J. H. PENG, X. W. CHENG, J. WANG, L. C. XIAO

ISSN 0543-5846
METABK 63(1) 25-27 (2024)
UDC – UDK 621-6.669.1/658.564:536.5:536.21/620.16:536.21/539.5=111

ANALYSIS OF TEMPERATURE FIELD AND THERMAL STRESS OF MOLTEN IRON SLAGGING-OFF ROBOT ARM

Received – Primljeno: 2023-04-25
Accepted – Prihvaćeno: 2023-08-10
Original Scientific Paper – Izvorni znanstveni rad

In this paper, the transient temperature field and thermal stress of the slagging-off robot arm were analyzed by finite element method, the temperature distribution and change of the robot arm in one working cycle were determined, and the thermal stress and thermal deformation of the slag-scraping plate after the skimming was completed were solved. The results show that the temperature of the equipment in the slagging-off process can reach 206 °C, and the heat can be transferred to the position of 200mm, which will not affect the key parts in the manipulator. Due to the direct contact with molten iron, the heat stress and deformation of the slag-scraping plate are large, which may result in the high melt loss rate of the slag-scraping plate.

Keywords: molten iron slagging-off robot; transient temperature field; thermal stress; thermal deformation

INTRODUCTION

Molten iron is the main raw material of converter steelmaking, the quality of molten iron has a direct influence on steelmaking process and steel quality[1]. The automatic molten iron slagging-off robot, as the technical extension of the artificial slagging machine, replaces the manual operation with certain risks. It has been recognized and applied by more and more metallurgical enterprises[2]. This equipment is directly in contact with molten iron and has a poor working environment. At present, the failure rate is generally high in actual use. First of all, during the operation of the equipment, slag-scraping plate needs to go deep into the high temperature molten iron, there is inevitable melting loss, which affects the service life of slag-scraping plate. Secondly, in the process of contact between the slag-scraping plate and high temperature molten iron, the heat transfer of the equipment will make the temperature of the hydraulic and electrical components inside the mechanical arm rise, which may lead to equipment failure, threatening the efficiency and safety of the equipment[3]. These bad conditions increase the failure of slagging-off robot arm, but also put forward a new challenge to the design of slagging-off robot arm. Therefore, it is necessary to analyze the transient temperature field, thermal deformation and thermal stress of the slagging-off robot arm.

DEVICE MODEL AND WORKING ENVIRONMENT

Using SolidWorks, the 3D model of the front end robot arm of the molten iron slagging-off robot was established. The model was imported into ANSYS Workbench for grid division, and the final finite element model was formed, as shown in Figure 1.

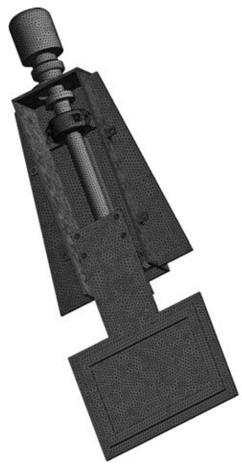

Figure 1 Finite element model of slagging-off robot arm

The slag-scraping plate is immersed in molten iron at a depth of 50 ~ 100 mm and then moves in a straight line to remove the scum on the surface of molten iron. The slag-scraping plate is a part directly in contact with high temperature molten iron. In order to prevent melting loss of the slag-scraping plate, it is necessary to spray heat insulation coating on the surface of the slag-scraping plate, and it needs to be immersed in the cooling liquid after each slagging-off[4].

TRANSIENT THERMAL ANALYSIS OF SLAGGING-OFF ROBOT ARM

The slagging-off process can be regarded as the cyclic repetition of three working steps:

J. H. Peng, X. W. Cheng, J. Wang, L. C. Xiao, M. P. Liu (E-mail: cxw@ncst.edu.cn), College of Mechanical Engineering, North China University of Science and Technology, Hebei, Tangshan, China.

(1) **Deslagging stage:** The slag-scraping plate is immersed in molten iron and the scum is peel out, the immersion depth is 100 mm, the temperature of molten iron is 1 250 °C, and the process is about 30 s;

(2) **Transfer stage:** In the process of transferring the robot arm to the coolant, the slag-scraping plate is exposed to the air at the ambient temperature of 40 °C, the process is about 5 s;

(3) **Cooling stage:** Dip the slag-scraping plate in the cooling liquid at 30 °C, the process is about 15 s;

Each stage is set as an analysis step, and corresponding thermal boundary conditions are set to carry out transient thermal analysis of the temperature changes of the manipulator in one working cycle.

Figure 2 shows the temperature variation curve of the robot arm in one working cycle. According to the data in the figure, the temperature of the slag-scraping plate reaches 206 °C after one working; The temperature drops slightly to 180 °C in the process of transferring from the molten iron to the coolant. Finally, when the slag-scraping plate is immersed in the coolant, the temperature drops rapidly to 59 °C.

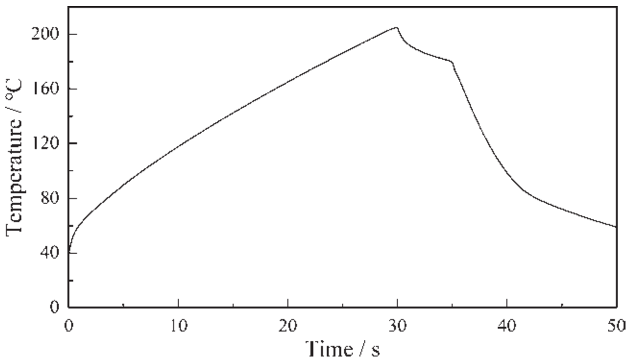

Figure 2 Temperature curve of the robot arm

Figure 3 shows the temperature distribution nephogram of the manipulator after the deslagging. It can be observed from the figure that, after 30 s of work, the temperature at the lower edge of the slag-scraping plate reaches the highest, reaching 206 °C. Other locations are affected by high temperature molten iron very low, the temperature change is not obvious.

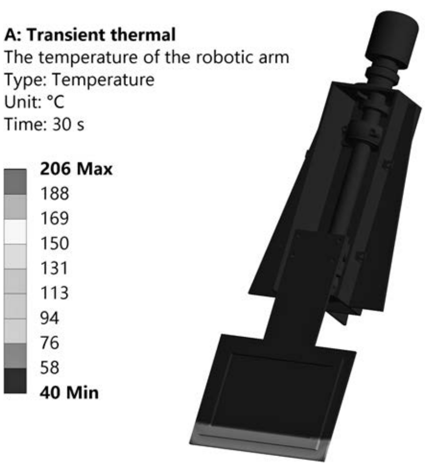

Figure 3 Temperature distribution nephogram of robot arm

Establish a “path” inside the slag-scraping plate from bottom to top, as shown in “ 1~2 “ in Figure 4. Solve the temperature on the path and extract the temperature distribution inside the slag-scraping plate, as shown in Figure 5.

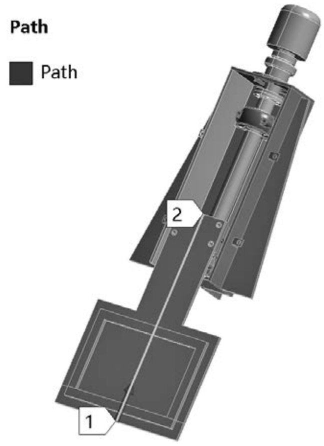

Figure 4 Temperature extraction path

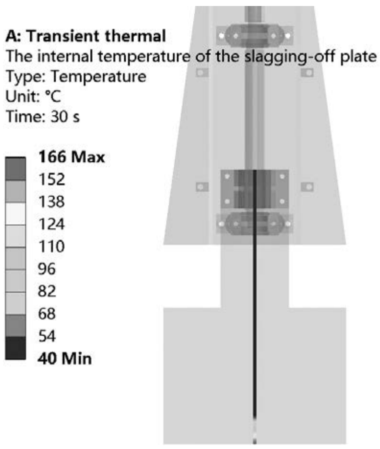

Figure 5 Temperature inside the slag-scraping plate

It can be observed from the figure that, from bottom to top, the temperature of the slag-scraping plate at the position of 200 mm drops to close to the ambient temperature. It can be seen that although the temperature of the contact part of the slag-scraping plate and molten iron is very high, due to the short contact time, the heat will not be transmitted to the upper end of the mechanical arm. The upper end temperature is stably controlled within the temperature range required by electrical components, ensure the safety of the equipment.

Figure 6 respectively show the surface temperature and internal temperature of the slag-scraping plate after cooling. It can be observed from the figure that after 15s of cooling, the surface temperature drops to 40 °C, the internal temperature is about 60 °C. By comparing the temperature data, it can be seen that after dipping the slagging plate into the coolant for 15 s, the temperature of the slag-scraping plate is close to the ambient temperature. At this time, the temperature drop rate has been reduced, and it is of little significance to continue cooling, so the cooling time of 15 s can meet the working requirements.

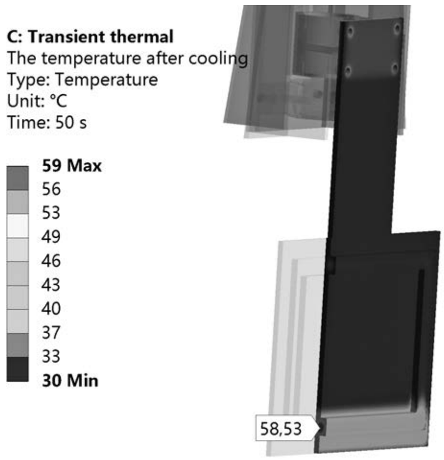

Figure 6 The temperature after cooling

THERMAL DEFORMATION AND STRESS ANALYSIS OF THE SLAGGING-OFF ROBOT ARM

Robot arm after 30 s slagging-off operation, the deformation distribution of the slag-scraping plate is shown in Figure 7. It can be observed from the figure that large thermal deformation occurs at both ends of the slagging-off immersed into the molten iron part, with the maximum deformation of about 1,1 mm.

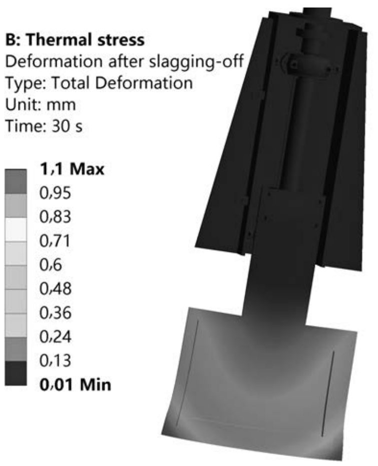

Figure 7 Thermal deformation nephogram of robotic arm

Figure 8 Thermal stress of robotic arm

The thermal stress distribution of the slagging-off robot arm is shown in Figure 8. It can be observed from the figure that the maximum thermal stress occurs in the middle of the lower edge of the slag-scraping plate, and the maximum value is 188 MPa. In addition, at the contact position between the slag slag-scraping plate and molten iron, due to the large temperature difference, also produced a large stress.

CONCLUSION

In this paper, transient thermal and thermal stress analysis were carried out on the robot arm of molten iron slagging-off in one working cycle, and the following conclusions were drawn:

(1) After one operation, the surface temperature of the slag-scraping plate rises to 206 °C, and after being immersed in the cooling liquid, the surface temperature drops to 45 °C, which is close to the ambient temperature and can continue to work.

(2) After a slag removal, the temperature of the mechanical arm will be transmitted upward to the position of 200 mm. Only the slag-scraping plate needs to be replaced regularly, and the key parts above the robot arm will not be affected.

(3) The high thermal stress and deformation of the slag-scraping plate during operation may lead to faster melting loss rate of the slag-scraping plate, affect the service life of the slag-scraping plate and increase the production cost. So it can consider the effect of strong heat insulation coating, reduce the thermal stress and thermal deformation of slag plate.

Acknowledgments

This research was supported by the Mineral Classification Crushing Equipment Technology Innovation Center Foundation of Hebei Province (Grant No. SG2021064).

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Note: The responsible translator for English language is T. K. Li -North China University of Science and Technology, China