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A Review: Defect Analysis in Casting Processes, Causes and Remedies

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ABSTRACT

A number of sectors seek to increase the quality and productivity of their manufacturing processes. As a result, a number of process parameters must be managed during the casting process to ensure that companies do not experience ambiguity or failures. In the casting process industries, technical solutions are required to reduce uncertainty and faults. This review paper represents numerous casting faults and root causes for engine parts throughout the casting process. Also, provide preventive action to improve quality and productivity at the industrial level.

Keywords: Casting defects: Causes and remedies for casting defects.

1.INTRODUCTION

Casting is a manufacturing method in which hot molten metal is poured into a mold box with a hollow hole of the required shape and allowed to harden. That solidified item is referred to as a casting. Casting is commonly utilized to create intricate shapes that would be difficult or expensive to produce using other processes. Casting is a procedure that involves the possibility of failure at any point during the process of producing the end product. As a result, required steps should be taken during the casting process to ensure that no defects exist. Defects are inevitable during the casting process.Minor flaws can be easily fixed, but high rejection rates can result in large changes at a high cost. As a result, die casters must be knowledgeable about the many types of defects and be able to determine the specific root cause as well as its treatments. This review paper attempts to give all casting-related defects, including their origins and treatments.

In the casting process, the material is first heated until totally melted before being poured into the mold's cavity. Once the molten metal is in the mold, it begins to cool. When the temperature drops below the material's freezing point (melting point), solidification begins. Solidification is a change in phase of the material that varies depending on whether it is a pure element or an alloy. A pure metal solidifies at a constant temperature known as its melting point (freezing point).An attempt has been made to analyze important faults, and suitable remedial techniques are proposed for cast masters to have a thorough understanding of such problems in order to reduce rejection rates.

2. CLASSIFICATION OF CASTING DEFECTS

In this work, defects are classified based of their source in casting. This classification groups flaws based on their source.Each of these categories comprises both surface and bulk flaws. This document explains the reasons and cures for different types of problems.

Classification based on the source of defects:

1. Heat-related defects include hot tears, cold shut, and thermal fatigue.
2. Metallurgical defects include porosity, sinks, inclusions, dross, and soldering.
3. Mechanically produced defects include surface scratches, bending, and undercuts.

3. DEFECTS CAUSED BY THE THERMAL EFFECT

The heat defects can be caused by heat stress, poor fluid contact, or incorrect eat removal rates.

3.1 CRACKS

Random cracks and oxides cause black fractures. Cracks are geometrical discontinuities in casting. Cracks typically arise during the heated and contracting phase of casting. Some cracks are visible with the naked eye, while others require magnification.

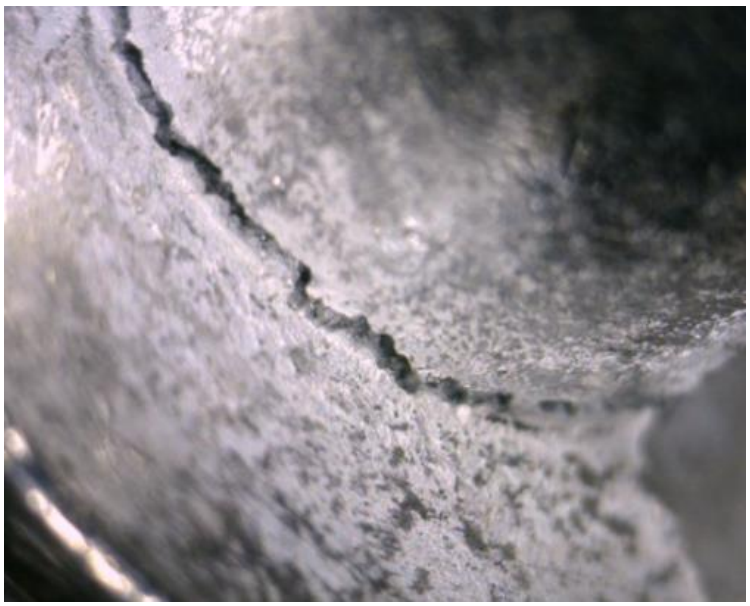

Figure 1: Crack (Source: Google)

➢ **Causes:**

- The contraction stress during casting cooling is too high.
- The casting is blocked in the mold.
- The casting was not equally cooled.
- The casting's structural design is illogical, with a rapid shift in geometry.
- Harmful contaminants are enhanced near the grain boundaries.

- The casting's surface interacts with the coating.

➢ **Remedies:**

- Casting should be properly designed.
- Use chillers for casting regions.
- Allow time for metal to cool.
- Lower correct pouring temperature.
- Provide feeders.
- Avoid sharp corners. Round off the corners
- To reduce die strength, add saw or coal dust.

3.2 HOT TEARS

Hot tears are a common casting fault. Semisolid casting causes irreparable failures. Hot tears appear in the final step of solidification.

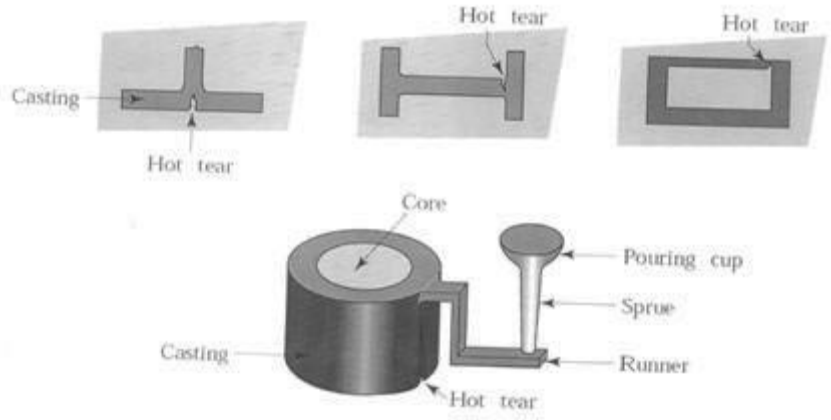

Figure 2: Hot tears (Source: Google)

➢ **Causes:**

- Thermal contraction led to abrupt section changes in castings.
- Improper gate placement.
- Incorrect metal pouring temperature.
- Improper solidification procedures.
- Thin portions.

➢ **Remedies:**

- Provide an appropriate fillet at intersections.
- The thickness should be consistent throughout the portion.
- Place the gate accurately near the die.
- Maintain precise metal pouring temperatures.
- Apply conventional solidification procedure.
- Use the minimum allowable thickness.Which depends on the casting technique.

3.3 COLD SHUTS

Cold shut occurs when microscopic metal droplets fall into a casting mould. When residual metal is placed into a mould, it solidifies and does not mix. Cold close refers to cracks with rounded edges. In cold shut, two separate metal streams do not fuse together.

Figure 3: Cold shut in part (Source: Google)

- **Causes:**
  - Reduce the fluidity of the mould.
  - Thin portion of casting.
  - Metal pouring temperatures are low.
  - Inadequate gate.

- **Remedies:**
  - Use metals with varying compositions.
  - Use the minimal thickness appropriate for the casting process.
  - Increase pouring temperature.
  - Place gating properly.

3.4 MISRUN

Misrun occurs when metal is not completely filled into a mould cavity, leaving an unfilled part.

Figure 4: Misrun in part (Source: Google)

➢ **Causes:**

- The thickness of the portion is too thin.
- Excessive die cavity fill time results in incomplete filling before metal hardens.
- Long flow distance within die cavity.
- Inadequate ventilation.
- Pouring interrupted.
- Metal temperature is too low.

➢ **Remedies:**

- The thickness should be consistent throughout the section.
- Decrease cavity fill time. Modify the gating design.
- To reduce flow distance, change the casting design.
- Provide proper ventilation.
- Pouring should be done uninterrupted.
- Increase the temperature of metal.

3.5 THERMAL FATIGUE

Aluminium die-casting dies are sensitive to significant thermal stress. Thermal fatigue is caused by thermal cycling, which shortens die life. A network of fissures forms on the surface of the die.

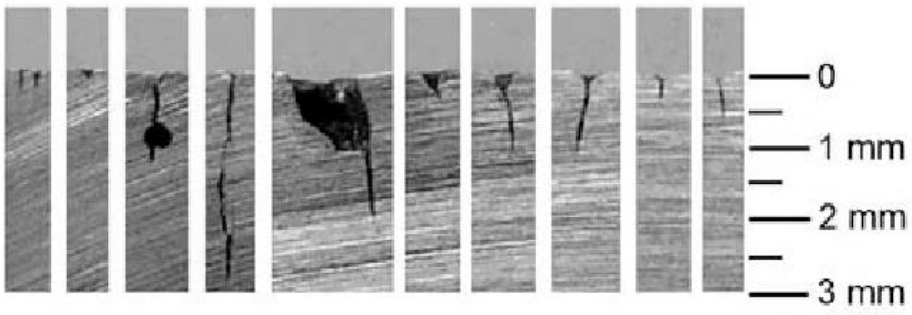

Figure 5: Thermal fatigue (Source: Google)

➢ **Causes:**

- When the die is continuously exposed to high temperatures.
- When edges and corners have short radius.
- When the temperature gradient at the gate is significant.

➢ **Remedies:**

- Cooling the die for a specific time is required.
- Determine acceptable radius for edges and corners.
- Lower temperature gradient near the entrance.

4. METALLURGICAL DEFECTS

Metallurgical flaws can be induced by factors such as alloy composition, melting temperature, mechanical qualities, and internal tensions.

4.1 POROSITY

Casting suppliers and customers commonly use the term "porosity" to describe casting flaws. Porosity refers to the presence of voids inside castings of varying sizes, shapes, and surface elements. Porosity can be classified into two types.

1. Gas Porosity
2. Shrinkage Porosity

4.1.1 Gas Porosity

Gas porosity in casting can be caused by trapped air, moisture from water-based die lubricants, or dissolved hydrogen in air. During metal pouring, the air in the cavity compresses and causes pressure to rise. It creates bubbles after cooling.

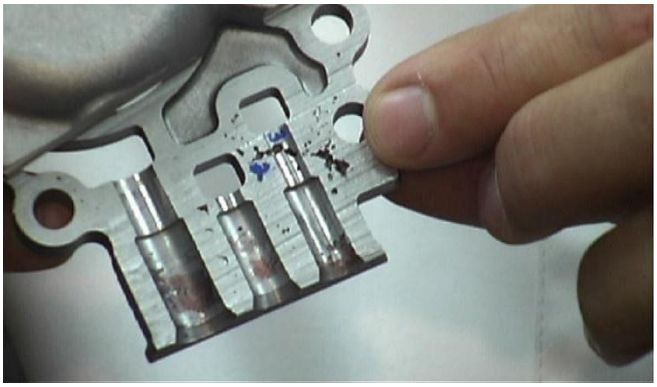

Figure 6: Gas porosity (Source:Google) Figure 7: Gas porosity in part (Source: Google)

➢ **Causes:**

- Metal pouring is too sluggish.
- Metal contains gas.
- The mould is too heated.
- Moisture in flux.
- Incomplete casting.
- The metal portion is too thin.
- Overheated molds.
- Metal pouring temperatures are low.

➢ **Remedies:**

- Metal is poured as quickly as possible, without interaction.
- Use vacuum degassing. Melt the metal in a vacuum.
- Maintain low mould temperatures.
- Proper venting of molds and cores.
- Ensure enough metal in the ladel to fill the mould.
- Improve the gating system.
- Improve casting design to eliminate thin metal sections and enhance runner design.
- Increase metal pouring temperature.

4.1.2 Shrinkage Porosity

Aluminium castings are frequently rejected due to shrinkage porosity. Internal cracks in casting can originate from various sources.

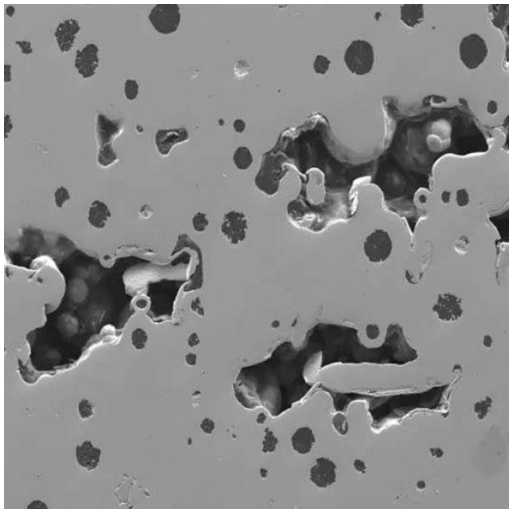

Figure 8: Shrinkage porosity (Source: Google)

➢ **Causes:**

- Increased metal concentration in a localized area.
- Casting geometry is complex, and metal pressure is too low.
- Poor gating and runner design.
- The metal is polluted.
- Lower metal volume during solidification.

➢ **Remedies:**

- Design the die with extra tolerance.
- Use simple geometry for casting.
- Higher metal pressure.
- Make changes to the design of the getting and runner.
- Use simulation software to optimize runner performance and cavity filling.
- Remove contaminants and clean the metal surface.
- Create a core hole in the centre and offset the ribs.

4.2 SINKS

Sinks arise in the presence of a subsurface cavity. Sinks are depressions on a part's surface that do not mimic the mold surface. Sinks are often noticeable as they reflect light.

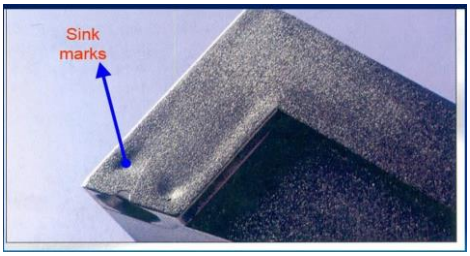

Figure 9: Sink (Source: Google)

- **Causes:**
  - Inadequate metal can be the major cause of sinking.
  - Gate sealing time is slow.
  - Low injection speed.
  - Significant volumetric contraction.
  - Metal cooling times are short.

- **Remedies:**
  - Use more metal while pouring to avoid sinks.
  - Increase gate sealing time.
  - Increase injection speed to reduce viscosity and provide additional backing pressure.
  - Move gates to issue locations.
  - Increase the cooling time of metal.
  - Reduce the temperature of metal.

4.3 BLISTER

Blisters arise when the internal pressure of gas-related porosity causes plastic deformation of the metallic surface.Blister is an example of metallurgical imperfection.

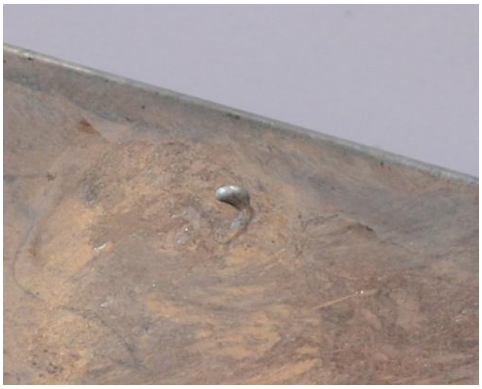

Figure 10: Blister (Source: Google)

➢ **Causes:**
- Extremely high injection rates.
- Gas pressure at the surface during fill.
- Eject high-temperature pieces from the die.
- High temperature on die surface.

➢ **Remedies:**
- Reduce the injection rates.
- Use vacuum filling for casting.
- Place temperature sensors near the die.
- Lower die surface temperature.

4.4 SOLDERING

Soldering is a major casting fault in the aluminium die casting process. Soldering is the process of adhering molten aluminium to the surface of die steel after casting. Soldering occurs after a few casting cycles.

Figure 11: Soldering defect (Source: Google)

➢ **Causes:**
- Poor gate design.
- Inadequate die cooling.
- Poor die surface polishing.
- Die temperatures are high.
- Improper iron content in alloy.

➢ **Remedies:**
- Allow more time for cooling.
- Maintain die surface.
- Lower die temperature.
- Use appropriate lubricants.
- Use iron within the recommended range of 0.8% to 1.1%.

4.5 SEGREGATION

Metals segregate due to changes in their chemical makeup. Segregation distinguishes between two categories.Microsegregation and macrosegregation. Microsegregation is a localized variation between dendritic arms. Diffusion is not a significant mechanism for microsegmentation due to the small distance involved (10-100 μm).

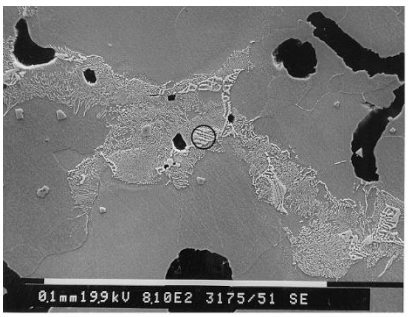

Figure 12: Segregation (Source: Google)

- **Causes:**
  - Local and non-equilibrium compositions can result in segregation.

- **Remedies:**
  - Heat treatment can effectively eliminate segregation.

4.6 INCLUSIONS

Inclusions in cast metal are caused by non-metallic particles from forging. These may include oxides, slag, dirt, sand, or nails. These inclusions can affect mechanical qualities, fatigue performance, and cause cosmetic faults.

Figure 13: Inclusions (Source: Google)

➢ **Causes:**
- Sand and grime are not properly removed from moulds.
- Improper gate system.
- During solidification, insoluble intermetallic compounds separate and concentrate in the residual liquid.
- Partially dissolved alloy additives in melt.

➢ **Remedies:**
- Clean the die on a regular basis.
- Improve the gating system.
- Pour clean, molten metal.
- Use a little amount of alloying material and master metal alloys to make the transformation.

4.7 DROSS

Dross is nothing but metal loss. Dross in aluminium casting includes 60.65% metallic aluminium. Drossing occurs when aluminium is melted and stored. During melting, aluminium oxide (AL203) and other oxides accumulate on the surface due to density differences.

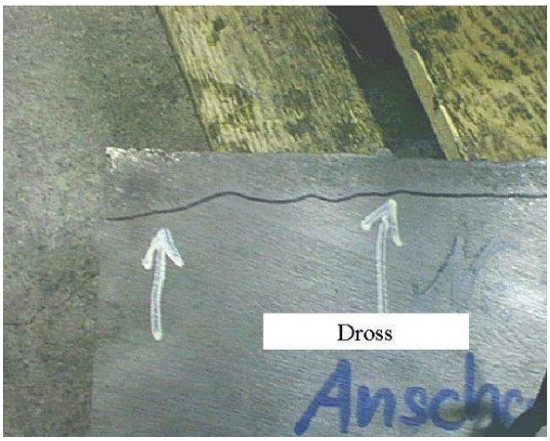

Figure 14: Dross (Source: Google)

➢ **Causes:**
- Oxides are formed when high-temperature liquid aluminium reacts with air during melting.
- Thermite reaction produces dross.
- Increased metal temperature.

➢ **Remedies:**
- Reduced reaction time leads to less dross production.
- Avoid stirring, which can trigger thermite reactions and oxidation.
- Reduce the temperature of the metal.

5. MECHANICALLY INDUCED DEFECTS

Surface markings, undercuts, and bending are mechanically induced defects caused by casting ejection and insufficient draft angles. Undercuts are caused by sand erosion by molten metal streams.

It creates a pattern around the gates and generates dirt in casting. External pressure and inappropriate ejection procedures might cause bending and surface markings. To avoid these problems, use an appropriate draft angle, standard ejection procedures, and modify the casting design.

6.CONCLUSION

This study introduces a new classification of faults and imperfections in Al alloy castings. Three types of casting flaws have been identified: filling-related defects, shrinkage defects, shape-related defects, and thermal-related defects. In brief, filling-related and thermal-related defects emerge from the interaction of melt flows at different temperatures, whereas undesirable phases are non-metallic phases such as oxides, refractory bits, and dross, which result from the interaction of melt and environment. Finally, thermal contraction flaws are fractures caused by casting contraction that is restricted by the die or the already solidified material. In this study, various casting faults are examined. Causes and cures are listed using references from various research articles.These will aid in the improvement of quality in enterprises by analyzing casting defects. This study will undoubtedly help to increase productivity. Casting rejections should be minimized to achieve improved quality.

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