# Determination and Study of Heat Transfer Coefficient in Frozen Sand Mold

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**Abstract:** Resin and other binders are widely used in traditional sand casting. It has caused serious environmental pollution in the casting process and has affected the physical and mental health of foundry workers. Frozen sand mold casting (FSMC) technology, which has the advantages of low cost, high performance, and green manufacturing, will become an essential means of green manufacturing in the automotive, rail transportation, aerospace, and other fields. However, the interfacial heat transfer behavior of FSMC technology in the casting process is still unclear. As an important parameter to describe the interfacial heat transfer behavior, the interfacial heat transfer coefficient (IHTC) has not been further studied in the field of FSMC. This method provides a reference for the determination of IHTC of different kinds of alloys in the process of FSMC. Moreover, the determination of the IHTC during the casting process of ZL101 aluminum alloy in this work provides important boundary conditions for the numerical simulation of the FSMC process.

**Keywords:**frozen sand mold casting (FSMC); inverse thermal conductivity problem (IHCP); cast aluminum alloy; interfacial heat transfer coefficient (IHTC); numerical calculation

## 1 Introduction

Casting aluminum alloy has the advantages of high performance, low cost, easy mass production of precision parts, etc. It is widely used in aircraft manufacturing, new energy vehicles, deep space probes, high-speed railway construction, and other fields [1-4]. With the continuous improvement of human manufacturing level and environmental awareness, the manufacturing of aluminum alloy gradually tends to be highly efficient, high performance, low cost, and green [5-6]. FSMC technology, which has the advantages of low cost, high performance, and green manufacturing, will become an essential means of green manufacturing in the automotive, rail transportation, aerospace, and other fields. The materials used for casting mold mainly include water and sand. The mold which mixed with water is formed in a lower temperature to content with a casting strength. Castings are obtained after pouring the mold [7]. As a result of less pollution, easy of shakeout, high recovery rate of molding sand, and better performance of casting, frozen casting is an advanced casting pathway for greening.

This study establishes a method for determining the IHTC during FSMC by combining the FDM and the CGM. The IHCP method is established by the FDM architecture and the CGM for solving the forward and inverse heat transfer problems, respectively. The accuracy of the IHCP process established based on the 1-D heat transfer assumption is verified experimentally and numerically. The IHTC was determined for different FSMC process conditions, including initial frozen temperature, water contents, and types of molding sand. Moreover, the influence of water content in frozen sand mold on IHTC was analyzed.

## 2 Numerical modeland experimental procedure

Figure 1 is the flow chart of FSMC technology, which is divided into six parts: sand mixing, vibration compaction, frozen billet making, cutting and processing, deep cooling and melting and pouring.

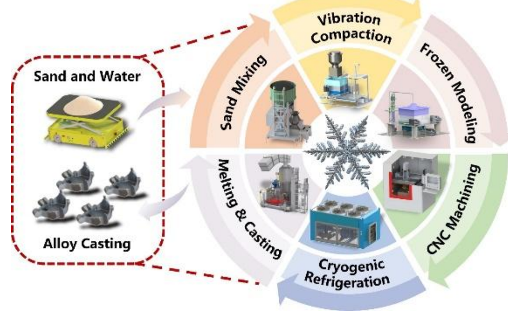


**Figure 1 FSMC technology diagrammatic drawing**

Based on the 1-D heat transfer assumption, the inversion method of IHCP for FSMC process was established by combining FDM and CGM. The calculation flow of the one-dimensional heat transfer model and the IHCP inversion model is shown in Figure 2. The calculation error of which is less than 1.6°C, which is lower than other related reports. In this work, a frozen casting thermometry experiment was designed, as shown in Figure 3. During the experiment, a data recorder was used to collect the temperature. Table 1 shows the process parameters of frozen casting thermometry experiment.

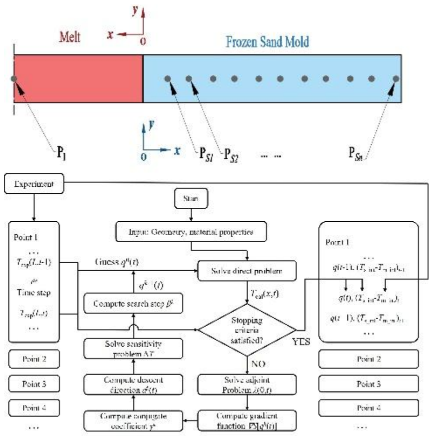


Figure 2 1-D heat transfer assumptions and IHCP inversion modeling calculation procedure

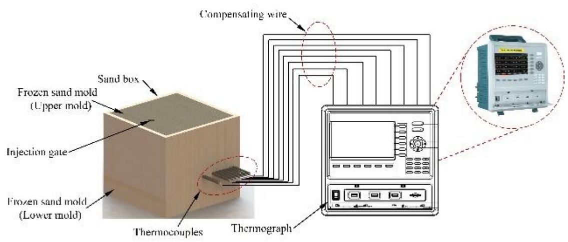


Figure 3 The frozen casting thermometry experiment

Table 1. Process parameters of frozen casting thermometry experiment

| Initial frozen temperature (℃) | Water content | Sand type |
|---|---|---|
| -34<br>-32<br>-30<br>-28<br>-26 | 2wt.%<br>3wt.%<br>4wt.%<br>5wt.%<br>6wt.% | Silicon and Chromite sand |

## 3 Result and discussion

The IHTC and temperature fields were calculated for 17 different process conditions by the IHCP process established in this work. For frozen sand mold, although different water content led to two distinct types of IHTC change rules, the essential reason was the same air gap change process. Figure 4 shows the variation of IHTC with 3wt.% and 5wt.% water contents with temperature.In the temperature range of 575 ℃ to 550 ℃ on the casting surface, the IHTC of the frozen sand mold with the water content of 2wt.%, 3wt.%, and 4wt.% appeared as 'Fluctuation'. Meanwhile, the IHTC of the frozen sand mold with the water content of 5wt.% and 6wt.% appeared as 'Turning'.

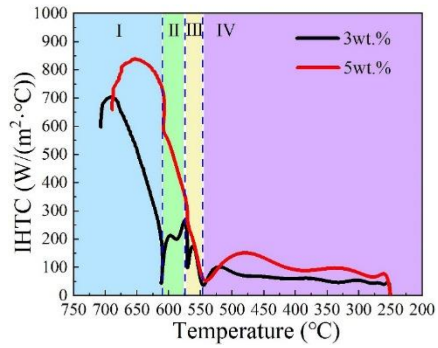


Figure 4 Two types of frozen sand mold IHTC trend with temperature variations

## 4 Conclusion

The calculated results show that the inverse analytical method can be successfully applied to determining the IHTC of ZL101 alloy during the frozen sand mold casting process. It suggested that the turning point for two IHTC change types was between 4%-5% water content. When the water content was below this value, the IHTC change followed a 'fluctuation type', while when the water content exceeded this value, the IHTC change showed a 'turning type'.

## 5 Acknowledgment

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