Gating system design for warpage reduction

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Abstract
Casting free defect is the main aim for foundry men. To achieve this foundry man does number of shop trial to eliminate defects and this takes lot of time to design proper system. Casting defects such as hot spot, shrinkage, misrun etc occur as result of solidification phenomenon. For better casting gating system plays an important role. Changes in feeder parameters- feeder position, shape, size can lead to appropriate casting of product. Selection of correct design is must for better yield of product but difficult to achieve. Casting simulation software’s have eased the life of foundry man by designing proper gating system. In this work AUTOCAST software has been used which is an easy to use program based on vector element method for solidification simulation to predict shrinkages and porosity easily. In this work we present simulation studies for large body part.

Key words: Sand casting, warpage, software, simulation, casting design.

I. INTRODUCTION
Sand casting is subjected to various defects which are controllable by proper foundry techniques but not fully preventable. Warpage is one of the defects in sand casting which is explained further.

Warpage
Warpage is an undesirable change that occurs during or after solidification of part in casting. It occurs mainly in large and flat surfaces due to variations of internal stresses in the material due to variation in shrinkage. The various factors that affect warpage are:
1. Mold temperature
2. Differential cooling
3. Wall thickness
4. Material selection
5. Flow restrictors and bypasses
6. Gating system
7. Inconsistent shrinkage

Causes of warpage
Non uniform cooling: when part is removed from mold it cools to uniform temperature but due to contraction at either side it warps.
Inconsistent shrinkage: inconsistent shrinkage may be due to material variation such as properties, moisture content, inconsistent melt and variation in mold and melt temperature.

Warpage can be minimized by design of multipoint gating system, use of chills, and use of bind cores during mold design, study of shrinkage curve, minimizing differential shrinkage, change in material, orientation effect, computer simulation technology etc.

In foundry industry three approaches have been adopted to study the flow through gating system namely- empirical relations derived from experimental observations, hydraulic based analysis, simulation. AUTOCAST software has been used to simulate the object.

Fig. Cross section of casting

Elements of gating system
Gating system has following elements:

a) Pouring basin: Molten metal enters the mold through basin.
b) Down sprue: From pouring basin the metal flows towards mold through sprue.
c) Ingate: To enter the inner cavity the metal has to pass through ingate.
d) Runners: Passage through which metal is distributed to different parts of the mold.
e) Vents: Openings that allow gasses to escape during solidification.
f) Risers: Reservoir of metal to compensate for shrinkage as the metal solidifies.

Design of gating system includes following parameters:

- a) Type of gating system used (top, parting, vertical, bottom)
- b) Position of gates and runner.
- c) Design of riser and sprue and there position.
- d) Gating ratio.
- e) Pouring time, pouring temperature, pouring rate selection.
- f) Layout of gating channel.

Goals of gating system

- a) To avoid trapping gasses in to the mold.
- b) To avoid shrinkage.
- c) System to trap nonmetallic inclusions.
- d) To provide enough metal to mold cavity before solidification starts.

The main objective of gating system is to allow clean, uniform flow of metal through mold without any turbulence. Gates

Important points:

- a) Discharge level is highest in gates farther to sprue and reduces around nearer gates. [Johnson]
- b) Ratio of flow rates depend upon gate to runner area ratios and discharge coefficient ratios. This implies that flow ratios are independent of distance between gates, length of runner between the gates. [Berger and Locke]
- c) For correct location and cross sectional area of each flow through each gate should be predicted properly.[Dr. B. Ravi]

Feeder design

Feeder is a reservoir of metal that flow through the cavity to prevent shrinkages. Feeders should be placed such that they solidify at last and are able to provide metal to casting for long time.

Feeder design is the driving force of gating system. Proper positioning of feeder in casting will yield better quality product.

Requirements of feeder design:

- Feeder shape: most preferable shape for feeder is cylindrical.
- Feeder size: (volume/area)² should be greater than the casting.
- Feeder position: there should be effective distance between the feeders.

II. LITERATURE SURVEY

Effect of shrinkage on warpage reduction

Shrinkage is the term for obstruction of fluid flow coupled with a difference in the specific volumes of liquid and solid metal. As the casting solidifies, the flow is restricted due to the metal that already solidified as the metal that is still fluid tries to compensate for the liquid/solid volume change. Large voids appear in part because of metal cut off in that area.

This void is termed 'macroporosity'. The area in which macro pores are formed is termed as a 'hot spot'. According to D.R. Gunasegarama et al. (2009) that shrinkage porosity defects occurring in castings are strongly influenced by the time-varying temperature profiles inside the solidifying casting because the temperature gradients within the part determines access to sufficient amounts of feed metal to a region.

Shrinkage pores will emerge in regions experiencing volume reduction due to phase change with no access to feed metal.

Casting simulation

The most of the casting methods designed are incorrect which can be properly simulated through software’s, hence enhancing productivity, saving resources such as labor, material etc. Simulation software’s provide clear view of defects in casting for better quality product. Computer simulation for casting prevents shop floor trials, labor, energy and wastage of material. (Dr. B. Ravi, 2005)

Simulation programs use FEM for computation, display etc. Most of the simulation works have been done using much software to identify hot spot hence defects such as shrinkage, porosity, hot tears. Many researchers have worked on casting simulation software’s for elimination of defects. Such as Prabhakara Rao et.al worked on Pro CAST software to reduce defects like shrinkage, porosity, hotspots etc. Thereby increasing yield of the casting. Similarly Dr. B Ravi worked on AUTOCAST software to do optimization of mold cavities, gating system thereby reducing time for method design and optimization. M. Yoo, J. K. Choi studied Z-Cast software for prediction of temperature distributions and solidification sequences in the casting so as to optimize the casting conditions

Steps included in computer simulation are volume discretization, applying boundary conditions, defining material and its properties, flow model, computation and solution monitoring and results.

III. RESULTS

Simulation results

Six iterations where carried out for different positions of feeders. 3D model of part is shown in fig a.

Fig. a  
Location of hotspot helps to design gating system accordingly. Current position of feeders for part with hot spot is shown in is shown in fig b. and consequent iterations are performed with different feeder position and in fig b, c, d, e, f, g.
Current position of feeders for part with hot spot position and solidification is shown in fig b. and fig c. Following 5 iterations are carried out on part indicating hotspot position and porosity level are shown in fig d, e, f, g, and h.

First iteration fig. d
Second iteration fig. e
Third iteration fig. f
Fourth iteration fig. g
Fifth iteration fig. h

Shrinkage is a volumetric change of the material as it cools from melt state to cool state. Driving force for warpage is variations in shrinkage. Warpage might not take place because of high variations in shrinkage of stiff parts but if stiffness of part is reduced and then shrinkages are applied, warpage takes place with lower internal stresses. Warpage is the result of non-uniform shrinkage. If the region shrinks unequally the stresses developed within the part causes part to deform or change shape or even crack. Warpage is caused by variation in shrinkage and shrinkage is caused due to porosity level in part. Since macro scale can be reduced with the help of proper gating system on the other hand it is difficult to reduce micro level. Therefore more is the porosity level less is the chances of warpage in part. In figures shown above the porosity level i.e. macro and micro porosity are compared for five iterations which indicate that the porosity level of fig f is more than that of other iterations carried out. Therefore it can be stated that chances of warpage reduction is more in iteration three.

IV. CONCLUSION

Optimum riser position leads to sound casting. A proper gating system design with the help of casting simulation software helps to eliminate defects at large.

REFERENCES


