Review on Casting Defect: Warpage

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Abstract— A casting defect is an irregularity in the metal casting process that is undesirable and in current global environment it has become a need for defect free castings with minimum production cost which have become the need of foundry. Some defects can be tolerated while other can be repaired otherwise they must be eliminated. Various defects develop in manufacturing processes depending on factors such as materials, part design, and processing techniques. While some defects affects only the appearance of the parts made, others can have major adverse effects on the structural integrity of the parts. This paper review casting produced by foundry with distortion as a major defect was analyzed and identified solution for its cause.

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

I. INTRODUCTION

Casting processes are widely used to produce metal parts in a very economical way. Casting defects results in increased unit cost and lower morale of shop floor personnel since casting process involves complex interactions among various parameters and operations related to metal composition, methods design, molding, melting, pouring, shake-out, fettling and machining therefore it often come across various defects which sometimes becomes impossible to remove. Chills are achieving directional solidification. It is used preferably when the intricate shape of the casting does not allow placing of risers on all the thick sections or in which the large sections are so located that it is impossible to place risers over them. In such cases there will be different cooling rate for different section, giving rise to internal stresses causes cracks. Simulation is the process of imitating a real phenomenon using a set of mathematical equations implemented in a computer program. Using casting simulation visualization of mold filling, solidification and prediction of the location of internal defects such as shrinkage porosity, cold shuts and sand inclusions can be done. Moreover it is not only used for existing castings but also used in developing new castings without shop-floor trials.

II. LITERATURE SURVEY

Sand casting, particularly, are subject to certain defect which in a well designed casting, are controllable by proper foundry technique, but are not wholly preventable. One such defect is warpage which is explained further.

A. Defect- Warpage:

The warpage of casting parts is a critical issue, especially for large industrial products. Besides, it is difficult to predict the warpage accurately in the casting process because of its complex dependence on mechanical and theremal factors.

Warping is one of the undesirable deformations in the casting which occur during or after solidification. Generally large and flat surfaces are prone to warp edge. Warp edge may also be due to

- Insufficient gating system that do not allow proper material feeding
- Due to low green strength of the mold or
- Inadequate/ inappropriate draft allowance in th pattern / mold cavity.

In warpage the surfaces of the molded part do not follow intended shape of the design. It results from molded-in residual stresses, which in turn is caused by shrinkage of molded part in the cavity. If there is shrinkage throughout the part the molding will not deform or warp, it simply becomes smaller. However, achieving low and uniform shrinkage is a complicated task due to the presence and interaction of many factors such as molecular and fiber orientations, mold cooling, part and mold design, and process condition. Inadequate thickness, extending over large areas of the cope or drag surfaces at the time of the mold is rammed causing rigidity of the pattern or pattern plate which is not sufficient to withstand the ramming pressure applied to the sand. The result leads to elastic deformation of the part and a corresponding, permanent deformation of the mold cavity. In diagnosing the condition, the surfaces of the pattern with those of the mold itself are compared which can also be probable cause of warpage.

Warpage in a molded part is result of differential shrinkage. Variation in shrinkage can be caused by molecular and fiber orientation, temperature variations within the molded part causes difference in both expansion and cooling and can result in bad warped product. Therefore always maintain the right heat temperature, and by variable packing, such as over-packing at gates and under-packing at remote locations, or different pressure levels as material solidifies across the part thickness, proper residence time has to be given for the individual molecules to absorb heat uniformly throughout the material. Otherwise it leads to difference in heat absorbed cool differently.

The variables that affect warpage are machine variations like unstable controller, wall thickness, mold temperature, gate location, flow restrictions and bypasses, inherent rigidity of the molded part. If the injection pressure is not enough, the individual molecules do not pack properly which results in a difference in the way they cool and solidify. Since enough pressure hasn't been provided there is too much space while the material is cooling down and the molecules move while cooling resulting in warpage.

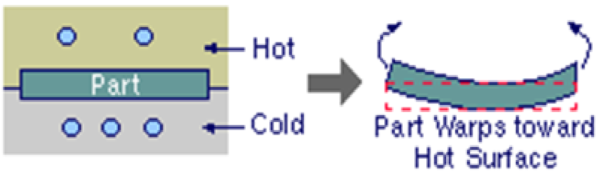

Fig. 1: warpage

Warpage can be minimized in following ways-

1) Assure adequate rigidity of patterns and pattern plates, especially when squeeze pressures are being increased.
2) Control of pouring temperature.
3) Ressisting normal contraction at local points by the use of gaggers.
4) Increase injection pressure which allows the cooling of the entire part while it is getting constrained.
5) Study of the shrinkage curve for reinforced materials.
6) Incorporation of flow aids or flow restrictors help in the alteration of the melt flow profile that in turn prevents warping.
7) Use computer simulation technology.
8) Multipoint gating system design helps to eliminate warpage problems by achieving a high pressure gradient.
9) Proper solidification and cooling of part. Solidification differs depending on a pure element or an alloy.
10) Chvorinov's Empirical relationship: Solidification time as function of the size and shape , T_f of a casting area is proportional to the square of its volume to area ratio, V/A, named modulus.

$$T_f = B\ (V/A)^2$$

B. Gating and Risering System:

Gating system is to lead clean molten metal poured from ladle to the casting cavity, with less turbulence. Risers are used to compensate for liquid shrinkage and solidification shrinkage. Facts for gating system are

1) No shrinkage defects: risers should be designed and placed such that the whole casting is free from shrinkage.
2) Steady metal front rises up in the cavity. There is no turbulence in the metal flow.
3) Initial dirty metal doesn't enter casting cavity neither does the slag.
4) Economy: Maximum yield. Weight of gating parts and risers is minimum.
5) Gating parts can be easily removed without affecting casting.
6) Pattern and gating parts fit on the match-plate with sufficient sand clearance.
7) .Risering calls for a thermal analysis of the part. Gating parts calls for the fluid flow analysis.

C. Feeder Design Rules:

Designing a proper feeding system to account for the warpage during solidification for a cast is guided by six main feeding rules [3]. Risers allow molten metal to flow into mold to make up for shrinkage These rules can be summarized as follows:

1) Heat transfer criterion: The feeder must solidify at the same time or later than the casting.
2) Mass transfer criterion: The feeder must contain sufficient liquid to meet the volume-contraction requirements of the casting.
3) The junction requirement: The junction between the feeder and the casting should not create a hot spot, i.e. be the last to solidify.
4) There must be a path to allow feed metal to reach feeding points.
5) Sufficient pressure differential requirement to cause the feed material to flow in the right direction and also to suppress the formation of cavities.

D. Simulation Software:

Simulation software is based on the process of modeling a real phenomenon with a set of mathematical; formulas. It is essentially a program that allows a user to observe an operation through simulation without actually performing that operation. Simulation software is widely used to design equipment so that final product will be as close as possible without expensive in process modification.

DR.B.Ravi *et al* [1] Casting simulation has become a powerful source to visualize mould filling, solidification and cooling, and to predict the location of internal defects such as shrinkage porosity, sand inclusions, and cold shuts. It can be also be used for troubleshooting existing casatings, and for developing new castings without shop floor trials. This will describe the benefits of casting simulation (both tangible and intangible), bottlenecks (technical and resource related), and some best practices to overcome the bottlenecks.

DR.B.Ravi *et al* [2] used intelligent assistant for casting Engineers (AutoCAST) and describes how it assists in designing, modeling, simulating, analyzing and improving cast products. Autocast software can automate casting design, modeling, simulation, analysis and suggestions for improvising while allowing user to control all decision. He also used computer simulation for casting solidification [4]. Various other casting software's can also be used for simulation purpose.

Jean Kor, Xiang Chen, and Henry Hu et al [3] used vector optimization approach through which many optimal solutions can be found. It yields good results and provides more flexibility in decision making when applied to the gating and riser design of a sand casting. S. M. Yoo, J. K. Choi [5] Z-Cast™ was used to simulate the fluid flow in a sand mold. The optimal processing parameters for the cooling were obtained from the analysis of fluid flow and solidification. Numerical simulations of mold filling and solidification were used to optimize the casting process. The simulations were used to predict the temperature distributions and solidification sequences in the casting to optimize the casting conditions.

Chokkalingam, Sidharthan[6] used Pro-E software to build a casting model. They redesigned feeding system by Cast Calci in C using standard formulas to do the calculation for the design of gating and risering system.

E. Applications and Benefits of Using Simulation:

- Save production resources.
- Develop a new casting faster.
- Optimize existing casting.
- Communicate with designers.
- Provides accuracy.

III. Conclusion

To reduce warpage proper gating system plays a major role with the help of casting simulation technology to reduce the lead time and improve productivity. This software will help for training new engineers in this field. In general, these defects can be eliminated by iteratively designing (gating) system through experience and experiments taking huge amount of resources (cost) and time which can be avoided by conducting trials on computer using casting simulation technology where each and every step can be taken into consideration.

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