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INVESTIGATION ON HEAT TRANSFER COEFFICIENT AT METAL-SAND MOULD INTERFACE IN SAND CASTING PROCESS - A REVIEW

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Abstract – To simulate the casting process and estimate casing defects, interface heat transfer coefficient is a necessary step towards it. For accurate simulation of any casting process the interfacial heat transfer coefficient (IHTC) or heat flux is required. IHTC value or Heat Flux value is vary essential which indicates the heat transfer at casting and mold surface interface. In any casting process, there are large number of factors which affects heat transfer and decreases quantification by theoretical means a challenge. Similarly, Experimental methods applied directly to temperature data collected from castings are also a challenge to interpret because of transient nature of many casting processes. Many researchers have applied inverse methods to estimate interfacial heat transfer coefficient at metal-mold interface in sand casting process.

Keywords- Metal-Sand Mould Interface, Sand Casting, Heat Transfer Coefficient (HTC), Heat Flux.

I. INTRODUCTION

The success of simulation-based process design of castings to predict accurately the thermal history and to locate hot spots inside the casting depends to a large extent on a reliable data base on the heat transfer boundary conditions specified at the casting/mould interface. Further, when the metal and the mould have good rates of conductance, the boundary between the two becomes the region of dominant resistance. When the molten metal is poured into a mould, the rate at which it can lose heat is controlled to a significant extent by the heat transfer at metal/mould interface. During the last two decades the use of solidification simulation software for both design of casting processes and their optimization from quality stand point has greatly increased with improvements in the computational technology. It is then essential to determine the Heat Transfer Coefficient (HTC) on metal-sand mould boundaries exactly. The computer simulation of solidification of castings offers a basis for predicting the solidification patterns and casting defects with accuracy.

During the filling process of an alloy, an interface layer between melt and mold unavoidably forms as different thermal response to temperature variation and coating effect. Meanwhile, the heat transfer of interface layer has an important influence on the solidification process. Hence, it is important to investigate the heat transfer of the interface layer, which leads to a problem of calculation of interfacial heat transfer coefficient (IHTC) between the metal/mold interfaces. Many researchers have contributed to the understanding of heat transfer at metal-mold interface, which can be characterized either by interfacial heat flux (q) or interfacial heat transfer coefficient (h). Modelling of the casting/mould interfacial heat transfer is one of the critical problems in numerical simulation of casting solidification as it is influenced by casting parameters like the type of alloy, super heat, latent heat of fusion and mould variables that include the roughness of the mould surface in contact with the solidifying alloy, thermophysical properties of the mould, preheat temperature etc.

II. LITERATURE REVIEW

Since past few decades' solidification simulation, particularly interfacial Heat Transfer Coefficient have been a foremost topic of research. Here, a review has been carried out on the history of solidification simulation for metal-mould interface, importance of IHTC in solidification simulation, methods available for the determination of IHTC and influencing parameters on IHTC. The present review includes solidification simulation, various aspects in solidification modelling, estimation of IHTC at metal/mould interface by inverse method and effect various parameters on heat transfer coefficient and heat flux.

A. ZHANG [1], et.al. have determined the interfacial heat transfer coefficient (IHTC) at the metal-sand mould interface by applying a nonlinear inverse estimation method during the low-pressure sand casting (LPSC) process. Experiments were conducted using plate shape castings with different thicknesses for both ZL205A and ZL114A aluminum alloys. To estimate interfacial heat transfer coefficient, a specific temperature sensor unit was developed to measure accurate temperature at predefined location inside the sand mould and cast metal. From their investigation they revealed that the time-dependent

IHTC during the LPSC mainly comprised two stages such as rapid increasing stage and maintain stage, and the second stage could be further divided into two parts based on the plate thickness. They have also found that IHTC was highly dependent on the casting material. LAZAR KOVACEVIC [2], et.al. estimated interfacial heat transfer coefficient at the metal mould interface by iterative algorithm based on the function specification method. For their investigation Al-9 wt.% Si alloy selected as cast material and sand mould was prepared by CO2 process. They obtained thermal history from the experiment and found out transient interfacial heat transfer coefficient. IHTC Graph was plotted against temperature and found that IHTC has nearly constant values at temperature up to 560°C. With increase in temperature to its liquidus temperature IHTC increases following 'S' shape. GIANFRANCO PALUMBO [3], et.al. investigated the most appropriate methodology to determine the heat transfer coefficients for the numerical modelling of the casting process of a super duplex stainless steel (ASTM A890 Gr. 5A) using a silica sand mould. They have utilized instrumented castings to acquire temperature changes for a number of points of interest by means of thermocouples. They Compared the temperature changes of different thermocouple location and determined interfacial heat transfer coefficient for metal mould interface.

The interfacial heat transfer coefficient between AZ91D magnesium alloy and silica sand was investigated by LIPING CHEN [4], et.al. They have selected a simple and feasible geometry for evaluation of interfacial heat transfer coefficient. They applied Beck algorithm of inverse heat conduction method to find out IHTC. They found that when the temperature of location of interface was 595-593°C HTC decrease rapidly from 525 to 410 W/m2 k due to the onset of air gap. When temperature was between 593-554°C IHTC decrease slowly due to continuous feeding and in the last stage IHTC decrease rapidly to a constant value. M.A. MARTORANO [5], et.al. have investigated the heat transfer coefficient at the metal-mould interface in the unidirectional solidification of Cu-8% Sn alloys. Charges of nominal composition Cu-8% Sn composed of electrolytic copper and tin were melted in an electric resistance furnace and deoxidized with Cu-15%P. The liquid alloy was cast into cylindrical shapes using the casting system. This system consists of a cylindrical thermal insulating sleeve made of a mullite based material (Kalmin TH1) standing on a copper base employed to extract heat directionally. The complete domain estimation can give heat transfer coefficient values between metal and water- cooled or massive copper base which are in good agreement with the published data. The heat transfer coefficient values at metal- insulating sleeve interface calculated by the whole domain estimation are widely spread compared with its absolute value. K.N. PRABHU and W. D. GRIFFITHS [6] have investigated the heat transfer during metal mould interface during solidification of Cast iron. An inverse method was used to measure the heat flow at metal mould interface during solidification of cast iron in dry sand and graphite sand mould. The interfacial heat transfer and interfacial heat flux was measured temperature inside the mould during solidification of metal. The sand mould heat flux transient showed a double peak during solidification of the metal. The graphite mould heat flux transient showed only a single peak associated with the formation of the stable solid shell. Gap is formed and there was a rapid decrease in HTC.

Heat flow at casting mould interface and study during solidification of Al-Cu-Si (LM 21) alloy in preheated cast iron mould in two different thickness, coated with graphite and alumina-based coatings were investigated by K. NARAYAN PRABHU [7] et.al. The thermal history at nodal locations in the mould and casting obtained during experimentation was used to estimate the heat flux by solving the one-dimensional inverse heat conduction problem. The cooling rate and solidification time were measured using the computer-aided cooling curve analysis data. The high values of heat flux transients obtained with thin moulds were attributed to mould distortion due to thermal stresses. For thin moulds, assumption of newtonian heating yielded reliable interfacial heat transfer coefficients as compared with one-dimensional inverse modelling. The time of occurrence of peak heat flux increased with a decrease in the mould wall thickness and increase in the casting thickness. S. K. MUTTAGI [8], et.al. have evaluated interfacial heat transfer coefficient between casting and round chilled moulds during solidification of aluminum alloy casting. Widely used LM 6 aluminum alloy was used as a casting material. To achieve unidirectional heat flow metallic chill is placed at the bottom. Different thickness metallic chills were used in order to observe the effect of thickness on heat transfer coefficient. Their study shows the heat flux is across the interface depends upon the thickness of the chill and time for airgap formation is delayed for higher thickness. HTC in the case of thinner chill is more than thicker chill.

M. M. PARIONA [9], et.al. investigated on numerical simulation of heat transfer during the solidification of Pure Iron in sand and mullite moulds. In this study reported, two dimensional numerical simulations were made of pure iron solidification in industrial AI 50/60 AFS greensand and mullite moulds, using the finite element technique and the ANSYS software program. Results in 2D were obtained, such as the heat transfer, the thermal flow, the thermal gradient, the convergence control and the behavior of the temperature in different selected paths. The result was completely different in both systems. This can be due to the fact that these moulds possess different physical properties. Therefore, cooling in the sand system was slower than in the mullite system. A. V. REDDY [10], et.al. have investigated metal-mould heat transfer coefficient during solidification of Sn and Sn-Pb alloys. Experiments were carried out in 50mm square cavity. Thermocouple measurement were carried out using chromel-alumel (K-type) thermocouples. In the case of solidification of pure Sn, an interfacial gap forms soon after nucleation, due to contraction of the melt upon solidification. The corresponding interfacial heat transfer coefficient can be determined from cooling experiments after solidification is complete. The use of this constant h in a numerical simulation of the solidification experiment resulted in good agreement with measured temperatures.

III. CONCLUDING REMARKS

- There are basically two methods to measure the IHTC. To measure the size of the gap formation between the metal casting and chill and correlate this gap size with the heat transfer coefficient. To conduct the temperature measurements in the casting and the chill at several designated locations and use an inverse method to derive the HTC.
- It has been found that value of heat transfer coefficient depends on the cast material, mould properties and freezing range of an alloy.
- San property and composition, the mold wall, casting thicknesses, and the coating material of the mold affect the thermal behavior at casting mould surface and so that heat transfer coefficient and heat flux value can be affected.

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