Defects, Causes and Their Remedies in Casting Process: A Review

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Abstract- Foundry industries in developing countries suffer from poor quality and productivity due to involvement of number of process parameter. Even in completely controlled process, defect in casting are observed and hence casting process is also known as process of uncertainty which challenges explanation about the cause of casting defects. In order to identify the casting defect and problem related to casting, the study is aimed in the research work. This will be beneficial in enhancing the yield of casting. Beside this, standardization (optimization) of process parameter for entire cycle of manufacturing of the critical part is intended in the proposed work. This study aims to finding different defects in casting, analysis of defect and providing their remedies with their causes. In this paper an attempt has been made to list different types of casting defects and their root causes of occurrence. This paper also aims to provide correct guideline to quality control department to find casting defects and will help them to analyze defects which are not desired.

Keywords: Casting; defects in casting; quality control in casting; causes and remedies for casting defects.

1. INTRODUCTION

Casting is a process which carries risk of failure occurrence during all the process of accomplishment of the finished product. Hence necessary action should be taken while manufacturing of cast product so that defect free parts are obtained. Mostly casting defects are concerned with process parameters. Hence one has to control the process parameter to achieve zero defect parts. For controlling process parameter one must have knowledge about effect of process parameter on casting and their influence on defect.

To obtain this all knowledge about casting defect, their causes, and defect remedies one has to be analyze casting defects. Casting defect analysis is the process of finding root causes of occurrence of defects in the rejection of casting and taking necessary step to reduce the defects and to improve the casting yield.

In this review paper an attempt has been made to provide all casting related defect with their causes and remedies.

During the process of casting, there is always a chance where defect will occur. Minor defect can be adjusted easily but high rejected rates could lead to significant change at high cost. Therefore it is essential for die caster to have knowledge on the type of defect and be able to identify the exact root cause, and their remedies.

2. CASTING DEFECT CAN BE CLASSIFIED AS FOLLOWS-

2.1. ***Filling related defect***

2.2. ***Shape related defect***

2.3. ***Thermal defect***

2.4. ***Defect by appearance***

These defects are explained as follows.

2.1 *Filling related defects*

2.1.1. *Blowhole*:-

Blowhole is a kind of cavities defect, which is also divided into pinhole and subsurface blowhole. Pinhole is very tiny hole. Subsurface blowhole only can be seen after machining. Gases entrapped by solidifying metal on the surface of the casting, which results in a rounded or oval blowhole as a cavity. Frequently associated with slag's or oxides. The defects are nearly always located in the cope part of the mould in poorly vented pockets and undercuts.

Fig.1 Blowhole

2.1.1.1. *Possible causes*

Resin-bonded sand

- Inadequate core venting
- Excessive release of gas from core
- Excessive moisture absorption by the cores
- Low gas permeability of the core sand

Clay-bonded sand

- Moisture content of sand too high, or water released too quickly
- Gas permeability of the sand too low
- Sand temperature too high
- Bentonite content too high
- Too much gas released from lustrous carbon producer

2.1.1.2. *Remedies*

Resin-bonded sand

- Improve core venting, provide venting channels, ensure core prints are free of dressing
- Reduce amounts of gas. Use slow-reacting binder. Reduce quantity of binder. Use a coarser sand if necessary.
- Apply dressing to cores, thus slowing down the rate of heating and reducing gas pressure.
- Dry out cores and store dry, thus reducing absorption of water and reducing gas pressure.

Clay-bonded sand

- Reduce moisture content of sand. Improve conditioning of the sand. Reduce inert dust content.
- Improve gas permeability. Endeavour to use coarser sand. Reduce bentonite and carbon carrier content.
- Reduce sand temperature. Install a sand cooler if necessary. Increase sand quantity.
- Reduce bentonite content. Use bentonite with a high montmorillonite content, high specific binding capacity and good thermal stability.
- Use slow-reacting lustrous carbon producers or carbon carriers with higher capacity for producing lustrous carbon. In the last instance, the content of carbon carriers in the moulding sand can be reduced

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2. 1.2.*Sand burning*

Burning-on defect is also called as sand burning, which includes chemical burn-on, and metal penetration.

Thin sand crusts firmly adhering to the casting. The defect occurs to a greater extent in the case of thick-walled castings and at high temperatures.

The high temperature to which the sand is subjected causes sintering of the bentonite and silicate components. In addition, the always present iron oxides combine with the low-melting-point silicates to form iron silicates, thereby further reducing the sinter point of the sand. Sintering and melting of the impurities in the moulding sand enable the molten iron to penetrate even faster, these layers then frequently and firmly adhering to the casting surface.

Fig.2 sand burning

2.1.2.1. Possible causes

Clay-bonded sand

- Lustrous carbon content too low
- Proportion of low-melting-point substances too high

Moulding plant

- Uneven mould compaction

Gating and pouring practice

- Uneven distribution of inflowing metal with resultant over-heating
- Temperature of liquid metal too high

2.1.2.2. *Remedies*

Clay-bonded sand

- Increase proportion of lustrous carbon producer. This in-creases the amount of coke as well as the amount of lustrous carbon, which then results in positive separation between mould and metal.
- Use purer silica sands or, if necessary, add new sand. Reduce dust content. If necessary, reduce the amount of bentonite.

Moulding plant

- Ensure uniform compaction. If necessary, increase heat removal from the moulds.

Gating and pouring practice

- Even out incoming metal flow
- Reduce pouring rate

• Reduce liquid metal temperature

2.1.3. *Sand inclusion*

Sand inclusion and slag inclusion are also called as scab or blacking scab. They are inclusion defects. Looks like there are slag inside of metal castings.

Irregularly formed sand inclusions, close to the casting surface, combined with metallic protuberances at other points. Sand inclusion is one of the most frequent causes of casting rejection. It is often difficult to diagnose, as these defects generally occur at widely varying positions and are therefore very difficult to attribute to a local cause. Areas of sand are often torn away by the metal stream and then float to the surface of the casting because they cannot be wetted by the molten metal. Sand inclusions frequently appear in association with CO blowholes and slag particles. Sand inclusions can also be trapped under the casting surface in combination with metal oxides and slag's, and only become visible during machining. If a loose section of sand is washed away from one part of the mould, metallic protuberances will occur here and have to be removed.

Fig.3 Sand inclusion

2.1.3.1. *Possible causes*

Moulding plant

• Break-up of mould sections during stripping of patterns, core setting or assembling of moulding flasks
• Uneven compaction of moulds, compaction too high in places.

Clay-bonded sand

• Low compactability
• Bentonite content too low, or poorly developed bentonite
• Inert material content too high
• Lump content too high
• High content of lustrous carbon producer

Resin-bonded sand

• Low core strength
• Excessive core mismatching

Gating and pouring practice

• Pouring rate too high, with heavy impact against mould wall surface resulting in erosion
• Ladle too far above pouring basin
• Pouring time too long

2.1.3.2. *Remedies*

Moulding plant

• Check moulds for pressure marks and, if necessary, insert pressure pads
• Carefully blow out mould cavities
• Improve pattern plates, increase pattern tapers and radii. Heat pattern plates and, if necessary, use release agent.
• Check the moulding plant for uniform flask stripping and overhaul moulding plant as necessary
• Automate core-setting. Check and, if necessary, modify core prints before start of production
• Ensure uniform mould compaction, avoid over-compacted sections

Clay-bonded sand

• Raise compactability and thus plasticity of the sand
• Increase bentonite content. Use bentonite with high specific binding capacity. Improve bentonite development by ex-tending mixing time or by pre-wetting used sand
• Reduce inert dust content. Decreasing the dust content re-duces lumps in the sand.
• Reduce content of lustrous carbon producer

Resin-bonded sand

• Increase the strength of the cores. Use greater proportion of binder.
• Compact cores more evenly and effectively and, if necessary, inject gas more evenly
• Avoid core mismatching.

Gating and pouring practice

• Avoid high pouring rates and impact of metal stream against mould walls
• Shorten pouring times, improve distribution of gates.

2.1.4. *Cold lap or cold shut*

Cold lap or also called as cold shut. It is a crack with round edges. Cold lap is because of low melting temperature or poor gating system.

When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called misrun. A cold shunt is called when two metal streams do not fuse together properly.

Fig. 4 cold shut

2.1.4.1. ***Possible Causes***

- Lack of fluidity in molten metal
- Faulty design
- Faulty gating

2.1.4.2. Remedies:

- Adjust proper pouring temperature
- Modify design
- Modify gating system

2.1.5. Misrun

Misrun defect is a kind of incomplete casting defect, which causes the casting uncompleted. The edge of defect is round and smooth.

When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called misrun. A cold shunt is called when two metal streams do not fuse together properly.

Fig.5 Misrun

2.1.5.1. ***Possible Causes***

- Lack of fluidity in molten metal
- Faulty design
- Faulty gating

2.1.5.2. ***Remedies***

- Adjust proper pouring temperature
- Modify design
- Modify gating system

2.1.6. ***Gas porosity***

The gas can be from trapped air, hydrogen dissolved in aluminum alloys, moisture from water based die lubricants or steam from cracked cooling lines.

Air is present in the cavity before the shot. It can easily be trapped as the metal starts to fill the cavity. The air is then compressed as more and more metal streams into the cavity and the pressure rises. When the cavity is full it becomes dispersed as small spheres of high pressure air. The swirling flow can cause them to become elongated.

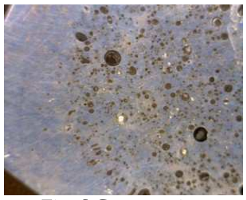

Fig. 6 Gas porosity

2.1.6.1. ***Possible Causes***

- Metal pouring temperature too low.
- Insufficient metal fluidity e.g. carbon equivalent too low.
- Pouring too slow.
- Slag on the metal surface.
- Interruption to pouring during filling of the mould.
- High gas pressure in the mould arising from molding material having high moisture and/or volatile content and/or low permeability.
- Lustrous carbon from the molding process.
- Metal section too thin.
- Inadequately pre-heated metallic moulds.

2.1.6.2. ***Remedies***

- Increase metal pouring temperature.
- Modify metal composition to improve fluidity.
- Pour metal as rapidly as possible without interruption. Improve mould filling by modification to running and gating system.
- Remove slag from metal surface.
- Reduce gas pressure in the mould by appropriate adjustment to moulding material properties and ensuring
- Adequate venting of moulds and cores.
- Eliminate lustrous carbon where applicable.
- If possible, modify casting design to avoid thin sections.
- Ensure metal moulds are adequately pre-heated and use insulating coatings.

2.2. ***Shape defects***

2.2.1. ***Mismatch defect***

Mismatch in mold defect is because of the shifting molding flashes. It will cause the dislocation at the parting line.


Fig. 7 Mismatch

2.2.1.1. *Possible causes*

- A mismatch is caused by the cope and drag parts of the mould not remaining in their proper position.
- This is caused by loose box pins, inaccurate pattern dowel pins or carelessness in placing the cope on the drag.

2.2.1.2. *Remedies*

- Check pattern mounting on match plate and Rectify, correct dowels.
- Use proper molding box and closing pins.

2.2.2. *Distortion or warp*

Warped Casting—Distortion due to warp age is known as warp defect.


Fig. 8 Distortion

2.2.2.1. *Possible causes*

Distortion due to warp age can occur over time in a casting that partially or completely liberates residual stresses.

2.2.2.2. *Remedies*

Common practice in iron casting is normalizing heat treatment to remove residual stress. In aluminum casting, a straightening between quench and aging might be required.

2.2.3. *Flash defect*

Flash can be described as any unwanted, excess metal which comes out of the die attached to the cavity or runner.

Typically it forms a thin sheet of metal at the parting faces.

There are a number of different causes of flash and the amount and severity can vary from a minor inconvenience to a major quality issue.

At the very least, flash is waste material, which mainly turns into dross when re-melted, and therefore is a hidden cost to the business.


Fig. 9 Flash defect

2.2.3.1. *Possible causes*

- Damage to die faces and die components
- Parts of the die have insufficient strength
- Bending, crowning of stretching of dies
- Cavities offset from centre of platen
- Insufficient machine clamp-up
- Pressure spikes at the end of cavity fill
- Excessive intensification pressure
- Incorrect intensification timing
- Damage, or wear, in toggle mechanisms
- Machine hydraulic malfunction
- Hydraulic valve or seal leaks

2.2.3.2. *Remedies*

If your sprue is very tall and the casting covers a wide area of the mold face, it's very possible for the mold to actually be forced up by the hydrostatic pressure of the metal. The seriousness of this depends density of the metal (aluminum is very light, but be careful with a bronze pour!) and the weight of the mold fighting it. The solution here is very simple: weight down the mold.

2.3. *Thermal defects*

2.3.1. *Cracks or tears*

Cracks can appear in die castings from a number of causes. Some cracks are very obvious and can easily be seen with the naked eye. Other cracks are very difficult to see without magnification.

Fig. 10 Crack

2.3.1.1. *Possible causes*

- Shrinkage of the casting within the die
- Undercuts or damage in die cavities
- Uneven, or excessive, ejection forces
- Thermal imbalance in the die
- Insufficient draft in sections of the die
- Excessive porosity in critical regions of the part
- Product design not matched to the process
- Inadequate die design

2.3.1.2. *Remedies*

- Reduce dry strength, add saw dust/ coal dust
- Reduce pouring temperature
- Avoid superheating of metal
- Use chills
- Provide feeders
- Avoid early knockout. Give sufficient cooling time.
- Correct composition
- Reduce sharp corners

2.3.2. *Shrinkage*

Shrinkage defects occur when feed metal is not available to compensate for shrinkage as the metal solidifies. Shrinkage defects can be split into two different types: open shrinkage defects and closed shrinkage defects. Open shrinkage defects are open to the atmosphere, therefore as the shrinkage cavity forms air compensates. There are two types of open air defects: pipes and caved surfaces. Pipes form at the surface of the casting and burrow into the casting, while caved surfaces are shallow cavities that form across the surface of the casting.

Closed shrinkage defects, also known as shrinkage porosity, are defects that form within the casting. Isolated pools of liquid form inside solidified metal, which are called hot spots. The shrinkage defect usually forms at the top of the hot spots. They require a nucleation point, so impurities and dissolved gas can induce closed shrinkage defects. The defects are broken up into macroporosity and microporosity (or microshrinkage), where macroporosity can be seen by the naked eye and microporosity cannot.

Fig. 11 Shrinkage

2.3.2.1. ***Possible causes***

The density of a die casting alloy in the molten state is less than its density in the solid state. Therefore, when an alloy changes phase from the molten state to the solid state, it always shrinks in size.

This shrinkage takes place when the casting is solidifying inside a die casting die. At the centre of thick sections of a casting, this shrinkage can end up as many small voids known as ‘shrinkage porosity’.

If the shrinkage porosity is small in diameter and confined to the very centre of thick sections it will usually cause no problems.

However, if it is larger in size, or joined together, it can severely weaken a casting. It is also a particular problem for castings which need to be gas tight or water tight’.

2.3.2.2. *Remedies*

The general technique for eliminating shrinkage porosity is to ensure that liquid metal under pressure continues to flow into the voids as they form.

2.3. 3. *Sink mark*

Solving molding sink mark and void problems

Definition: Sink marks and voids both result from localized shrinkage of the material at thick sections without sufficient compensation.

Sink marks appear as depressions on the surface of a molded part. These depressions are typically very small; however they are often quite visible, because they reflect light in different directions to the part. The visibility of sink marks is a function of the color of the part as well as its surface texture so depth is only one criterion. Although sink marks do not affect part strength or function, they are perceived to be severe quality defects.

Voids are holes enclosed inside a part. These can be a single hole or a group of smaller holes. Voids are caused when the outer skin of the part is stiff enough to resist the shrinkage forces thus preventing a surface depression. Instead, the material core will shrink, creating voids inside the part. Voids may have severe impact on the structural performance of the part. molding sink mark and void.

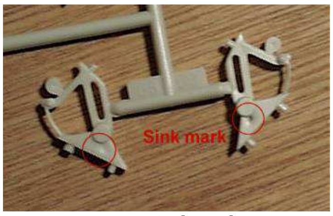

Fig. 12 Sink mark

2.3.3.1. ***Possible causes***

Sink marks are caused mainly by thermal contraction (shrinkage) during cooling. After the material on the outside has cooled and solidified, the core material starts to cool. Its shrinkage pulls the surface of the main wall inward, causing a sink mark. If the skin is rigid enough, deformation of the skin may be replaced by formation of a void in the core.

Localized geometric features sink marks typically occur in moldings with thicker sections, or at locations opposite from ribs, bosses or internal fillets.

High volumetric shrinkage

Insufficient material compensation

Early gate freeze-off or low packing pressure may not pack the cavity properly.

Short packing or cooling time

High melt and/or mold temperatures

2.3.3.2. ***Remedies***

Optimize packing profile

As sink marks occur during packing, the most effective way to reduce or eliminate them is to control the packing pressure correctly. To determine the effects of packing on sink marks, use a simulation package such as Mold flow Plastics Insight.

Change part geometry

Alter part design to avoid thick sections and reduce the thickness of any features that intersect with the main surface.

Reduce volumetric shrinkage

Relocate gates to problem areas

This allows these sections to be packed before the thinner sections between the gate and the problem areas freeze.

Optimize the runner system design

Restrictive runner system design can result in premature gate freeze-off.

2.4. ***Defects by Appearance***

2.4.1. ***Metallic projection***

Joint flash or fins. Flat projection of irregular thickness, often with lacy edges, perpendicular to one of the faces of the casting. It occurs along the joint or parting line of the mold, at a core print, or wherever two elements of the mold intersect.

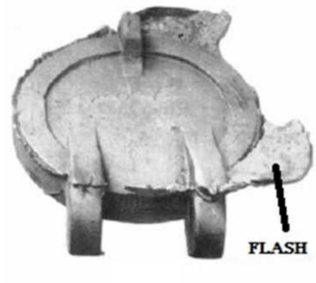

Fig. 13 Mettalic projection

2.4.1.1. ***Possible causes***

Clearance between two elements of the mold or between mold and core; Poorly fit mold joint.

2.4.1.2. ***Remedies***

Care in pattern making, molding and core making. Control of their dimensions; Care in core setting and mold assembly.

2.4.2. ***Cavities***

Blowholes, pinholes, Smooth-walled cavities, essentially spherical, often not contacting the external casting surface (Blowholes). The defect can appear in all regions of the casting.

Fig. 14 Blow hole

2.4.2.1. ***Possible causes***

Blowholes and pinholes are produced because of gas entrapped in the metal during the course of solidification:

2.4.2.2. ***Remedies***

Make adequate provision for evacuation of air and gas from the mold cavity; Increase permeability of mold and cores.

2.4.3. ***Dicontinuities***

Hot cracking. A crack often scarcely visible because the casting in general has not separated into fragments. The fracture surfaces may be discolored because of oxidation. The design of the casting is such that the crack would not be expected to result from constraints during cooling.

Fig 15 Body cracks

2.4.3.1. ***Possible causes***

Damage to the casting while hot due to rough handling or excessive temperature at shakeout.

2.4.3.2. ***Remedies***

Care in shakeout and in handling the casting while it is still hot; Sufficient cooling of the casting in the mold.

2.4.4. ***Incomplete casting***

Poured short. The upper portion of the casting is missing. The edges adjacent to the missing section are slightly rounded; all other contours conform to the pattern. The spree, risers and lateral vents are filled only to the same height above the parting line, as is the casting.

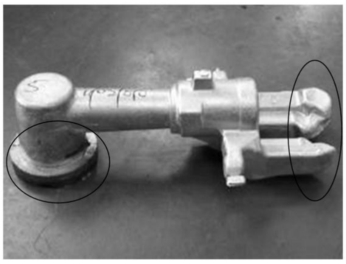

Fig. 16 Incomplete casting

2.4.4.1. ***Possible causes***

Insufficient quantity of liquid metal in the ladle. Premature interruption of pouring due to workman's error.

2.4.4.2. ***Remedies***

Have sufficient metal in the ladle to fill the mold, Check the gating system. Instruct pouring crew and supervise pouring practice.

2.4.5. ***Incorect dimenssion or shape***

Distorted casting. Inadequate thickness, extending over large areas of the cope or drag surfaces at the time the mold is rammed.

Fig. 17 Distortion

2.4.5.1. ***Possible causes***

Rigidity of the pattern or pattern plate is not sufficient to withstand the ramming pressure applied to the sand. The result is an elastic deformation of the pattern and a corresponding, permanent deformation of the mold cavity. In diagnosing the condition, the compare the surfaces of the pattern with those of the mold itself.

2.4.5.2. ***Remedies***

Assure adequate rigidity of patterns and pattern plates, especially when squeeze pressures are being increased.

2.4.6. ***Defective surface***

Flow marks. On the surfaces of otherwise sound castings, the defect appears as lines which trace the flow of the streams of liquid metal
.

Fig. 18 Defective surface

2.4.6.1. ***Possible causes***

Oxide films which lodge at the surface, partially marking the paths of metal flow through the mold.

2.4.6.2. ***Remedies***

- Increase mold temperature;
- Lower the pouring temperature;
- Modify gate size and location Tilt the mold during pouring

2.4.7. Rat Tail and Buckles

Rat tails and buckles are caused by the expansion of a thin outer layer of moulding sand on the surface of the mould cavity due to metal heat.

Fig. 19 Rat tail

2.4.7.1. POSSIBLE CAUSES

- A rat tail is caused by depression of a part of the mould under compression which appears as an irregular line on the surface of the casting.
- A buckle is a more severe failure of the sand surface under compression.

2.4.7.2. REMEDIES

The mould must provide for proper expansion instead of forming compressed layers to avoid this defect.

3. CONCLUSION

In this research work different casting defects are studied. By referring different research papers causes and their remedies are listed. These will help to quality control department of casting industries for analysis of casting defect. This study will definitely be helpful in improving the productivity and yield of the casting. Rejections of the casting on the basis of the casting defect should be as minimized and all the above research is heading in the same direction.

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