International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 10, October-2018

EFFECT OF DIFFERENT CHILL PARAMETERS ON SOLIDIFICATION OF CASTINGS – A REVIEW

Keyur V Patel[1], Prof. Mamta P Patel[2]

[1]*Reasearch Scholar, Mechanical Engineering, Babaria Institute of technology,*
[2] *Assistant Professor, Mechanical Engineering, Babaria Institute of technology,*

Abstract – ***The interfacial heat transfer coefficient (IHTC) is an important factor for precise simulation of casting simulation of heat transfer in castings. The large number of aspects prompting heat transfer renders 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. Inverse methods offer a solution and have been applied successfully to predict IHTC in many cases. Chill material, chill size or thickness, superheat, chill surface roughness, chill cooling conditions etc. are different parameters which have significant effect on heat transfer at casting-chill surface interface.***

Keywords- Sand Casting, Heat Transfer Coefficient (HTC), Heat Flux, Casting-chill interface.

I. INTRODUCTION

Today in industry, demand for highly competitive products in foundry manufacturing is very high. So, there is a need to develop reliable tools for process evaluation. 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 and metal-chill boundaries exactly. which are, on the other hand, usually very roughly evaluated in the available FEM codes, thus resulting in process simulations often far from reality. Further the computer simulation of solidification of castings offers a basis for predicting the solidification patterns and casting defects with accuracy. However, the success of any commercially available casting simulation packages depends to large extent on the use of accurate thermophysical data and boundary conditions by solidification modeler.

The use of chills during freezing of aluminum or any non-ferrous metal or alloy plays a major role in promoting directional solidification. One of the important factors that affects heat transfer from the solidifying casting to chills is resistance offered by casting-chill surface interface. The interface becomes significant when the metal and the chill have reasonably good rates of thermal conductance. Many researchers have contributed to the understanding of heat transfer at metal-mold interface and casting-chill interface which can be characterized either by interfacial heat flux (q) or interfacial heat transfer coefficient (h).

II. LITERATURE REVIEW

Solidification simulation in general and IHTC in particular, have been a main topic of research since several years. In this work, a review has been carried out on the history of solidification simulation, importance of IHTC in solidification simulation, methods available for the determination of IHTC and influencing parameters on IHTC. The present review includes (i) Solidification simulation (ii) Various aspects in solidification modelling (iii) Estimation of IHTC (iv) Estimation of IHTC by inverse method (v) Effect various parameters on IHTC.

A. MENEGHINI [1], et.al. have investigated the effect of chill material and thickness on evolution of Heat Transfer Coefficient (HTC) in sand casting of aluminum alloy. The variation in time of the HTC in the whole cooling process was reconstructed with many kinds of chills, different in size and materials. Cast iron, aluminum, and copper were used as chill materials. They have also considered HTC between aluminum and sand mould. Experiments were performed with a A356 alloy, cooled on chills made of cast iron, copper and aluminum. Their main design standards were to ensure a foremost unidirectional heat flow during solidification and, at the same time, to replicate typical foundry environment and processing conditions. The surfaces of the chills were those typically used in the foundry, having a mean Ra value of 0.8 µm and with a square grid 10mm×10mm of about 1mm depth grooved on the surface. In order to investigate the influence of chill thickness on heat flow, three different chills thickness were used (H= 30, 60 and 90 mm). Two K-type thermocouples of 1mm diameter were introduced in the chills. All the thermocouples, calibrated at the melting point of aluminum, were connected by coaxial cables to a data logger interfaced with a computer and the temperature data were acquired automatically every 0.5 s during solidification time. The temperature files were used in a finite difference heat flow program to estimate the transient heat transfer coefficients. The alloy was melted in an electric resistance-type furnace until the molten metal reached a predetermined temperature. The melt, after degassing by means of argon and modification with strontium, was kept still until the temperature of 730 ◦C was reached and then poured into the casting chamber. The sand used in the casting experiments was a sand silica. Prior to casting the assembly was heated with a C2H2 flame for 10 min in the basin zone. They have observed very long solidification times are present with cast iron chills and intermediate behavior for aluminum chills. HTC values from typical 3000–4000 W/m^2K with 30mm chill up to 7000-8500 W/m^2K with 90mm chill. A different behavior of HTC distribution in process time is also apparent: whereas in 30mmchill the HTC continuously decreases after a first early maximum, in 60 and 90mm chills an almost steady increase in HTC can be observed, until a maximum is obtained after about 30 s of cooling. The different time of effectiveness of the different chills is also interesting: the 90mm one has the longest time of heat sub traction, about 42 s; 33 s is the time of effectiveness of 60mm chill.

M.A. GAFUR [2], et.al. have investigated the effect of chill thickness and superheat on casting/chill interfacial heat transfer during solidification of commercially pure aluminum. They investigated HTC for pure aluminum square bar castings with cast iron chill at one end. Commercially pure aluminum (Al 99.5%; Fe 0.25%, Cu 0.15%, balances other) was melted in gas fired pit furnace. The liquid metal was degassed using hexachloroethane tablets before pouring into the mould. For fluxing, ammonium chloride was used. The heat transfer coefficient increased from a vary small value to a peak value and decreased sharply thereafter to reach a steady value. The peak heat transfer coefficient was obtained at the end of filling and were in the range 1535-36 W/m^{2}°C corresponding to superheats of 45-140 °C and the steady values obtained were in the range 900-2100 W/m^{2}°C. The effect of chill thickness on heat transfer coefficient was found to be negligible. They have obtained higher heat transfer coefficient for higher super heats. The effect of chill thickness was not significant for heat transfer coefficient.

LIQIANG ZHANG [3], et.al. have developed inverse heat conduction model and its application to determination of heat transfer coefficient during casting solidification. Tapered cylinder casing geometry was selected and solidified against copper chill to obtain temperature data required for input to inverse model. Three K-type thermocouple were positioned within the mould at 2, 5 and 10 mm from the chill to measure the evaluation of temperature with time. Results shows IHTC was varying with time. HTC values vary from 1200 to 6200 Wm-2 K-1. HTC was high at initial time period and then steeply decrease.

Heat transfer coefficients during solidification of an Al-4.5% Cu alloy have measured by WILLIAM DAVID GRIFFITHS [4], et.al. Chill material used was copper with varying surface roughness. Chills were water cooled and in cylindrical shape. Two orientations of the experiment were used. With the chill placed in the base of the refractory fiber tube solidification occurred in upward direction and with chill placed in the top of the tube, solidification occur vertically downward. Six K-type thermocouple were used to monitor temperature changes in casting and the chill. To obtain heat transfer from measured temperature data the one-dimension transient heat conduction equation was solved using an explicit finite difference technique for both the solidifying casting and the water-cooled copper chill. For these experimental arrangement and casting chill interface, interfacial heat transfer coefficient found to have wide scatter varying within the range of 10 to 40 kW m^{-2} K^{-1}. No consistent relationship was observed between heat transfer coefficient and chill surface roughness. It was also found that effect of cerium addition has also a significant effect on heat transfer at casting chill surface interface by K.N. PRABHU [5], et.al. effect of cerium addition on casting/chill interfacial heat flux and casting surface profile during solidification of Al-14 % Si alloy. The heat transfer studies were carried out by using copper, brass and cast-iron chills. A stainless-steel tube of 50mm outer diameter with a wall thickness of 1 mm attached at the top of the chill. On 1.5% Ce addition, the pick heat flux increased by 38%, 42% and 43% for solidification against copper, brass and cast-iron chills respectively. The surface profile analysis has shown that Ce addition resulted in smoother casting surface in the case of copper and brass chills and rougher surface in the case of cast iron chilled casting. The casting surface profile was convex towards the copper and brass chill surfaces and concave towards the cast iron chill surface.

It was also found that different chill cooling conditions have different effect on cooling rate, micro structure and interfacial heat transfer coefficient for sand casting. F. FARHANG MEHR [6], et.al. have investigated the same for A319 aluminum alloy as cast metal. Solid copper chills and water-cooled chills, with and without delay in water cooling, were examined in study. Chill preheat was found to have only a small effect on cooling rates between 5 and 50 mm from the casting chill interface, pour superheat a moderate effect and water Colling a significant effect. According to the experimental results, the melt temperature drops 60°C during the pouring process. Chill preheat was found to have only a relatively small effect on the cooling achieved with A319 wedge casting over the range of condition. Cast superheat was found to have moderate effect on the cooling rate for the same condition. Water cooling condition was found to significantly reduce the cooling rate on 5 and 50mm locations. Switching the water on with a 10sec delay was shown to be effective. SAHIM H. M. [7], et.al. have determined metal-chill interfacial heat transfer coefficient during the unidirectional solidification vertically upward of a cylindrical Al-Si alloy casting on the water-cooled surface of copper and steel chills. They have compared the interfacial heat transfer coefficient for both the copper and steel chills. Liquid metal was cast in a ceramic mold made of an alumina silicate refractory tube of length 290mm, inner diameter 28 mm and wall thickness 10mm. A finite difference method was used for solution of inverse heat conduction method. Six computer guided thermocouple were connected with chill and casting. The thermocouples were placed symmetrically, at 5mm, 37.5mm and 75mm from the interface. The alloy was melted in an electric resistance oven until the molten metal alloy reached a pre-determined temperature (980K), above their melting temperature of 849 K, and then cooled to room temperature in the mould. The HTC have varied between about 19-9.5 kW/m^2K and 6.5-5 kW/m^2K on copper and steel chill respectively. The IHTC could be affected mainly by the contact position and area between the casting and chill surface roughness. W.D. GRIFFITHS [8], et.al. have measured during the unidirectional solidification of Al-7 wt.% Si alloy castings against a water-cooled Cu chill. Alumina-silicate fiber refractory tube of length 300mm, inner diameter 25mm and wall thickness 20mm used as a mould. The mould were arranged so that solidification occurred vertically upward, vertically downward or horizontal. Every refractory fiber mould was preheated at 900°C and cooled at room temperature. HTC vary between 2.5 and 9 kW/ m2K depending upon orientation on the direction of solidification. Solidification vertically upward was associated with the highest values of the HTC while vertically downward has lower values of HTC.

M.A. TAHA [9], et.al. have investigated effect of melt superheat and chill material on interfacial heat transfer coefficient in end chill Al and Al-Cu alloy castings. They have used copper, steel and dry molding sand as chill materials while commercially pure aluminum and Al-4.5 t. % Cu alloy as cast materials. The cast ingots have cylindrical shape with 12.5mm diameter and different length of 95 and 230mm. It solidifies different superheats 50-110°C. A computer program solving one direction heat conduction equation was used to compute the temperature history at numerous points along the ingot length. They have found that HTC increase with increase in superheat, HTC was found to be higher for copper chill than for sand chill and it increase with increasing specimen length. T.S. PRASANNA KUMARA [10], et.al. have found transient heat flux at casting chill interface during solidification of Aluminum base alloy. They have used Al 13.2 pct. Si and Al-3 pct. Cu 4.5 pct. Si as casting alloys and Cu-10 pct. Sn – 2 pct. Zn alloy as chill materials. In their investigation, the chill was partially embedded in sand, with its external surface exposed to ambient conditions. Thus, the chill could be treated as the wall of metallic mould, as in the case of gravity die casting. Co2 sand mould with square chill at one end used for casting bar of aluminum alloys. Carbon dioxide sand mould ware made using washed grade silica sand of AFS fineness number 65 and 5 pct. sodium silicate as binder. Alloy ingots were melted in an electric resistance type furnace and degassed with hexachloroethane tablets before pouring. The pouring temperature was 1023K. They found that Qmax depends upon the thickness of the chill and its thermal diffusivity. The alumina coating generally resulted in higher heat flux values than fireclay coating. N. A. EL-MAHALLAWY [11], et.al. obtained the metal mould heat transfer coefficients by using experimental and computer simulation results of lead solidifying in end chill experiments. Commercial purity lead (99.98wt %) is used with a superheat of 170K. Steel cylindrical mould (1.5ram thickness, 200mm long, 24ram internal diameter) surrounded by a 70mmm thick asbestos insulation. The mould is internally coated with a dried layer of alumina + magnesia in water-glass and is fixed on a water-cooled copper chill block. A computer simulation model is set up to find time temperature curves for the nodal points corresponding to the thermocouples used in the experiments. In the present set-up the heat flow is mainly one-dimensional. First high and constant value was obtained because of good contact. After starting of solidification gap is formed and there was a rapid decrease in HTC.

III. CONCLUDING REMARKS

- It has been found that value of Heat Transfer Coefficient (HTC) depends upon various factors like casting material, Superheat, Chill surface roughness, chill material, chill size, mould material and applied pressure (in squeeze casting).

- Chill surface coating, preheat and water-cooling condition have also a significant effect on HTC during casting/chill surface interface.
- It has been found that 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.
- There is no such data available that, how much size of chill should be used for particular casting? So, there is a need to develop correlation between modulus of casting, chill size and material.

REFERENCES

[1] A. Meneghini and L. Tomesani, "Chill Material and size effect on HTC evolution in sand casting of aluminium alloy", Journal of materials processing Technology, 162-163 (2005) 534-539.

[2] M. A. Gafur, M. Nasrul Haque and K. Narayan Prabhu,"Effect of chill thickness and superheat on casting /chill interfacial heat transfer during solidification of commercially pure aluminium", Journal of materials processing technology., 113(2003)257-265.

[3] Liqiang Zhang, Carl Reilly and Luoxing Li,"Development of inverse heat conduction model and its application to determination of heat transfer coefficient during casting solidification", Heat mass transfer, 10.1007/s0023-014-1304-6.

[4] William David Griffiths and Ramazan Kayikei,"The effect of varying chill surface roughness on interfacial heat transfer during casting solidification", Journal of Material Science., 10.1007/s10853-006-0388-x.

[5] K N Prabhu and V Vijeesh,"Effect of cerium addition on casting/chill interfacial heat flux and casting surface profile during solidification of Al 14% Si alloy",2016 IOP Material science and engineering.,117 012034.

[6] F. Farhang Mehr, C Reilly, S Cockcroft. et al.,"Effect of chill cooling conditions on cooling rate, microstructure and casting/chill interfacial heat transfer coefficient for sand cast A316 alloy", International journal of cast metal research.,2013.

[7] Hasi Mehmet Sahin, Kadir Kocatepe, et al.," Determination of unidirectional heat transfer coefficient during unsteady-state solidification at metal casting-chill Interface., Energy conversion and Management, 47(2006)19-34

[8] Griffiths W. D.,"The heat transfer coefficient during the unidirectional solidification of an Al-Si alloy casting., Metallurgical and material transactions", Volume 30B June 1999-473.

[9] Taha M.A., et.al., Effect of melt superheat and chill material on interfacial heat transfer coefficient in end chill Al and Al-Cu castings., Journal of material science 27(1992) 3467-3473.

[10] Prasannakumar T.S., et.al., Heat flux transients at the casting/chill interface during solidification of alluminum base alloy., Metallurgical and material transactions., Volume 22B October 1991-717.

[11] El-Mahallawy N.A., et.al., Effect of melt superheat on heat transfer coefficient for alluminum solidifying againat copper chill., Journal of material science 26 (1991)1729-1733.