IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 6 Ver. I (Nov. - Dec. 2015), PP 43-54
www.iosrjournals.org

Casting Defects Analysis in Foundry and Their Remedial Measures with Industrial Case Studies

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Abstract: *In this current scenario of globalization, foundries play a key role for manufacturing industries as they are the major source of castings. As a key industry a foundry's performance should be effectively high in terms of production with minimum number of rejections. Castings are the major inputs for most industrial products hence foundry industry is most indispensable. Casting is an integrated process considered as an artwork with experienced professionals for high quality yield, even then in highly controlled environment defects are dominant to take place leading to rejections, contrary to rejections a foundry's key attempt is to satisfy the demands neglecting quality levels. The challenges of casting defects are to be identified and minimized for effective castings. This study provides an intense knowledge of critical casting defects and their root cause analysis. In this paper efforts are made to achieve technically feasible remedies for minimizing several casting defects and improving the quality of castings which will serve as control measures for quality control professionals with zero defect concepts.*
Keywords: *Casting Defects, Cause and Effect Diagram, Centrifugal Casting, Defects Analysis.*

I. Introduction

Defects formation in castings is one of the most vexed topics of foundry industries. Foundry industries mostly rely on different process parameters to control such defects ensuring high efficacy of casting with an optimum yield hence controlling of such parameters becomes necessary by sound knowledge of possible causes, for this the probable defects should be analyzed and their root causes have to be studied. This paper brings out the industrial case study of castings having prominent defects. The work was carried out based on production trials. An attempt has been made to analyze the critical defects and possible remedial measures are suggested for cast masters to have a sound knowledge about such defects with an aim to minimize rejections rates. The data was collected to take decisive action for quality improvement with reduced rejection in castings.

II. Methodology

Cause and Effect diagram is a powerful tool that aids in determining the control factors on quality output. The data was analyzed using Ishikawa Cause and Effect Diagram.

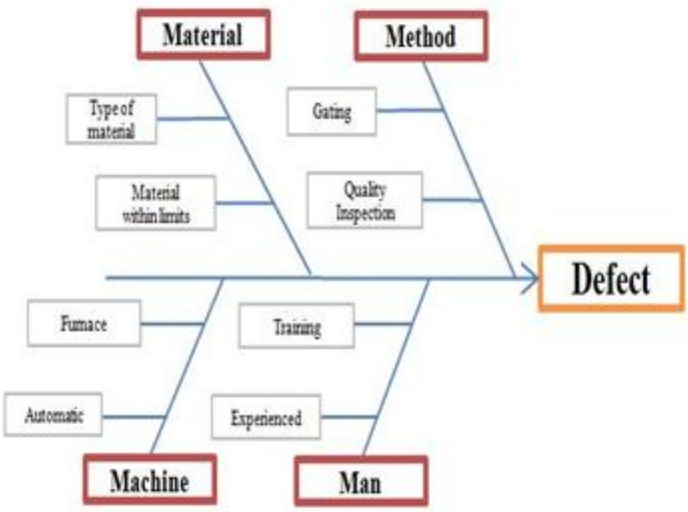

Fig.1. Ishikawa Cause and Effect Diagram

III. Casting Defects

The major casting defects are classified as follows:

3.1. Blowhole

Blowhole is a type of casting defect mostly prevalent in castings, further divided into pin holes, endogenous and exogenous blowholes. Entrapment of air resulting due to pouring of liquid metal takes the form of rounded contours or spherical cavities. Surface blows or inter granular cavities appear in cope of the mould.
Pinholes result when the hydrogen present in liquid metal evolves due to less solubility during solidification resulting in triangular appearances, prevalent mostly in thinner castings which are revealed after machining.

3.1.1. Case Study

Sheave of Grade 270-540 IS1030 undertaken for study showed blowholes on groove edges.

3.1.2. Causes

- High moisture on chills.
- Low permeability of sand.
- Improper sand mixing.
- Inadequate vents.
- Use of undried coatings.
- High turbulence during filling.
- High bentonite content.
- Excessive Gas Entrapment.
- Liquid metal not properly degassed.
- High binder content.

Fig.2. Blowhole

3.1.3. Remedial Measures

- Avoid over ramming of sand.
- Use dry chills only.
- Optimum pouring temperature at1585 degree centigrade for mild steel.
- Avoid using fine sand grains.
- Provision of adequate venting.
- Use dried and properly dressed cores.
- Reduce binder and additives.
- Control of Aluminum level.
- Increase runner height for increased static pressure.
- Adjust carbon equivalent value.
- Use water based zircon coatings.

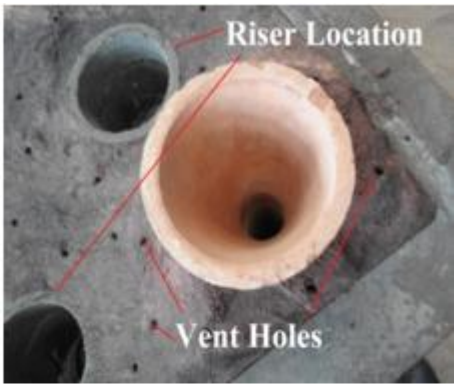

Fig.3. Vent Holes and Riser Placing

3.2. Shrinkage

Shrinkage is a type of casting defect resulting due to formation of shrinkage cavity as such due to lack of design and insufficient feed metal. Shrinkage results due to formation of a closed loop at a specific point during solidification which creates a cavity because of absence of feed of molten metal. Shrinkage can be classified into three types as open (macro porosity), closed (internal/blind shrinkage) and axial shrinkage.
Open shrinkage appear on the exterior of casting surface resulting due to volume contraction from liquid to solid state. These are visualized as shallow cavities on casting surface. Closed Shrinkage results due to dense network of dendritic crystals which restricts void feeding of thick sections. Axial shrinkage is a result of long freezing time at the centerline of casting due to high pouring temperature.

3.2.1. Case Study

Bottom bearing housing of Grade EN-9 alloy undertaken for study showed internal shrinkage defect towards the centerline.

3.2.2. Causes

- Unevenly dried sand with low compressive strength.
- Mould wall shift due to high metal pressure.
- Chills not placed properly.
- Sudden change in thickness of sections.
- Too many sharp internal corners causing hot-spots isolation.
- Excessive Ferro Silicate use during metal charging.

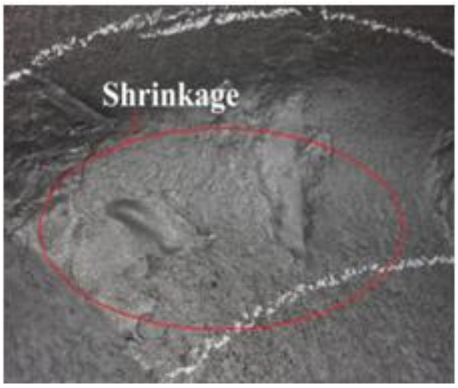

Fig.4. Shrinkage

3.2.3. Remedial Measures

- Dry mould using CO_2 gas for at least 60 seconds for high rigidity.
- Use of chills at correct position to for directional solidification.
- Feeding of sharp corners to avoid hot spots.
- Riser to be properly located.
- Use of inoculants.

Fig.5. Chills Placing at Ends

3.3. Hot Tears/Cracks

Hot tears are predominant due to imbalance in temperature caused during solidification. These appear to be sharp and broken jagged lines at the edges of casting.

3.3.1. Case Study

Bottom Chock of Grade EN-9 alloy undertaken for study showed hot tear near thick sections.

3.3.2. Causes

- Use of coarse size sand grains.
- Mould disturbance before complete solidification.
- Imperfect riser location.
- Abrupt changes to be avoided which increase internal stress
- High binder and ramming density
- Hydrogen content too high
- Low amount of eutectic cells at grain boundary
- Excess amount of sulphur/phosphorus present

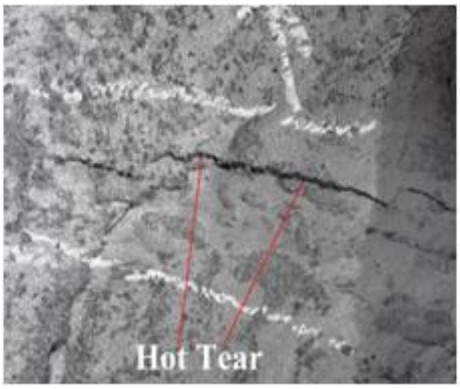

Fig.6. Hot Tears

3.3.3. Remedial Measures

- Sufficient cooling of mould to be done.
- Avoid sharp turns/corners.
- Provision of draft during removal.
- Deoxidize to kill sulphur/phosphorus present.
- Use inoculants mixture of Mn/Si/Mg to reduce sulphur/phosphorus content.
- Use of fine sand grains.
- Add coal dust to increase eutectic cells during solidification.

Fig.7. Smooth Corners with Zirconite Paint

3.3. Lamination defect

Lamination is a defect mostly occurring in centrifugally casted pipes especially stainless steel pipes visualized as layer of pipes separated from its adjacent layer appearing as a laminated layer protruding from the pipe.

3.3.1. Case Study

Centrifugally Casted Pipe of Grade SS HK40undertaken for study showed lamination defect protruding from pipe periphery.

3.3.2. Causes

- Use of low quality charge metal and scrap.
- Low rpm or extremely high rpm during pipe solidification.
- Friction between pipe die and material is low.

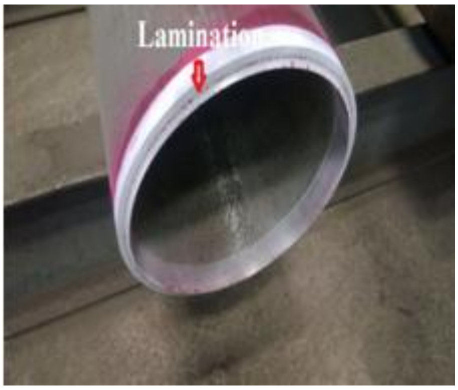

Fig.8. Lamination

3.3.2. Remedial Measures

- Pipe to be rotated at optimum speed of 500rpm.
- Use of best quality materials for charging.
- Locking of pipe die by correct flange size.
- Asbestos sheet for packing should be of good quality and properly aligned in pipe die.

Fig.9. Asbestos Alignment

3.4. Lumps

Lump is a defect occurring in pipes which are centrifugally casted. These appear as blisters on external surface of pipe as a result of air locking between liquid metal and pipe die.

3.4.1. Case Study

Centrifugally Casted Pipe of Grade SS HK40 undertaken for study showed lumps defect on pipe surface

3.4.2. Causes

- Present of air voids in pipe die& metal interface.
- Low adhesion between metal and pipe during rotation.

Fig.10. Lumps

3.4.3. Remedial Measures

- Increase rotation speedup to 475 to 500 rpm.
- Proper preheat of pipe die.
- Pouring ladle and die to be free from any foreign particles.
- Increase number of mould coatings inside pipe die.

Fig.11. MOLD Coat

3.5. Sand Inclusion

Sand Inclusion is one of the most common casting defects. Tearing of sand while preparing mould section manifests itself near casting edges to cause such defect. Most of the sand inclusion occurs at variable positions leading to a localized defect. Abrading away of sand by hot metal flowing past the mould also forms a part of this defect. These inclusions are mostly accompanied by CO bubbles and oxide particles. Sand inclusions stuck under the casting surface and are mostly visible during the treatment.

3.4.1. Case Study

Ball Valve of Grade ASTM A300 WCB undertaken for study showed sand inclusion near parting walls.

3.5.1. Causes

- Tilting of metal stream directly to cores causing erosion.
- Use of unevenly compacted moulds.
- Mould breakage during assembly.
- Uneven sand mixing.
- Improper pouring practices leading to mould disturbances.

Fig.12. Sand Inclusion

3.5.2. Remedial Measures

- Use of high bentonite content.
- Proper ramming of sand for uniform compaction.
- Frequent cleaning of mould boxes.
- Use of properly dressed cores.
- Proper mixing ratio of reclaimed sand and binder.
- Proper pouring time.
- Optimum pouring height.

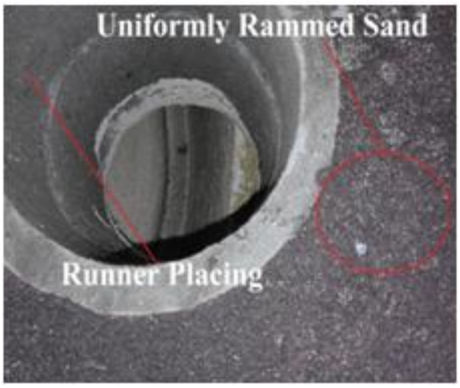

Fig.13. Sand Ramming and Runner Placing

3.6. Flashes

Flash is an excess material projecting from casting, generally visible as a thin metallic sheet, perpendicular to the casting face. Mostly irregular in thickness occurring along the parting line of mould intersection and acting as hindrance to quality. Hot metal leakage from the platen centre tends the formation of flashes adding extra weight to material.

3.6.1. Case study
Grid plate of Grade SG500/7IS1865 undertaken for study showed flashes defect.

3.6.2. Causes
- Excessive Clearance between top and bottom parts of mould box.
- High pouring pressure.
- Use of mould with poor pattern designs.
- Patterns having cavities at the end.
- Improper clamping of top and bottom parts.

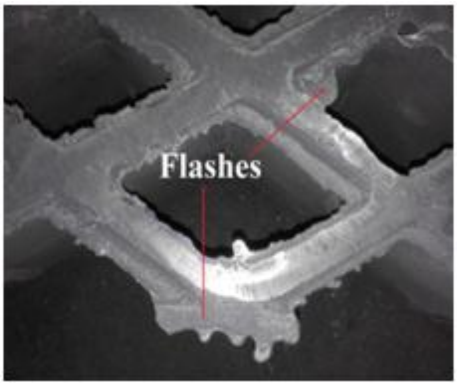

Fig.14. Flashes

3.6.3. Remedial Measures
- Sealing of mould box near parting line.
- Ensure end cavities to be filled to avoid metal leakage.
- Dimensions to be controlled.
- Carefully setting mould assembly.
- Proper core setting.

Fig.15. Core Clearance Setting

3.7. Mismatch
Mismatch is a defect in which shifting of top and bottom parts of a mould above or below the centerline takes place causing the casting to be defective. Segments dislocated above the centerline leads to this serious defect.

3.7.1. Case Study
Valve of Grade ASTM A216 WCB undertaken for study showed mismatch.

3.7.2. Causes
- Clamping cope and drag using worn out dowels.

- Faulty pattern designs of top and bottom parts.
- Inadequate amount of weight kept on cope part.

Fig.16. Mismatch

3.7.3. Remedial Measures
- Use of proper gating system.
- Heavy weight to be kept on top of casting. ensuring no dislocation of cope part.
- Ensure top and bottom parts are aligned properly.
- Replace worn out dowel pins with new ones.
- Use locators to match top & bottom parts.
- Use C-Clamps to clamp the mould box.

Fig.17.Heavy Weights on Cope

3.8. Misrun

Misrun defect generally caused due to lower fludity of molten metal. Predominant in castings having large surface area to volume ratio. A smooth and incomplete cavity depicts this defect. Lower pouring Temperature causes discontinuity of fluid streams leading to misrun.

3.8.1. Case Study

Wind Box of GradeSG500/7IS1865 undertaken for study showed misrun defect at thin section.

3.8.2. Causes
- Lower pouring temperature.
- Intermittent Pouring.
- Pouring Delayed.
- Back Pressure during Pouring.
- Inadequate venting.

Fig.18. Misrun

3.8.3. Remedial Measures
- Sufficient pouring temperature to ensure fluidity.
- Design proper gating system.
- Cleaning of mould box before pouring.

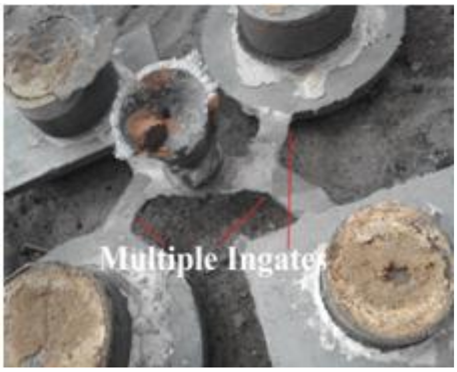

Fig.19. Multi Gates System

3.9. Defective Surface

Streaky lines resulting due to molten metal flow resulting in a pattern of lines which appear as series of small channels is known as defective surface.

3.9.1. Case Study

Valve of Grade ASTM A216WCB undertaken for study showed defective surface at flange face.

3.9.2. Causes
- Formation of oxide films.
- Foreign impurities flowing on casting surface.
- Low temperature of mould.
- High slag content.

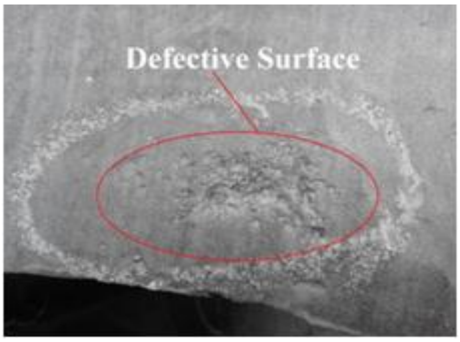

Fig.20. Defective Surface

3.9.3. Remedial Measures

- Preheat the mould before pouring
- Check for slag formation during charge
- Pouring temperature to be lowered

Fig.21.Mould Preheat at 45°C

IV. Conclusion

A focus on industrial case studies for casting defects is discussed in this paper. By using cause and defect analysis concept the various causes and remedial measures are suggested. This study will be highly useful in reducing casting defects in industries and improving the quality of casting with minimized rejection. Foundry professionals will find it highly useful in increasing the yield of casting.

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