INTERNATIONAL EDUCATIONAL APPLIED RESEARCH JOURNAL (IEARJ)
Volume 03, Issue 06, June 2019
E-ISSN: 2456-6713

Thermal Observation of Casting for Aluminium Alloy at Various Moulding Sand

Manmohan Yadav[1], Yogesh Kumar Tembhurne[2]

[1]*Research Scholar, Department of Mechanical Engineering, B.E.R.I. Bhopal, India.*

[2]*Asst. Prof., Department of Mechanical Engineering, B.E.R.I. Bhopal, India.*

Abstract: ***The grain size and mechanical properties of cast metal are defined by the geometrical characteristics and thermophysical properties of the metal and the mold. Heat loss from the mold to the environment through convection can also affect the mechanical properties of cast metal. Present study reports two-dimensional numerical simulations made of aluminium alloy solidification in industrial AI 50/60 AFS greensand and mullite molds, using the finite element technique and ANSYS (version 14.5) software. FEA software like ANSYS may play an important role in predicting cast defects before the actual casting.***

Metallurgical characteristics, such as the attack zone in the feed head and hot top were not taken into account in this study, since they are irrelevant the behaviour of heat transfer of the metal to the mold. Owing to the moulds temperature dependent thermo physical properties, this type of problem is of nonlinear characteristic.

Keywords: *Casting Process, Heat Transfer, Finite Element Technique, ANSYS Cast Defects.*

INTRODUCTION:

1. **Casting of Metal:** To a effective effective production in castings knowledge of the following operations required:
   - Preparation of moulds and patterns
   - Melting and pouring of liquefied metal
   - Solidification and further cooling to room temperature
   - Inspection and quality control
2. **Mould construction:** Casting can be produced in either permanent metal mould or expandable refractory mould. The use of metal moulds or dies for making parts in die casting has certain major limitations.
3. **Mould design:** This reduces the number of moulding operations and minimizes sand consumption. These objectives are achieved by the use, whenever possible, of multiple casting moulds in which two or more patterns are grouped round a common sprue or feeding system:
   (i) Better utilization of mould material
   (ii) Higher yield
   (iii) Reduce production time per casting
4. **Casting solidification:** Solidification in all castings begins with the initiation of crystallization at the mould walls shortly after casting is poured, thus forming a thin layer of solid metal there, solidification proceeds by gradual thickening of this layer of solid metal.
5. **Basic mechanisms of heat transfer:** The basic mechanics of heat transfer includes conduction, convection, radiation, boiling and condensation out of which conduction, convection and radiation play important role in casting.

   (i) Conduction: In the context of metal casting, conduction is the mechanism by which heat is transferred within the solidifying metal and the mould. Conduction can be steady state or transient state. In casting application, transient conduction is more prevalent.

   Heat conducted through a medium is given by

   $$Q = \frac{KA}{t}(\Delta T) \quad (1)$$

   Where

   Q = Heat flow

   K = Thermal conductivity of the medium

   A = Area through which heat is flowing

   t = Thickness of the medium through which heat is flowing

   ΔT = Temperature difference between two surfaces.

   (ii) Radiation: In contrast to conduction and convection, which involve transport of energy through a material, energy may also be transferred through a vacuum. The mechanism is by electromagnetic radiation, and is specifically called thermal radiation. Radiation occurs on the outer surfaces of the mould and at casting-mould interface.

The net radiant exchange between two surfaces is given by:

$$Q = \varepsilon_1 A_1 \sigma (T_s^4 - T_\infty^4) \quad (2)$$

Where

ε_1 = Emmisivity of the surface

σ = Stefan-Boltzmann constant = $5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$

T_s = Mould Surface Temperature

T_∞ =Ambient Temperature

(iii) Convection: Convection mode of heat transfer is considered in many contexts like

1. Heat transferred within liquid metal
2. Heat lost from outer surface of the mould
3. Heat transferred at metal-mould interface

Heat transfer at the outer surface of the mould is assumed to take place by natural convection and radiation. The heat transfer value is given by:

$$Q = hA(T_s - T_\infty) \quad (3)$$

Where

Q = Heat flow through convection

h = Convective Heat Transfer Coefficient

A = Surface Area through which heat is flowing

T_s = Mould Surface Temperature

T_∞ = Ambient Temperature

LITERATURE REVIEW:

Qiao et al. identified Corrosion or breakdown can also occur due to high speed and temperature in the molten metal. To predict such defects, analysis of flow and heat transfer must be conducted during the packing stage of the cast. The solidification time is shorter in thin part compare with the thick part. Microstructure for prediction aspects including nucleation density, grain size, the more adequate for filling the nucleation density larger but grain size smaller, directly determines the physical and mechanical properties of finished components.

Pariona et al. cooling in the sand system was slower than in the mullite system. This fact caused a larger thermal flow and thermal gradient in the sand system than in the mullite system. These phenomena happen especially in the cold zone of the cast metal, where the solidification begins. Heat loss from the mold to the environment through convection can also affect the mechanical properties of cast metal. It was also observed that, in the convergence process, the mullite system needed a larger iteration number, probably because it reached lower temperatures than the sand system, during the same time of solidification. In the cooling curves, at several points of the sand system presented phase changes, however, this did not happen in the mullite system.

Prabhu et al. The peak mold temperature increased with an increase in the casting thickness due to its higher heat content.

The estimated heat flux transients showed a peak due to the formation of a stable solid shell, which has a higher thermal conductivity compared with the liquid metal in contact with the mold wall prior to the occurrence of the peak. The high values of heat flux transients obtained with thin molds were attributed to mold distortion due to thermal stresses.

Seetharamul et al. A single cooling environment over its solidification period exists for a static casting whereas continuous cast section encounters different environment- mould, sprays, pinch rolls contact, radiation before complete solidification take place. Thus the continuously cast change rapidly from one zone to another resulting in higher thermal stresses than in ingot castings. Continuous cast section, in addition, is also stressed by pinch rolls, bending and straightening operations during solidification mould oscillation, misalignment of mould and roller cages. Ferrostatic pressure can also produce sufficient stress to cause bulging across the wide faces of large slabs.

Cervera et al. Thermo-mechanical contact conditions between the mould and the part are specifically considered, assuming that the heat flux is a function of the normal pressure and the thermal and mechanical gaps. A fractional step method arising from an operator split of the governing equations is used to solve the non-linear coupled system of equations, leading to a staggered product formula solution algorithm suitable for large-scale computations.

Vijayaram et al. Solidification simulation of castings provides time-temperature data, temperature contours, hot spot locations, degree of recalescence, latent heat of fusion and solidification time.

Canales et al. The temperature at which the complex Al-Si-Cu-Mg eutectic is formed is unaffected by either silicon or iron. The iron rich intermetallic were of the α- type due to modifying effect of manganese present in the experimental heat.

Kang et al. Die design by computer simulation has some advantages compared with the conventional process that is performed by designer’s experience and trial and error. The experiment of semisolid casting was performed with the conventional die design concept. Various defect shapes were found on the surface of the semi-solid cylinder block parts. Evaluation of die gate system to obtain parts without defects was realise by computer simulation.

Alawadhi et al. Conduction mode of heat transfer is widely considered in thermal system, and the effect of natural convection is assumed negligible. The present work studies the effect natural convection of liquid water on the solidification rate. Apparent capacity method was used to simulate the release of the latent heat.

Prashant et al. Calculated modulus is always less than effective modulus of neck. It is possibility that neck modulus would be more than feeder modulus and reverse feeding from casting to feeder will occur and it will result in shrinkage porosity in casting.

Sergey et al. Comparison of numerical results to available experiment data show that the formulated model provides a solution of acceptable accuracy despite some uncertainty in material properties and boundary and initial conditions.

Das et al. Thermal stress in the mullite mold is less than the sand mold. For the sand-mullite composite mold shrinkage is least as well as shrinkage for the cast is also least. But the thermal stress is more than the mullite mold. So optimization can be done as a future work for best combination of mold materials in a composite mold with optimum thicknesses.

Objectives:

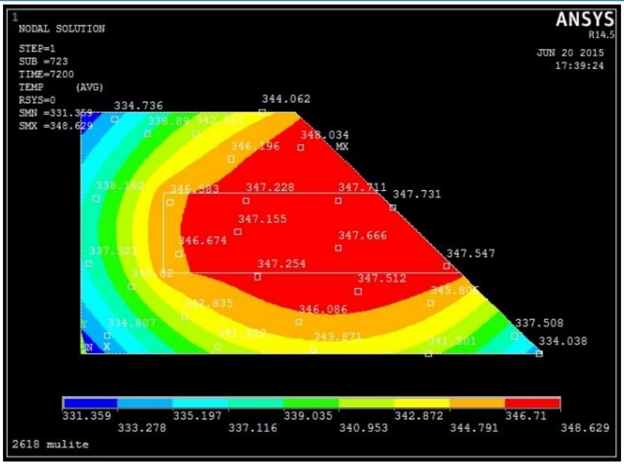
To understand the physics of the solidification process of casting, factors affecting solidification process of casting & Study the inter-relationship of these parameters and their relative influence on the solidification process of castings.

Methodology:

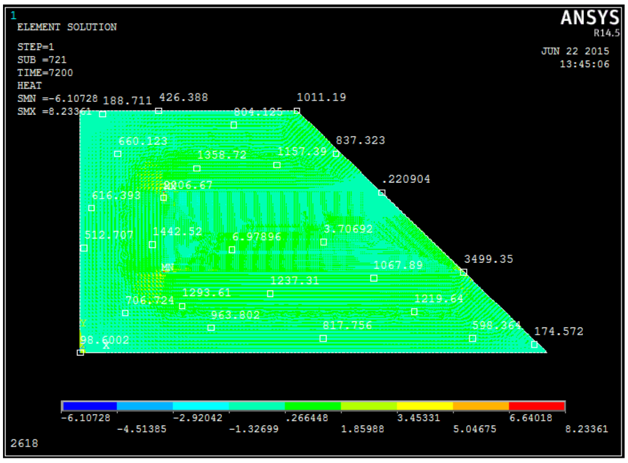
The cast object and mold design has been referred from the work of M. M. Pariona and A. C. Mossi [3]. In their work M. M. Pariona and A. C. Mossi considered a channel shaped cast object which was cast using pure iron
The temperature profiles through the mould are drawn and the solidification time of a casting is calculated. Temperature dependent properties for Aluminium are taken into consideration. Temperature dependent material properties like thermal conductivity and enthalpy are used to determine heat transfer during phase change. The following three steps are used to carry out the analysis.

RESULTS AND DISCUSSION:

The phenomenon of convection that occurs between the mold and the environment was included in this study the sand mold had a range of temperature variation between 303 K and 431 K and the mullite mold had a range of 343 K and 378 K, consequently, in the sand mold there was a larger range of temperature variation.



Thermal flow in assembly



It can be observed that the largest magnitude of the thermal flow corresponds to the minimum point (MN) of the temperature distribution, because at this point the solidification begins.

Inside sand mold and mullite mold for 2618 T6

Cooling curve in sand was represented by the points P9 and P11 because they were very near to the cast metal.

Heating curves in the mullite mold are presented at points P7, P13, P14, P15, and P16 because these points are far from the cast metal. On the other hand, at points P11, P9 and P8 only the cooling curves are presented, because they are close to cast metal.

Inside cast with sand mold and mullite mold for 2024 T6

In case of mullite mold slope of cooling curve is steep up to temperature 482 and 460 second of solidification from start point of solidification and then slope of the cooling curve is uniform and going to converge to temperature of 377K at the end of 7200 second of solidification.

Slope of cooling curve for cast in sand mold is uniform, and means cast is going to solidify slowly. As compare to cast inside of the mullite mold. In sand mold slope of cooling curve is steep up to temperature of 538 K and 400 second of solidification and then slope of the cooling curve is going to converge to temperature of 435 K at the end of 7200 second of solidification.

Inside sand mold and mullite mold for 2024 T6

The heating and cooling curves in the mullite mold are presented at points P6, P7, P8, P9, P10, P11 and P12 there is an abrupt heating, and cooling presents an accentuated fall, as compared with the sand mold. And heating curves in the mullite mold are presented at points P14, P15, and P16 because these points are far from the cast metal. On the other hand, there is no cooling curve inside the mullite mould.

CONCLUSIONS AND FUTURE SCOPE:

This study is a comparative work of the numeric simulation using finite element method for solidification process of Aluminium alloys in sand and in mullite molds, during 2h of solidification. Results in 2D were obtained, such as the heat transfer, the thermal flow, the thermal gradient, the convergence control and the behaviour of the temperature in different selected points. The result was completely different in both systems. This can be due to the fact that these molds possess different physical properties. Therefore, cooling in the sand system was slower than in the mullite system. This fact caused a larger thermal flow and thermal gradient in the sand system than in the mullite system. These phenomena happen especially in the cold zone of the cast metal, where the solidification begins. It was also observed that, in the convergence process, the mullite system needed a larger iteration number, probably because it reached lower temperatures than the sand system, during the same time of solidification. In the cooling curves, at several points of the sand system presented phase changes, however, this did not happen in the mullite system. This phenomenon can be explained by the fact that in the sand system the cooling is slower than in the mullite system. Possibly in the sand system the diffusion phenomenon prevails. The cooling curves characterize the grain size and mechanical properties of metal; hence, owing to the smaller grain size of metal cast in mullite molds, this type of mold grants better mechanical properties to the cast part. The cooling and/or heating in the molds was also studied, and in the mullite mold the heating and cooling are abrupt, but all the curves in both systems tend to converge.

Future scope:

The effect of Interfacial Heat Transfer Coefficient (IHTC) and radiation can be studied in more detail and its temperature dependent values can be incorporated in the simulation as boundary condition. It is useful to extend the scope of the project to other casting processes and materials.

Currently it is limited to ferrous sand castings.

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