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Factors Leading to Major Casting Defects and their Influence on Productivity of Foundry

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ABSTRACT

In recent times, with the constant utilization of natural resources, every manufacturing unit is turning towards a lean approach. Foundries are no exception to this. Although the fundamental responsibility of a foundry is simply to convert raw metal into a useful casting, it is imperative on their part that the output confirms with the quality as desired and is free from defects of any kind. However, there may be factors like the rate of cooling of molten metal being poured, mould properties, metallurgy of the molten metal being poured and the mould geometry and rigidity to name a few which may have their influence on the casting quality and the overall productivity of the foundry. While striking a balance between the quality and productivity, there may be certain deviations undertaken from the regular course that may lead to casting defects. This paper intends to highlight such interdependencies and suggest indirectly the most feasible means to control casting defects in order to ensure attainment of both quality and productivity. Casting defects considered for this work shall be those observed at a major scale and those which require adequate attention on account of frequency of occurrence. A conclusion shall be drawn towards the end dictating the major findings of the study.

KEYWORDS: *Defect, productivity, foundry, moulding, casting*

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A. Major factors affecting casting quality

Castings are a collective outcome of various activities performed in a definite sequence. While doing so, there are certain necessary check points that need special consideration failing which, the outcome may not be conforming.

Starting from the very design of the mould which is governed by the pattern and core if applicable, every detail plays a vital role in the outcome. Gating system being the next major contributor, bears the solemn responsibility of ensuring even distribution of the molten metal being poured.

Furthermore, the sand used for the casting process has multiple facets. Properties like permeability, grain fineness and clay content govern the surface finish and bulk strength of castings.

While it may be quite comprehensive to mention every factor affecting casting quality, four major factors shall be considered for this study viz. the rate of cooling of molten metal being poured, mould properties, metallurgy of the molten metal being poured and the mould geometry and rigidity. Each of these shall be elaborated in context of this study as follows.

Casting process involves heating up of a ladle filled with raw metal of a desired metallurgy to a certain temperature where it is converted from solid form to liquid and to used this phase to pour the metal into the cavity to obtain the desired casting. The moment pouring of molten metal commences, cooling of the same sets in. According to Newton's law of cooling, "The rate of cooling of a system is directly proportional to the temperature difference between the system and surrounding". Abiding by this law, once the process of pouring is done with, the rate of cooling is the highest while with passing time, the same slows down. This implies that the bulk takes a longer time to cool than the surface. According to the energy equilibrium consideration, until the complete system is evenly distributed with energy, the remnant imbalance bears the potential to cause casting defects. Thus the cooling time needs to be clearly defined for a particular heat so that by the end of the cooling process, the casting is does not have any warm intricacy which may lead to stress concentration, thereby posing the possibility of casting defects.

Mould properties are highly dependent on the moulding sand being used. Three important characteristics that can be considered are permeability, grain fineness number and the clay content. While the clay content can be an additive leading to the mould strength and binding, permeability needs to be adequately addressed while carrying out the moulding. Permeability is simply the ability of the mould to vent out entrapped gases so that there is no movement of the mould walls thereby leading to distortion of any kind at any feature of the casting. It is closely linked to the grain fineness number which is an overall measure of the particle size. Finer the grains, better the surface finish but lesser is the permeability which may lead to certain pronounced sub-surface defects. This makes it imperative to provide additional venting in the box as found appropriate.

Metallurgy of the molten metal being poured is necessary to be comprehended to the best possible extent while designing the gating system and the cavity. Depending on the alloying elements, properties of molten metal like viscosity, density and fluidity vary. Desired results are largely a function of a pre-determined metallurgy backed with appropriate design of the cavity including the gating system.

Mould geometry refers to the design of mould box wherein the cavity is created. The wall thickness of mould is necessary to be adequate in order to avoid defects related to the packing. Rigidity of a mould is the ability of its components viz. cope, drag and cheek if applicable to remain intact during the pouring and cooling process.

These are a few factors that bear a major share in influencing the quality of castings, be it of any metal.

B. Major casting defects observed for grey cast iron, carbon steel and stainless steel castings

This study shall be largely limited to Grey cast iron, Carbon steel and stainless steel castings. When these castings are encountered, there are certain commonly observed defects that are likely to occur.

As a premier thought, it is necessary to ponder over the idea that what causes the casting defects. It is a well established fact that if the process is followed, the end result is always as desired. As a corollary, one may state that if the process is not followed as defined, the occurrence of castings defects would be quite inevitable and their frequency would be high if not taken care of.

As a part of observations it was found that there are six casting defects that are quite prominent are need academic attention in all regards. These have been considered for this study while other numerous defects shall be out of purview of the same. The casting defects taken up for study include blow holes, pin holes, shrinkage, surface roughness, shift and sand inclusions.

Subsequent sections shall elaborate these defects and shall set a premise to this study. Casting defects are certainly undesirable but at the same time, it is evident that they are not completely avoidable too. Hence it is required that efforts are taken up to reduce the same to the best possible extent.

C. Elaborate comprehension of casting defects and interdependence of factors causing the same

In this section, each casting defect under investigation shall be firstly understood. Thereafter interdependence of the factors affecting the same shall be presented to link the factors with the casting defects.

C.A. Blow holes

Blow holes are caused due to entrapped gases forming bubbles within the bulk of the casting. Until discovered by machining process, these defects may remain unnoticed and may lead to severe failures due to stress concentration. Blow holes are generally spherical in shape are few in number. Their peculiar characteristic involves a surface luster which can be attributed to the presence of the entrapped gases.

Gases can bet entrapped in the bulk of the casting due to a number of reasons like sand permeability, gating system, design of intricacies, casting wall thickness and metallurgy to name a few.

Permeability of the sand is a function of the grain fineness number. For sand with large number of fine particles, there is a greater degree of packing of the sand grains in the mould. This leads to possibility of entrapped gases if the venting system is incapable of letting the entrapped gases as exhaust.

Design intricacies may be the product requirement but gating system can be kept a check and measure to ensure that the thinnest of the cavity is completely filled with the molten metal.

Casting wall thickness is the cavity between the mould wall and the core. Depending on the metal being poured, there is a certain minimum value that needs to be maintained in case of sand castings. Failure to adhere to this condition can invite untoward occurrence of blow holes.

C.B. Pin holes

Pin holes are frequently observed in stainless steel castings. This a sub surface defect that can again be attributed to incomplete deoxidation of the molten metal in the mould.

Pin holes generally occur at locations where the molten metal cools in an uneven manner leaving certain hot spots to pave way to occurrence of the defect.

C.C. Shrinkage

Shrinkage mainly refers to the occurrence of undersize dimensions on the casting as that compared to the desired dimensions. During the process of cooling of the metal poured into the cavity, due to the property of solids of contraction on cooling, metals too tend to contract and shrink with the onset of cooling. Taking this into account, shrinkage allowances provided may work best in the presence of a properly designed gating system.

There are two standpoints when it comes to shrinkage defect. One being lack of consideration of the shrinkage and the mould wall movement allowance and the other being improper design of the gating system.

Owing to the properties of the metal being poured and the shape to be cast, there are various allowances that are provided on the pattern to accommodate certain changes that take place in the casting while cooling is onset. Shrinkage allowance for gray cast iron is lesser than that for carbon steel which is slightly lesser than that for stainless steel. Thus to cast a part of given dimension, the cavity for grey cast iron may be of the least volume while that of the stainless steel shall be most. In event the same is swapped, there can be shrinkage defects that can be observed. Using a grey cast iron cavity for steel can result into castings with undersize dimensions while using of steel cavity for grey cast iron leads to lesser shrinkage and greater material to be machined. Either ways, the loss is on the manufacturer.

Mould wall movement allowance is provided considering the minor movement of the mould wall due to pressure when the molten metal is poured. Loosely packed facing and backing sand may lead to an oversized casting in this case.

C.D. Surface roughness

This is a surface defect and is clearly visible to the observer. The prominent causes include employment of too coarse grain sand leading to an uneven surface and a relatively high pouring temperature.

This is the reason, the grain fineness number of the sand used has to be pre-determined so that necessary actions can be administered.

Pouring temperature is defined as a relative term because depending on the size of the cavity, the molten metal may tend to vapourize a relative quantity of facing sand and create room for surface roughness. The secondary effects of surface roughness include occurrence of sub-surface porosity.

C.E. Shift

Casting manufactured using multiple peace patterns are prone to this defect. depending on the space and moulding box availability at the foundry, a pattern may be split in two or more pieces. Generally, when the pattern and core box are newly manufactured, the locators are easily placed and the cavity can be produced accordingly. However with time, wear of pattern reference surfaces can cause shifts in the cavity. This may be one reason for shifts, the other being movement of mould boxes during and after pouring. If not held in place, the mould boxes holding the molten metal have the tendency to move apart to establish the equilibrium to cool the metal within much more evenly. If adequate constrains are not in place, shifts in castings may occur which would be highly undesirable. Another reason for occurrence could be a misaligned core which may lead to internal movement and distortions if the moulding sand at the core print is not compacted adequately.

C.F. Sand Inclusions

In this defect, one can observe sand grains entrapped in minor pockets of the castings. Sand and mould cavity preparation are further causes of this defect wherein a small lump of sand may get detached from the surface of the cavity and can appear as a sand inclusion.

Metallurgy of the molten metal being poured may also be responsible in the event of presence of oxides and reaction products of metals being cast.

Gating system is another cause wherein Too narrow runners and gates can lead the flowing molten metal to initiate the casting defect.

D. Influence of defect causing factors on productivity of foundry

Having comprehend the influence of various parameters on the defects caused, the study shall now be extended to influence of defect causing factors on the productivity of the foundry.

Productivity of a foundry may be defined as efficient conversion of raw metal into castings with minimum casting defects and rejections thereby. Defect causing factors have their own role in the productivity and the economics of moulding and casting process.

The rate of cooling of molten metal being poured is characteristic to the given metal. It is also dependent on the shape and volume of the cavity. Intricacies also contribute a major part in the determination of the overall cooling time. If all these factors are considered, the cooling time required for a casting would be in terms of hours which may not be economically feasible for a foundry owing to space constraints and mould box requirements. Thus it may be observed that after a short cooling duration of an hour or two moulding boxes may be withdrawn and used for moulding of further cavities. At this stage, although the metal is externally cooled, there are intricacies where the metal is not completely cooled and this may lead to distortions in castings. Although space is a major constraint, specific cooling areas can be designated with vertical arrangement wherein the heaviest moulds are placed at the bottom and relatively lighter ones are placed at the subsequent top levels.

Mould properties include the level of compactness of the sand, quality of sand used, box size and so on. Unlike earlier, currently there are moulding machines that can ease the job of manual labour. However, if one tries to compact the sand in a particular mould box, there would be a pile up of boxes at the station leading to a bottleneck. Additional moulding machine may although be an option but the overall flow line may be greatly affected. Thus to strike a balance, it is a practice to ram the sand for a certain standard duration. This is most of the times sufficient but in rare cases, may lead to defects. Sand reclamation is necessary to save on unnecessary costs at a foundry. However, after a certain number of cycles, it is necessary that the sand is prepared afresh to ensure better quality of castings.

Metallurgy is an area wherein minor variation of the constituents can lead to major changes in the end product. Addition of carbon is an example to the point. It can largely affect the metallurgy of the casting if not controlled.

Mould geometry and rigidity is another important consideration in this wise. The physical condition of the mould box including the walls and the dowel pins used to secure the boxes with reference to the match plate plays a vital role in the production of sound castings. Due to excessive and repetitive use, there may be wear and tear of the dowel pins which can lead to loosely fit moulds and can lead to defects like shifts. These aspects may not be addressed in detail due to their petit magnitude but it is necessary to have cognizance of their effects so that major defects can be avoided.

Conclusion

Thus it can be concluded that various factors leading to major casting defects have been comprehended and from the study of their influence on productivity, it has been found that there are certain practices that call for deviation from the set processes which are undertaken to save on certain parameters like time and money, but are potentially deterrent to the overall productivity. It is recommended that the cooling time required by the casting is provided in total without consideration of engagement of mould box, moulding and associated processes are carried out appropriately and the metallurgy is taken care of during the manufacturing activities.

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