Casting process design of high pressure and heat resistant steam chamber casting

Junhao Sun *

Department of Metallurgical and Materials Engineering Campus of Jiangsu University of Science and Technology, 215699, Zhangjiagang, China

* Corresponding Author Email: 215699s15312328815@163.com

Abstract. This paper is about the casting process of high pressure and heat resistant steam chamber casting. The castings are made of ZG15Cr2Mo1. The internal and external quality requirements of the casting are demanding. There are many grade 0 and grade 1 defect areas in castings, which requires that these positions should not have shrinkage cavity and porosity and other defects.This casting scheme includes the design scheme of modeling, modeling material selection, coating selection, parting surface and casting system establishment, process parameters establishment, sand core design, casting riser design, cold iron design and so on. By using AnyCasting and MAGMA to simulate and predict the feasibility of the casting process scheme, a more appropriate casting process design scheme was finally determined to ensure the density of the casting metal at the flaw detection site, and eliminate the defects of shrinkage porosity and porosity of the casting, so as to ensure the requirements of leakage of the casting in practice, and make the casting meet the defect rating. At the same time, the production rate of the scheme is relatively high, which can reduce the production cost.

Keywords: High Pressure and Heat Resistant Steam Chamber, The Casting Scheme, Analogue Simulation.

1. Introduction

The steam chamber usually works under the condition of high temperature, high pressure and high speed, which requires very high performance of castings, and the shape of the steam chamber is complex, so the appropriate casting process design is very important. At present, the casting process design mainly includes sand core design, gating system design, the riser and chill's structure optimization design and casting process equipment design. Because of the particularity of the defect requirements of parts, this paper mainly discusses the structure optimization design of riser and chill.

2. The design of casting process

2.1. The structure and process requirements of casting

The high pressure and heat resistant steam chamber casting is made of alloy steel, which is ZG15Cr2Mo1.It should meet two technical requirements: first, the casting should conform to JB/T 10087-2016 "Pressure Steel Casting of steam turbine-Specification"; The size of the non-machined surface of the casting shall be carried out according to the tolerance GB/T 6414 standard. The second is to meet 100%UT, MT nondestructive testing. [1] Third, it can withstand the pump water pressure of 8.25Mpa, 10min watertight. The shape of the parts is shown in Figure 1:

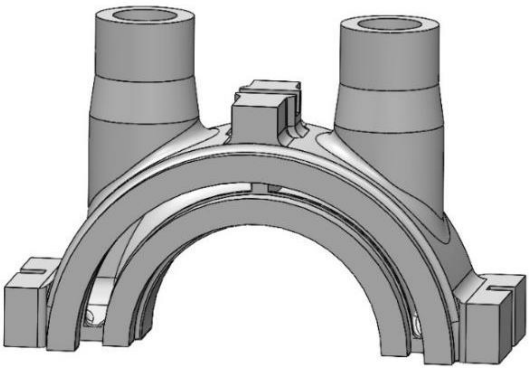


Figure 1. Steam chamber parts drawing

2.2. Establishment of casting process scheme

2.2.1 Selection of molding materials, core materials and coatings

Modeling method choose manual modeling. Manual modeling operation is more flexible, you can use a variety of different shapes and cores.

The molding material uses alkaline phenolic resin **sand [**2], because alkaline phenolic resin sand resin does not contain N, P, S elements, there is secondary hardening phenomenon at high temperature, crack tendency is smaller than furan resin sand, does not release irritating gas, good production environment, good sand cleaning performance.

Chrome ore is selected as core material for two reasons: First, chrome ore has a good anti-alkaline slag effect, and does not react with iron oxide; Therefore, chromium ore can avoid thermochemical sand; Second, in the process of molten metal casting, chromium ore itself occurs solid sintering, prevent the penetration of molten metal, so as to prevent mechanical sand adhesion. The coating is made of water quartz powder and should be microwave dried.

2.2.2 Parting surface and pouring system

The parting surface adopts the central parting mode, as shown in Figure 2:

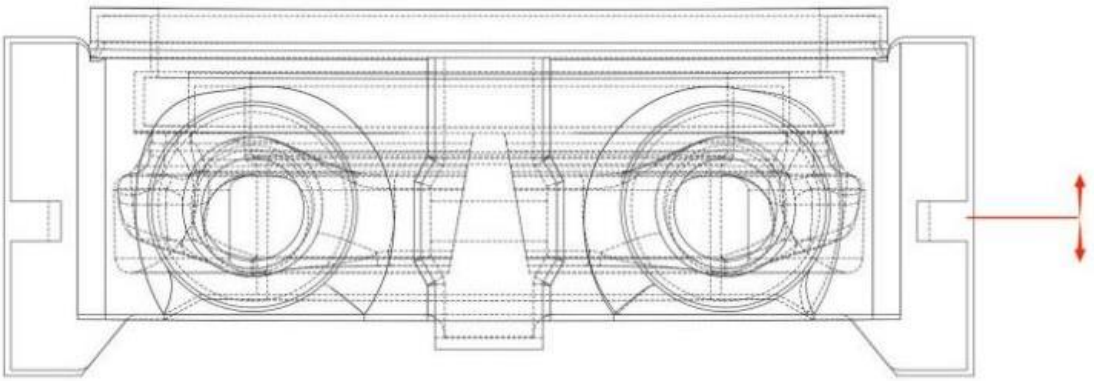


Figure 2. Location diagram of parting surface

The gating system adopts open bottom injection type:

According to the structure and production conditions of the casting, the casting is cast with a single encapsulation hole, with a diameter of 60mm. Single encapsulation hole area is 28.3cm2.

When the diameter of the encapsulation hole is 60mm, the calculated flow rate of the weight is 90kg/s, then the pouring time is 53s, the rising rate of liquid steel in the cast is 10.57s.

In the gating system design, the cross-sectional area of the straight runner is 50.94cm^2, the cross-sectional area of the cross runner is 25.47cm^2, and the cross-sectional area of the inner runner is 18.87cm^2.

The gating system and its assembly drawings are shown in Figure 3 and 4.

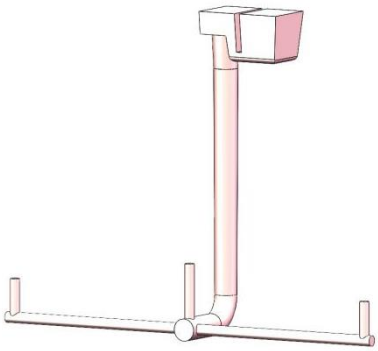


Figure 3. Casting system

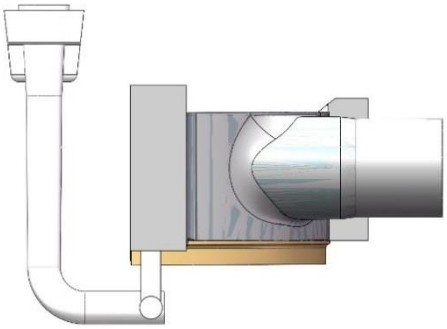


Figure 4. Casting system assembly drawing

2.2.3 Dimensional tolerance, weight tolerance and machining allowance of castings

By referring to the tolerance value of the casting size, we can know that the casting size tolerance grade is 13. It can be seen that this casting is a steel casting and hand-molded by sand casting. According to this condition, the geometric tolerance level of the casting is 6 ~ 8, and 7 is taken.

The maximum nominal size of this casting is 1642mm. According to GB/T 6414-2017, the tolerance of straightness of the casting is 6mm, the tolerance of flatness of the casting is 9mm, the tolerance of roundness, parallelism, verticality and symmetry of the casting is 14mm, and the tolerance of coaxiality of the casting is 20mm.

The casting tolerance class of this part is CT 13. According to GB/T6414 - 2017, the weight tolerance value of the casting can be seen from the nominal weight of the casting is 8%.

As the maximum size of this casting is 1642mm, refer to Table 3.2[3] to confirm that the machining allowance (RMA*)* of the casting is 21mm.

The size of the blank can be determined according to the dimensional tolerance of the casting, machining allowance and the basic size of the casting. The basic size calculation method of the blank is different under different circumstances.[4]

The machining allowance in the top view is shown in Figure 5. The allowance marked in red is the machining allowance, while the allowance marked in blue is the part that needs machining.

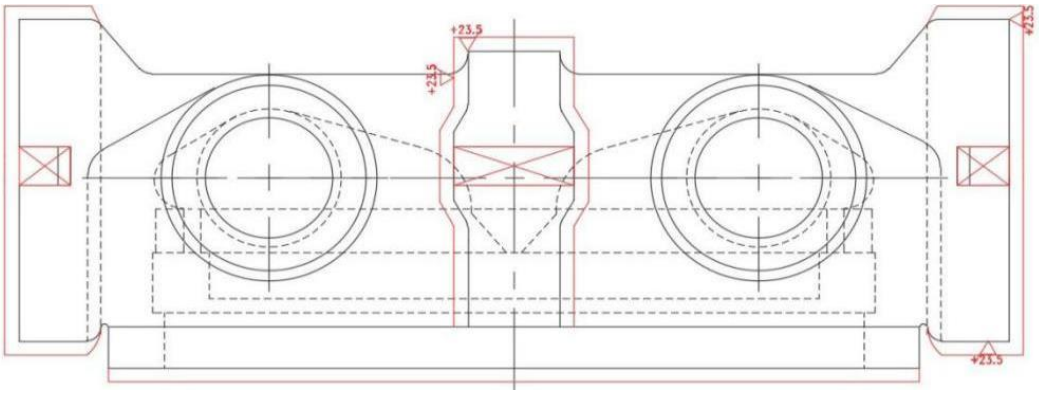


Figure 5. Machining allowance diagram

2.2.4 Other process parameters

Casting line shrinkage rate of 1.8% was selected.[5]

Because this casting uses wood mold, the height of the measuring surface is between 25~400mm, so the drawing inclination is 0°30'.

According to the maximum contour size of the casting, it can be found from Table[6] that the minimum wall thickness is 15~20 mm. The minimum wall thickness of the casting is 78 mm, which meets the requirements of the minimum wall thickness of the casting.

According to Table 3.59[3], the minimum casting groove diameter shall be 140mm.

Refer to Table 2.11[7] for the values. Because the casting shape is divided into two halves, and the upper and lower parts are not symmetrical, the negative number of parting should be taken in the upper shape, and it is dry type, so the negative number of parting should be taken 3mm.

For the high pressure and heat resistant steam chamber, the core made of chromite ore is adopted. To ensure the dimensional accuracy of the inner cavity of the casting, the inner cavity is set into two identical integral cores.

The core bone material of the casting is cast steel, sand eating in 25~40mm.

The core frame size is selected as 30×25mm.

Core tooth diameter selection range is 15~20mm, this casting selection of 20mm.

The ring is made of round steel, and the diameter of the ring is 8mm.

In the process of core making, an exhaust duct is set up in the sand core so as to draw the gas in the sand core out of the mold.

2.3. Feeding system

2.3.1 Riser position and size calculation

Dark riser is selected for all risers, and side riser is selected for bottom pouring riser. The placement position is shown in Figure 6:

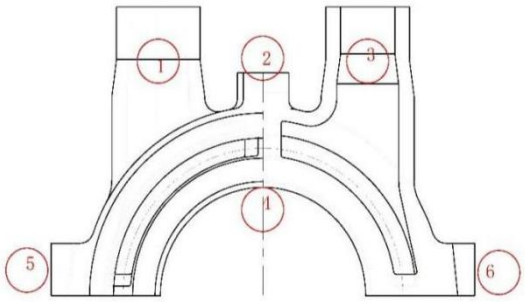


Figure 6. Riser position diagram

2.3.2 Riser size calculation

The modulus of the riser includes the modulus of the riser neck and the modulus of the whole riser, and the modulus of the casting refers to the modulus of the casting at the joint with the riser neck. The general relation expression is [3]:

$$M_R = fM_C \tag{1}$$

In the above equation, the modulus amplification coefficient generally ranges from 1.1 to 1.2, and the dark-top riser is 1.1.

Take riser 1# and 2# as an example:

$$Mc = \frac{ab}{2(a+b)} = 4.32cm \tag{2}$$

$$M_R = 1.1M_C = 4.752cm \approx 4.8cm \tag{3}$$

The calculation of other risers is similar and will not be repeated.

According to the calculation results and referring to the standard size table of dark riser [3], the size of riser is obtained as follows:

Table 1. Riser dimensions

number	type	MC （cm）	MR （cm）	coefficient（mm）
#1；#2	cylinder-shaped	4.11	4.53	$h=1.5d=360$，$a=d$
#3；#4	cylinder-shaped	4.46	4.91	$h=1.5d=390$，$a=d$
#5	Waist shape	4.88	5.37	$a=240, b=h=360$
#6	cylinder-shaped	4.05	4.45	$h=1.2d=300$

2.3.3 Heating jacket design

The wall thickness of the cylindrical heating riser sleeve shall be 1/5 of the diameter of the heating riser, and the wall thickness of the waist riser shall be 1/10 of the sum of the length and width of the riser.Through calculation, the thickness of the riser sleeve is 60mm.

2.3.4 The design of cold iron

After conversion of V0-Vr, the cold iron weight calculation formula [3] :

$$Gch=\frac{\rho_L(L+\Delta H)}{t_{ch}}V_0\frac{M_O-M_r}{M_0} \tag{4}$$

For steel castings, assuming that the filling temperature of steel castings is not 1550℃, the average temperature of cold castings at the end of gradual solidification is set as 600℃. After conversion, we can get:

$$G_{ch}=7.4V_0\frac{M_0-M_r}{M_0} \tag{5}$$

The application of the above formula can be easily calculated in the setting of cold iron casting parts need to set the weight of cold iron.

3. Simulation result and analysis of design scheme

3.1. Simulation results before feeding in horizontal casting condition

Fig. 7 Is A Schematic Diagram of Defects Before Filling.

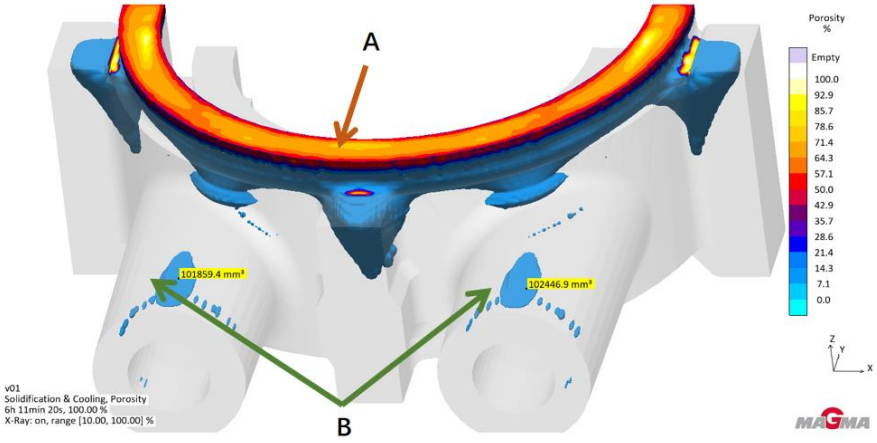


Figure 7. Schematic diagram of defects before filling

According to the analysis of the figure above, position A is the overall upper surface defect of the box, position B is the upper surface defect of the hole, which can be directly supplemented through the riser during the process design.[8] The selection of horizontal bottom casting, the overall height of the small drop is small, filling the liquid steel will be very stable.

3.2. Simulation results after optimization

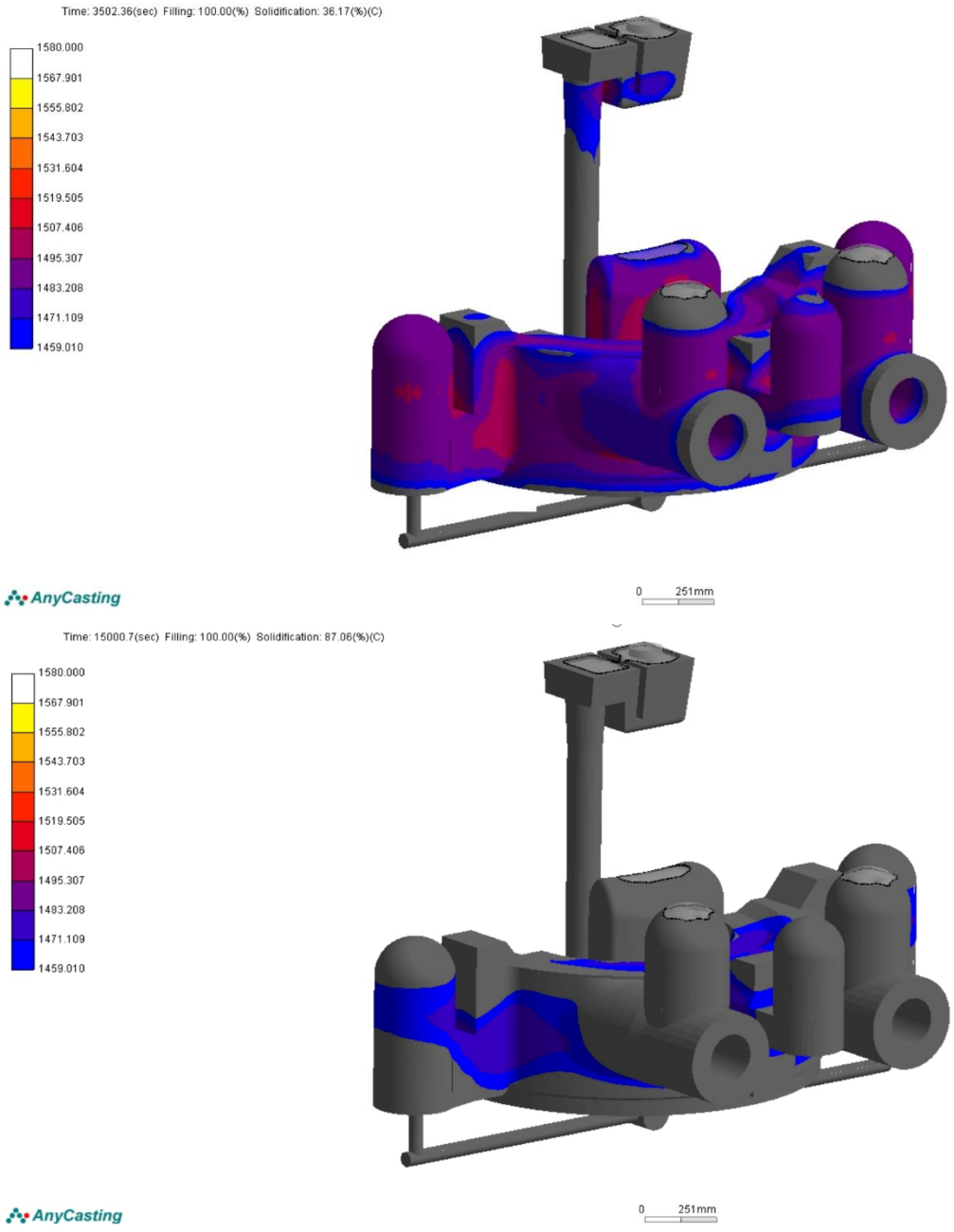
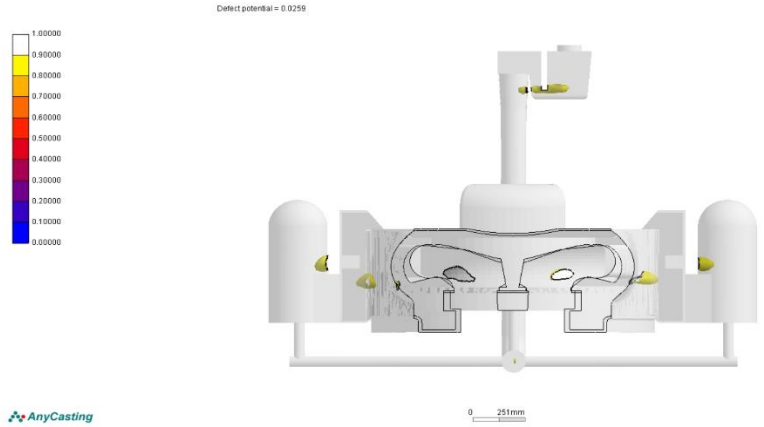


Figure 8. Temperature field diagram

Figure 8 shows the temperature field diagram in the solidification process under the optimized technological scheme. As can be seen from the solidification simulation results, the pores on the top of the casting were discharged into the riser, and there was still a large hot section in the middle of the casting cavity, which indicated that the cooling iron was set properly and the solidification sequence of the casting was improved [9].

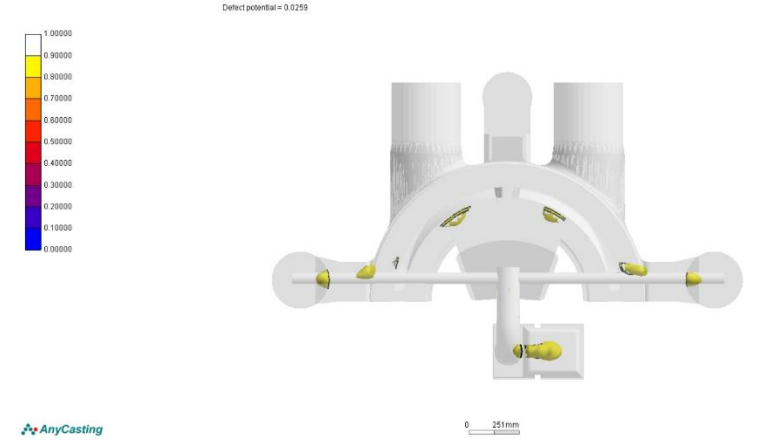
After the filling optimization, Anycasting software was used for simulation, and the defect probability chart after the filling was obtained, as shown in Figure 9.



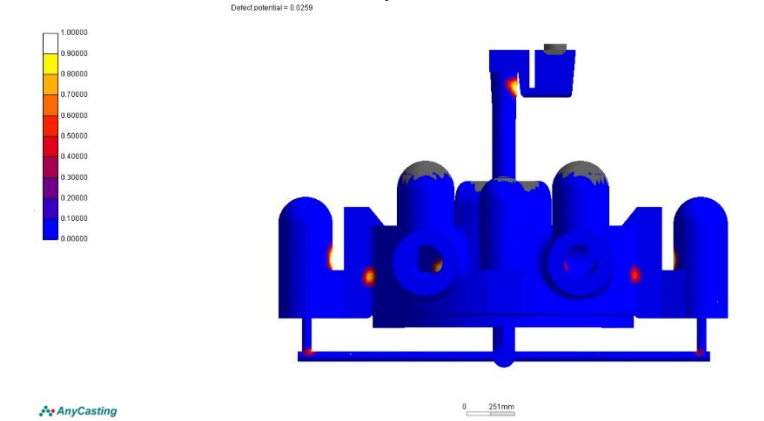
a. Defect top view



b. Defect bottom view



c. Defect profile



d. Defect probability graph

Figure 9. Probabilistic defect diagram of residual melt modulus

From the probability defect diagram of residual melt modulus, it can be seen that the shrinkage and porosity of the cavity in the casting have been eliminated. The role of riser and cold iron is obvious, and the solidification sequence has been significantly improved, thus achieving the purpose of reducing defects. In addition, it can be seen from the figure that the position defects of parts requiring Q.L.0 or Q.L.1 are less or even disappear, and the partial defects requiring Q.L.5 are significantly reduced compared with the first optimization. The remaining defects are not enough to affect the quality of parts. The final simulation results of optimization show that the metal liquid rises steadily and rapidly, without turbulence, spatter and enrolling phenomenon, and the solidification sequence is reasonable with fewer defects, which proves that the design of the bottom-injection open pouring system is reasonable, and the size of the riser and cold iron in the optimization scheme is reasonable.

Finally, according to relevant requirements of parts, we need to carry out UT ultrasonic testing and MT magnetic particle testing of parts.[10]

4. Conclusions

This process adopts the pouring method of flat casting, through setting riser and cold iron to make the casting have a bottom-up sequence solidification, to ensure the density of the casting metal at the flaw detection site, and eliminate the defects of shrinkage cavity and porosity of the casting. By setting the air vent reasonably, the tendency of pinhole porosity in castings is reduced and the requirement of leakage in castings is guaranteed. At the same time, the production rate of the scheme is relatively high, which can reduce the production cost of the factory. Overall, it belongs to a reasonable casting scheme.

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