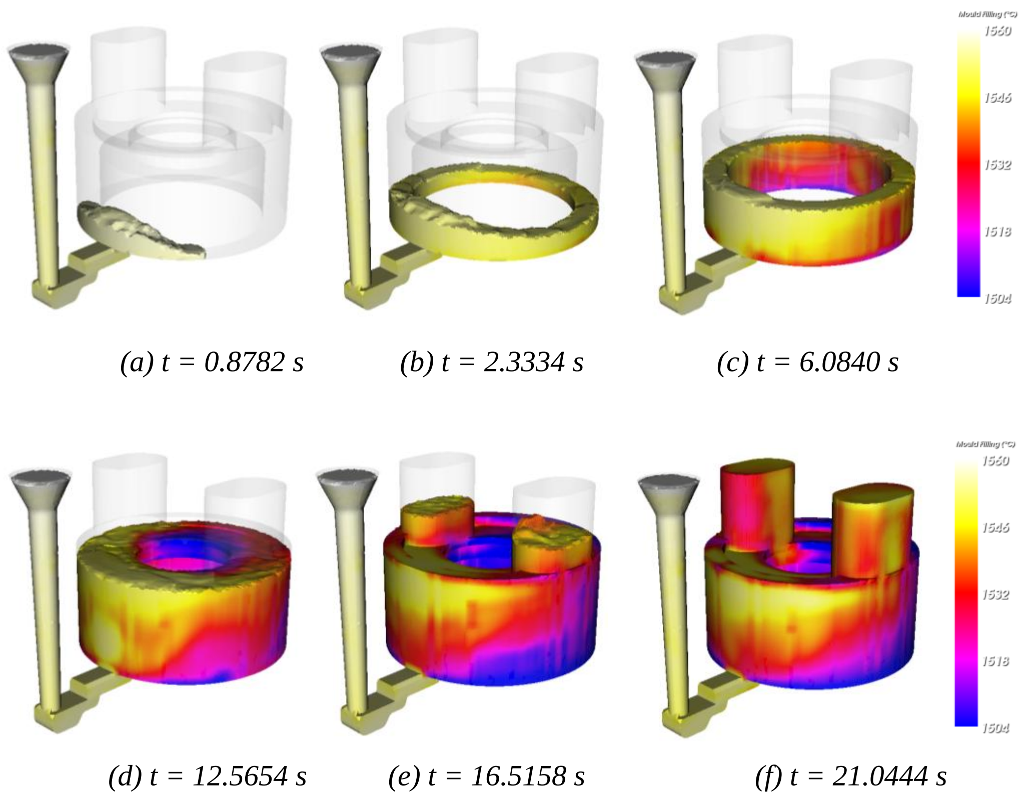


Figure 11. Mould-filling process of optimized scheme II.

The simulation results show that the liquid gating has filled the cast-steel smoothly and no turbulence existed in the filling process. The experimental casting has been performed successfully and with no casting defects.

4 Conclusion

The design of casting technology has been accomplished by ViewCast. The location, size and scale of the shrinkage in the cast have been clearly observed by simulating the solidification process. The gating system and the risers have been designed using ViewCast and the solidification simulation tests to achieve the progressive solidification of the casting. The mould-filling simulation verifies whether the liquid metal gate fills the mould smoothly and avoids turbulence in the filling process. The computer aided design made by ViewCast software could achieve the casting parameter effectively and expediently. The optimized scheme *II* is preferred to the scheme *I*, because the former eliminates the casting defects more effectively and also allows the metal liquid to flow into the mould more smoothly and steadily than the latter.

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