Intelligent Design and Optimization of Feeding System inCastings Based on Reinforcement Learning

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Abstract: The feeding system can effectively reduce the shrinkage porosity in the design of casting process and then improve the casting quality and process yield. therefore, the automatic and intelligent design of the feeding system plays an essential role in the casting process design of complex structural castings. In this paper, an intelligent design method of feeding system for complex structural castings based on reinforcement learning is proposed. By combining simulation with reinforcement learning model,a novel design method with high quality and efficiency of feeding system is realized. Firstly, the adaptive design method of the initial process of feeding system based on temperature gradient descent is established to provide the required environment for reinforcement learning model. Secondly, The tabular form Q-learning method in reinforcement learning is adopted, and the initial process design is regarded as the environment, and the return is obtained from the results of the solidification and heat transfer simulation. The specific size of the riser is optimized by selecting the optimal action and state in the optimization process of each step, and the above steps are iterated repeatedly until the termination condition is met. Thirdly, the influence of changes in different model parameters on the optimization results is discussed by modifying the Q-learning model, and the model parameters are updated to determine the optimal reinforcement learning model suitable for this environment. Finally, the model is tested by intelligent design of feeding system for several groups of complex structure castings. The test results show that the model has a good effect on a variety of complex structure castings, which proves the validity and reliability of this model.

Keywords: feeding system; reinforcement learning; solidification simulation; process optimization

1 Introduction

The design of feedingsystem is very essential in the casting process.The feeding system can affect the casting filling solidification process, thus affecting the feeding effect and the distribution of defects inside the casting.Especially for castings with complex structure, the design of the feeding system is extremely difficult, which makes the casting defects difficult to effectively eliminate, thus affecting the quality and service performance of the castings.In the design of feeding system, the key problem to be solved is to find out the internal relationship between feeding process and casting defect distribution.At present, many methods have been devoted to solving this internal relationship,mainly including modular method, geometric heat knot method, and numerical simulation based test design.

2 Experimental procedure

(1)An adaptive generating model for initial process of feeding system based on temperature gradient descent is proposed.Firstly, the solidification heat transfer process of the casting itself was simulated to obtain the temperature change law at different times in the casting and the temperature gradient at different positions.Secondly, all possible locations of the feeding system are obtained by the geometric surface discrimination method, and the effectiveness screening is carried out.Finally, the initial process of the feeding system is generated(as shown inFigure 1).

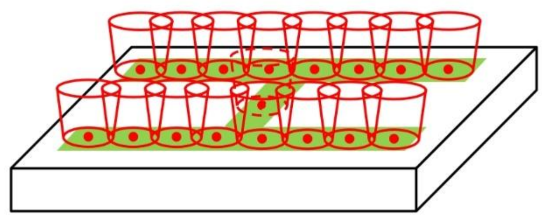

Figure 1 Riser design pointsgenerated randomly

(2)An automatic position optimization method of feeding system based on temperature gradient descent is proposed.In the heat transfer process of casting solidification, the relatively low temperature part of the casting is the last part of solidification.Therefore, the final solidification position can be found by the method of temperature gradient descent, and the feeding system can be set here.The temperature field calculation results generated in the first step can be used to optimize the distribution position of randomly generated feeding system according to the direction of temperature gradient decline, so as to achieve the purpose of automatic design of feeding system(as shown in Figure 2).

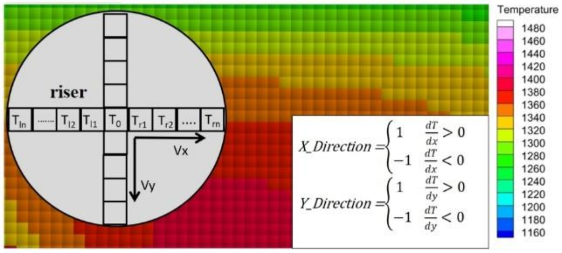

Figure2 Optimization of riser position based on temperature gradientdescent

(3)After completing the initial riser design scheme constructed above, we can use the above design scheme as the environment to build a reinforcement learning model (as shown in Figure 3).The reinforcement learning method adopted in this paper is Q-learning method.Q-learning is a temporal difference method used to solve problems based on Markov decision process (MDP).The core idea of Q-learning method is to optimize the decision-making strategy of the agent by constantly updating the Q-value function.Specifically, Q-Learning uses the Bellman equation to update the Q-value function, which states that the value of Q in the current state is equal to the current reward plus a discount on the maximum value of Q in the future.

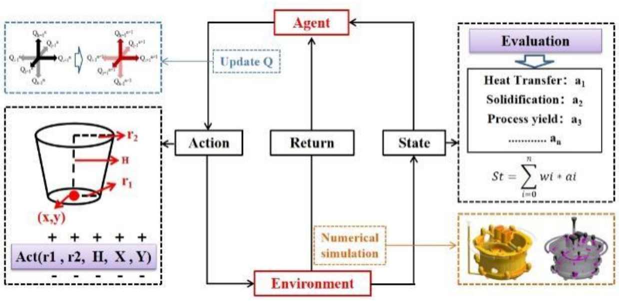

Figure 3 Reinforcement learning methodology framework

3 Result and Discussion

A typical casting with complex structure is selected for testing. Firstly, the surface of the three-dimensional model of the casting is analyzed to find out the area where the riser can be designed. Secondly, the temperature field simulation is carried out for the casting.Finally The designing results are obtained based on reinforcement learning (as shown in Figure 4).As can be seen from Figure 4, risers are concentrated in the region with the highest casting temperature and the final solidification, and the higher the temperature, the larger the risers are, which is conducive to eliminating shrinkage holes. Therefore, the design method of the model is consistent with the experience of the casting process.

In order to test the effect of the feeding system, solidification simulation is used, and the defect results showed that the shrinkage holes could be effectively eliminated(as shown in Figure 5).

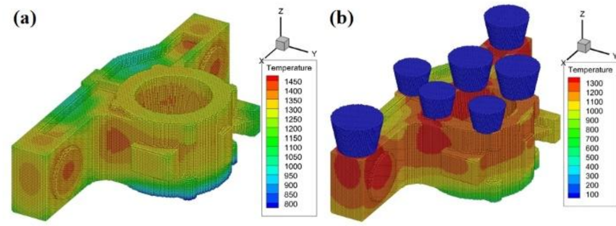

Figure 4 The results ofriser designing: (a) simulation results of temperature field; (b) riser designing results

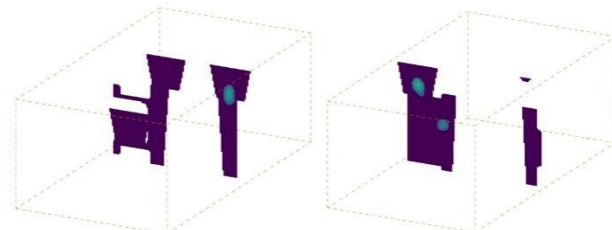

Figure 5 Simulation of shrinkage based on the designed feeding system

4 Conclusions

(1) The design of riser based on structure identification and temperature field simulation is realized, and the feeding system is effectively designed without the assist of manual experience.

(2) The designed feeding system can eliminate the shrinkage and porosity of castings well, which proves that the design model in this paper is effective.

5 Acknowledgment

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