Determining Defects Formation on the Castings Surface by Computer Simulation of Casting Processes

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Abstract: Foundry production is one of the energies and resource intensive industries. Despite the undeniable advantages of foundry production, one of its disadvantages is the insufficiently high quality of the castings surface due to the possible formation of various surface defects such as burn-on, calcination, metal penetration, wrinkles and vitrification. Prevention of the casts surface defects on the surface of steel and cast-iron castings is carried out by applying special foundry (protective) coatings. Foundry coating is one of the most important parts in the foundry industry. Prediction of the casting surface defects, appearance and internal quality of castings depends on the correct choice of foundry coatings, which can be done due to analysis of the casting technology parameters and computer simulation of casting processes.

Keywords: castings surface; casting processes simulation; defects prediction

1 Introduction

Information about local overheating of the foundry mold during pouring and solidification may be used to predict casting surface imperfections and identify defect formation. The poured melt is cooled due to the foundry mold absorption of its physical heat (about 20%), heat of crystallization (70%) and phase transformations (1%-2%). Temperature of the foundry mold and its boundary layers and temperature in the contact zone "alloy – foundry mold" determine interaction processes between them, such as possible melt penetration, probability and kinetics of chemical reactions between melt oxides and material of the foundry mold and stress-strain state of the casting-mold system, including the occurrence of thermomechanical stresses.

2 Experimental procedure

The intensity of the aforementioned processes is the root cause of a diverse range of casting surface defects, including burn-on burn-in sand, metal penetration with and without chemical reactions. For example, according to opinions about the mechanism of burn-in formation, filtration of the melt is needed when the metallostatic pressure of the melt exceeds the capillary and gas back pressure of the foundry mold. At the same time, temperature in contact zone between alloy and boundary layers of foundry mold must be above a certain temperature or a critical temperature (T_{crit}). T_{crit} may be found from crystallization range of the alloy because it loses its ability to flow after the formation of the solid phase. It is rather close to the zero-fluidity temperature and can take on different meanings for various types of alloys. Alloys which crystallize in the form of a solid solution (austenitic steels) T_{crit} will close equal to the liquidus temperature, but for alloys which crystallize with a high eutectic content it will close to the solidus temperature. For alloys which crystallize with peritectic transformation, T_{crit} is recommended to take as an equal to half the sum of the liquidus temperature and the solidus temperature of the alloy. The critical temperature value for iron-based alloys can be determined based on the iron-cementite diagram.

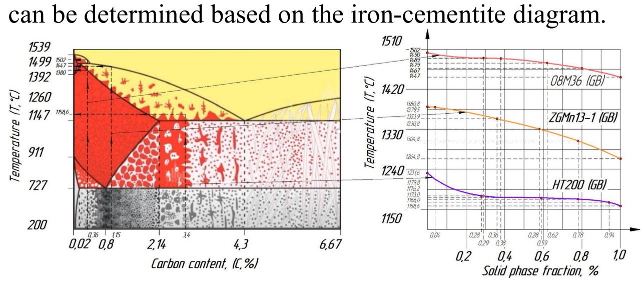


Figure 1 Determination of critical temperature

Figure 1 schematically shows the determination of the T_{crit} value for casting alloys which are widely used in the production of various castings such as steel 08M36 (GB), which has a peritectic transformation, austenitic steel ZGMn13-1 (GB) and cast iron HT200 (GB) which is crystallized with an amount of eutectic.

It is necessary to identify an area of the foundry mold and time intervals where the temperature exceeds the critical temperature in order to determine defect formation on the casting surface due to computer simulation. This approach to predict the formation of surface defects in castings can serve as the basis for the development of effective methods for their prevention, including through foundry coating application.

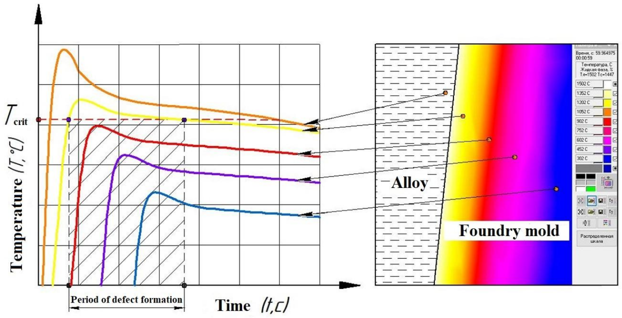


Figure 2 Temperature distribution in the contact zone "alloy-mold" and near-surface layers of the mold

Potential period of defect formation can be found by cooling curves, which describe melt temperature changes near the casting surface (Figure 2). Interval is situated between the points where the mold temperature is higher than T_{crit}.

3 Result and discussion

Computer simulation of casting processes was implemented by Polygon software. V-block [1, 2] were used for simulation, the shape of which is the inclined tetrahedral prism with a V-shaped through channel (Figure 3).

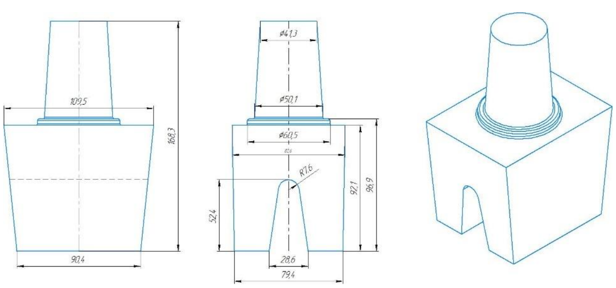


Figure 3 V-block

First of all, we simulated pouring processes with main goal to take into account the heating of the mold during the pouring period (Figure 4).

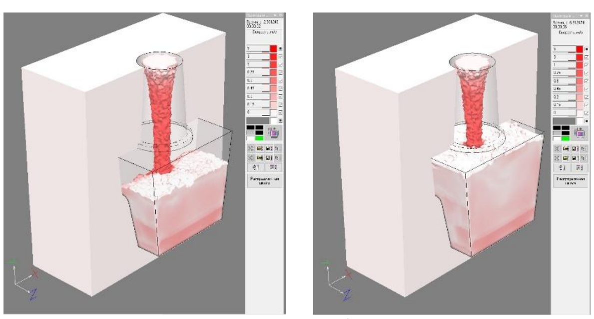
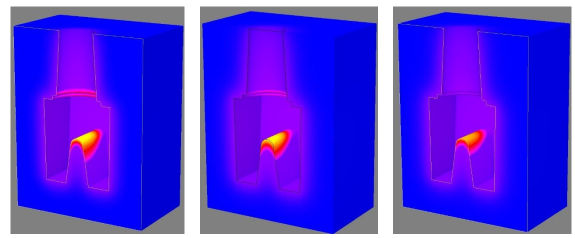


Figure 4 Pouring of V-block

It was established that filling occurs in 9.01 s for steel 08M36 (GB), 8.97 s for steel ZGMn13-1 (GB) and 8.99 s for cast iron HT200 (GB). Maximum temperature of foundry mold during this period is 284 °C, 260 °C and 240 °C.

Simulation of solidification processes made it possible to establish local areas of the casting mold and time intervals where the temperature exceeds T_{crit} (Figure 5).



a b c

Figure 5 Temperature distribution in the foundry mold (a- steel 08M36, b - steel ZGMn13-1, c - cast iron HT200)

T_{crit} equal 1,475 °C for steel 08M36, time interval is 962.5 s, and the maximum surface temperature of the casting mold occurs in the area of the V-shaped protrusion and is 1,490 °C. For steel ZGMn13-1 this time interval is 716.6 s (T_{crit} = 1,360 °C), and the maximum surface temperature of the foundry mold also reaches into the area of the V-shaped protrusion and equal 1,369 °C. For cast iron HT200, the time interval for potential defect formation is 3,066 s (T_{crit} = 1,158 °C), and the maximum mold surface temperature (1,230 °C) reaches in the area of the V-shaped protrusion.

4 Conclusion

It is important to note that identified time intervals for defect formation and areas of the mold where the temperature exceeds T_{crit} can be used to perform thermodynamic analysis of chemical reactions between melt oxides and material of the foundry mold. A similar approach could be implemented to analyze the stress-strain state of the casting-mold system in order to determine areas of the casting mold where high-temperature stresses may arise, which could lead to deformations and cracking of the foundry mold.

References

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