NON-FERROUS ALLOYS CASTING DEFECTS : CAUSES & CURES

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ABSTRACT: Casting of metals is a process known to mankind for thousands of years, and widely used for sculpture, especially in bronze, jewellery in precious metals, and weapons and tools in the ancient time. But as technology advanced with human progress this has become a major and integral part of today's manufacturing process. While lot of work has been done to identify the casting defects there is little contribution in the field of casting of alloys specially non - ferrous alloys. This study identifies various defects in non ferrous alloys castings giving root causes for their occurrence and its remedies. Most widely used non - ferrous alloys are alloys of zinc and aluminium and the casting process commonly used for alloys is Die casting which has been taken as a major consideration in this study. The knowledge acquired can be used to take decision about the suitability of the application of the materials for the castings production, identify the defects and work towards it's elimination.The results expected out of this project seem to be of great use in creating a sustainable environment and reducing material wastage in industries by reducing rejected parts due to defects and increase the quality of castings.
Keywords : aluminium alloys castings, Zinc Alloy Castings, Non-ferrous Alloys, Casting defects, Die Casting.

I. INTRODUCTION

CASTING is a process where solid metal is dissolved, heated to a suitable temperature (heat treated to change chemical structure), then added to a mold or cavity in molten state, the mold keeps it in shape during solidification. As the end product, any object simple or intricate can be obtained from any material that can be dissolved with nearly any setting required by the designer.

Alloys derived from non - ferrous metals are referred to as non - ferrous alloys and it's furnaces and equipments for casting alter substantially from ferrous alloys therefore need specialised procedures. The metals most commonly used for no - ferrous alloys casting are aluminium, zinc, copper, brass, magnesium, titanium, bronze and lead castings.The most widely accepted and used technique is DIE CASTING that can be identified into two parts :

- HOT CHAMBER : for alloys with low melting temperature, ex: zinc, tin. lead.
- COLD CHAMBER : for alloys with high melting temperature, ex: aluminium, brass and magnesium.

The irregularities that occur in the end product after the casting process is termed as CASTING DEFECT, some defects can be tolerated while some can be repaired, otherwise the casting is eliminated. They are mainly classified into 5 main categories, mostly on the basis of their occurrence:

- Gas Porosity Defects
- Shrinkage Defects
- Mold Material Defects
- Pouring Metal Defects
- Metallurgical Defects

DEFECTS are those conditions in a casting that if not corrected the casting must be rejected.

DISCONTINUITIES are interruptions or imperfections in the physical continuity of the casting, if the casting is imperfect but still useful and in tolerance, the imperfections should be deemed discontinuities.

This study gives an organised knowledge of the casting defects that occur in non - ferrous alloys which enables us to identify the several types of defects. It tries to arrive the root causes due to which defects arise and also suggests remedies either to prevent the occurrence of defects or their removal if already occurred.

II. CASTING DEFECTS IN NON - FERROUS ALLOYS

Defects in non - ferrous alloys can be classified as follows:

2.1 LAPS AND SURFACE LAMINATIONS

Description: This is the most common type of defect found in Die Casting components. The effect of these type of defects on material properties are all very similar, but the causes and cures are not. It is necessary to know the process in detail to know about the defect causes and cures.

General Effects on Material

- Material strength is reduced, Fatigue Strength in particular.
- Spoils the Aesthetic Surface.
- While the product is in service, metal flakes may come off which affect efficient functioning.
- Sometimes Fluids may get trapped resulting in staining or bleeding.
- Dimensions are affected across parting lines.

4.1.1 - Surface Cold Shuts

Appearance: Laminated layers of discontinuities are found parallel to the surface, These laminations exist in the areas where the die is coldest. These laminations generally outline the flow patterns.

Causes: The major cause of Surface cold shut is the long time taken to fill the cavity during metal pouring. Time for cavity fill should be aimed at below 20ms.

Cure: Dies should be maintained at low temperatures, temperature between 350F - 450F is suitable.

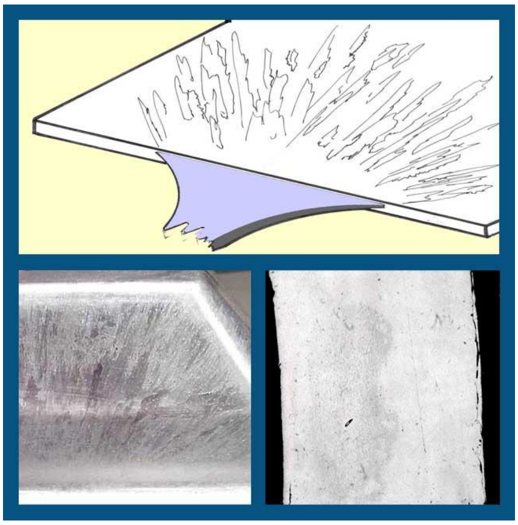

Fig 2.1.1 Surface cold

2.1.2 - Vortexing

Appearance: It appears as concentric or spiral laps associated with the filling pattern or the features in the die such as sharp corners. In severe cases it may also cause holes right through the part.

Causes: It is caused by a combination of long cavity fill time, high velocity at the gate and jetting action of the metal which flows into the cavity or around die feature.

Cures: Modification in the feed pattern or in the shape of the die cavity should be considered to allow smooth filling patterns to occur.

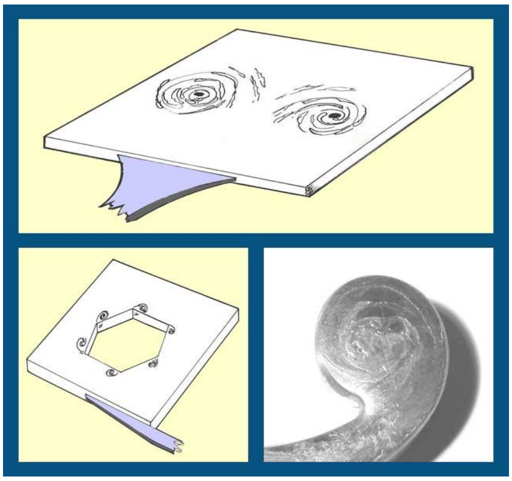

Fig 2.1.2 Vortexing

2.1.3 - Splashing and Shotting

Appearance: As the feed ends up in corners, dead ends and shadow areas of the casting isolated laps or spherical particles associated with it become visible. This defect is sometimes mistaken for soldering.

Cause:

- The city fill time is long, over 40 mili-seconds.
- The die temperature is low, below 350F.
- The control over the fill pattern is poor.

Cures: The time taken to fill the cavity should be reduced and temperature should be maintained at a standard value, there should be firm control over the fill pattern.

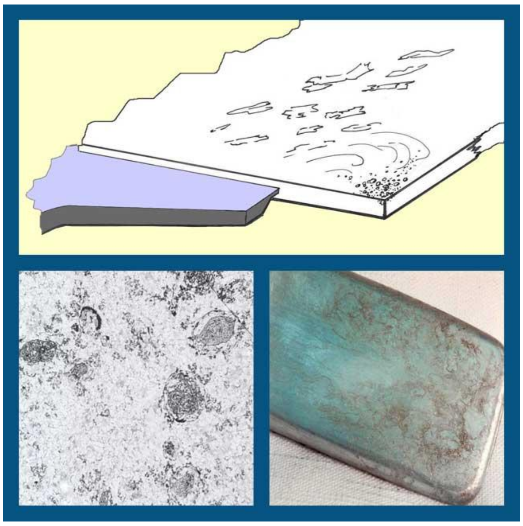

Fig 2.1.3 Splashing and shooting

2.1.4 - Lamination

Appearance: Cold laps have a "fish scale:" like appearance and are usually more isolated than other types of surface defects. They are most of the times associated with parting line flash, the flash surface usually bears signs of lamination.

Causes:

- It occurs if two die halves are separated at the end of the cavity fill.
- Some underlying causes are: poor support of the tool, insufficient die lock and high final metal pressure (impact pressure).

Cures: New and well maintained tools, dies, etc should be used to increase surface finish and prevent occurrence of laminates..

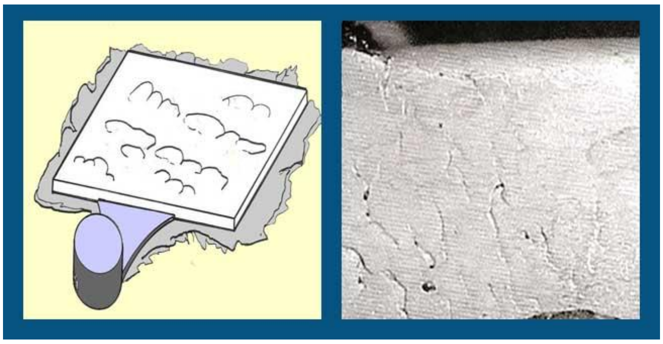

Fig 2.1.4. Lamination

2.2 SURFACE PROTRUSIONS AND INTRUSIONS

Description: These defects arise due to a variety of causes associated with both process control and component/die design. Generally, like other defects the effects of these type defects on material properties is similar but there causes and cures are not.

General effects on Material

- It spoils the aesthetic surface thus increases the finishing costs.
- It might affect dimensions across parting line but mechanical properties are not seriously affected.

2.2.1 - Blisters

Appearance: Convex bubbles come up on the surface of the casting, they appear usually in the hottest areas or in portions where gases are likely to be trapped close to the surface.

Causes:

- Due to excess lubrication of the die or water that enters in cavities from cracks in the die.
- Lower velocities at gate, below 100 feet per second.
- If adequate venting is not provided it encourages and exacerbates the problem

Cures: Excess use of lubricants must be avoided.
The process must be ensured of adequate gating and venting systems.

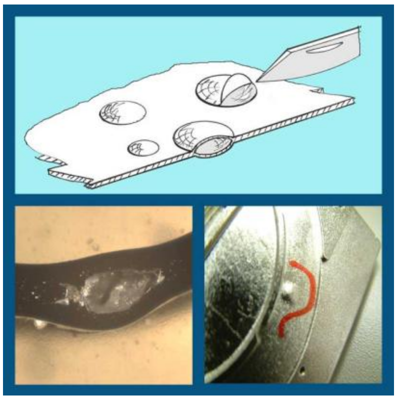

Fig 2.2.1 Blisters

2.2.2 - Sinks

Appearance: They appear as concave depressions, usually in areas of thick sections or in areas where there are changes in sections associated with ribs, etc. Sinks are also very much associated to shrinkage porosity.

Causes:

- The design of the component contains sudden changes in section thickness
- The final metal pressure is insufficient (1500psi is preferred minimum) or pressure transmission form gate to the affected area is poor.

Cures:

- The size of gates and runners must be increased to delay the gate freeze off time.
- The thickness variations should be minimised by modifying the part thickness of the design as suggested.
- The thickness of ribs. bosses and gussets should be redesigned to be at 50% to 80% of the attached (base) wall thickness.

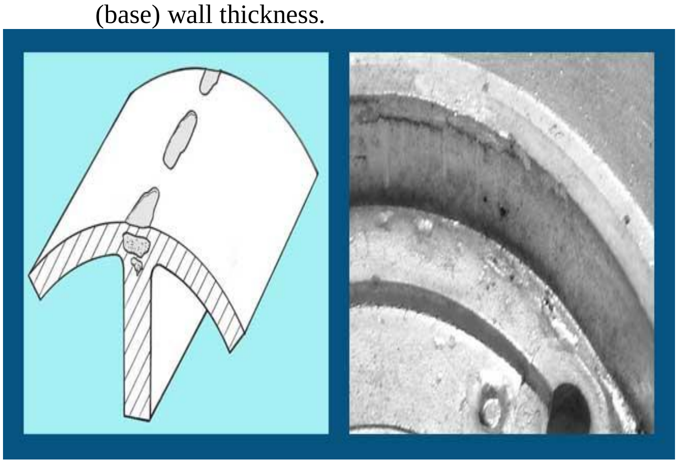

Fig 2.2.2 Sinks

2.2.3 - Lakes

Appearance: Very shallow depressions on the surface only 0.001 to 0.003 inches deep are called Lakes. they can only be seen on smooth surfaces under very good lighting and sometimes also appear on slightly convex or concave surfaces.

Causes:

- Till now no definite cause has been established but the defects usually associate to poor die temperature control.
- Caused by high local temperature gradients, aggravated by poor cavity filling conditions.

Cures: The formation of lakes can only be effectively prevented by improved temperature control.

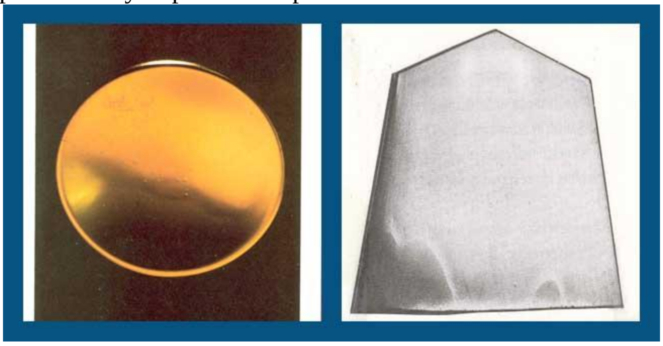

Fig 2.2.3 Lakes

2.2.4 - Drag marks and Galling

Appearance: These defects appear like rough protrusions, grooves and galling which are parallel to the direction of draw of the die, they are generally related to areas with no or little draft or areas where soldering has occurred.

Causes:

- Sometimes caused by the part shrinking on a core or bad die alignment, but mostly zero draft or undercuts should be checked.
- Ineffectiveness or insufficiency of die lubrication can also be a factor.
- Due to Roughness of Die caused by cracks or die soldering.

Cures:

- Sufficient allowances must be provided.
- High quality and effective lubricants must be taken in use.

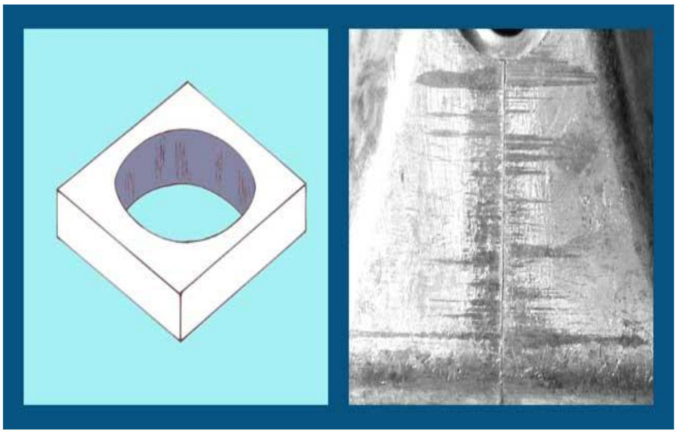

Fig 2.2.4 Drag marks and Galling

2.2.5 - Solder or Burn - on

Appearance: These are rough depressions appearing on the casting. caused by metal build-up in the die. These defects are usually associated with drags. There may be protrusions in serious cases, when the surface of the die has been lost.

Causes:

- High temperature of the metal or the die, over 450F
- High velocity of the molten metal, over 160 feet per second.
- Direct impact or interaction of the metal on the die surface.
- This effect may be initiated by Drag and Galling.

Cures: The die should be thoroughly inspected for any unwanted metal formations and cleaned before molten material is poured.

The process should be properly planned to ensure adequate velocity and temperature of the molten material.

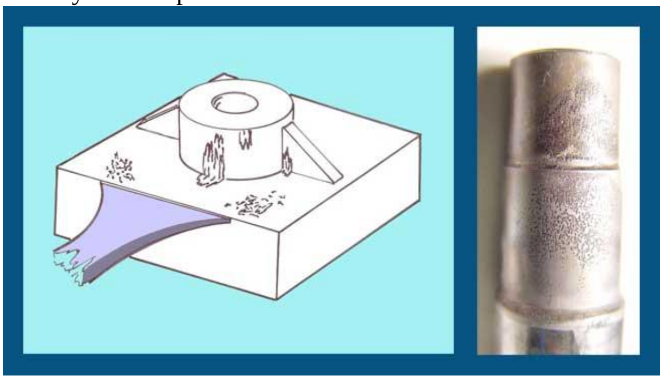

Fig 2.2.5 Solder or Burn on

2.3 GAS POROSITY

Description: In die castings Gas Porosity is always present to some extent. This is because gases in the cavity mix with the in-flowing metal and cannot be separated or escape. Cases where very fine porosity exists require careful metallurgical polish, upto 3 microns or less and microscopic examination is required.

General Effects on Material

- As the effective thickness of the section is lessened mechanical properties are reduced.
- The notch effects and stress concentration effects of other types of porosity machining problems & drill “wander” are not produced by the spherical shape of the pores.

2.3.1 - Hydrogen Gas Porosity

Appearance: This defect occurs one in hydrogen alloys as Zinc cannot absorb hydrogen gas. It appears as usually well distributed, very shiny spherical or almost spherical pousuallyres. The appearance of the machined surface is spoiled and the section strength is reduced but pressure tightness is improved due to it’s occurrence.

Causes: The molten metal absorbs hydrogen, mainly from water vapour and expels it back to the surface of the casting as metal solidifies.

Cures: Purging the molten metal with nitrogen or a reactive gas before the casting operation may remove hydrogen gas porosity.

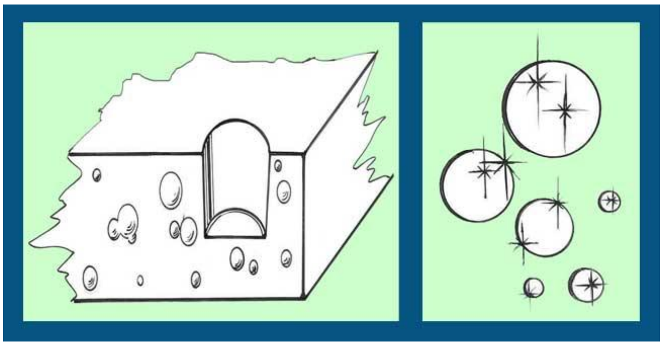

Fig 2.3.1 Hydrogen Gas Porosity

2.3.2 - Gas Porosity (Oxidizing Gases)

Appearance: These defects appear as cavities which are spherical, oval or tear-drop shaped, with slightly roughened, darkened surfaces. They may gather in the centre of thick sections or hot areas of the die. Occasionally, the porosity may be close to the surface giving rise to blisters or plating problems.

Causes: Excess die lubrication, common amount of die lube ranges between 0.3-0.9oz of diluted lubricant per pound finished casting.

- Cracks in the die give passage for water to enter, causing porosity.

Cures: Low gate velocity, below 100FPS and inadequate venting also encourage and exacerbate the effect, both should be avoided.

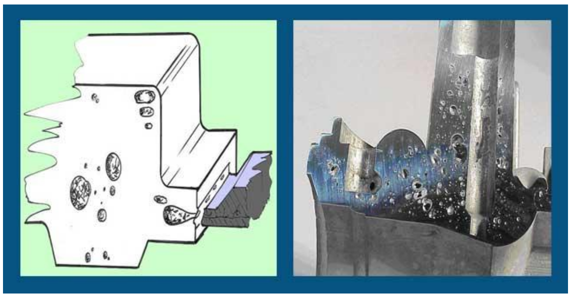

Fig 2.3.2 Gas Porosity (Oxidizing Gases)

2.4 - SHRINKAGE POROSITY

Description: As metal changes from liquid to solid, shrinkage occurs which causes this type of porosity. Depending upon the alloy, the section shape and the process variables it can occur in various forms, from roughly spherical, or cubic shapes to thin crack-like defects. The shrinkage types do not have a clear-cut separation and more than one type may be present in the same area of the casting.

General Effects on Materials

Shrinkage porosity badly affects mechanical properties. The more the defects are crack like, the worse is their effect on material. Porosity can also cause pressure leakage as it is often interconnected, corrosion problems may also exist due to entrapped fluids.

2.4.1 - Gross Shrink Porosity

Appearance: This defect appears to be roughly spherical or cubical in shape and usually exists in areas that are last to solidify like the thicker sections or the heat centre. This type of porosity sometimes occurs at the gate due to the same reasons.

Causes: Large changes in the section thickness results in

poor feeding during solidification.
Sometimes due to worn plunger rings or sleeve, there is a lack of final metal pressure, below 1500PSI.
Cures: Additional gating or sprue of proper size, if attached directly to the heavy or thicker sections of the casting can help in filling the cavity and provide necessary feed material to counteract shrinkage as cooling occurs.
Using a rounded gate instead of a square or flat gate further reduces the formation of these defects at gates.

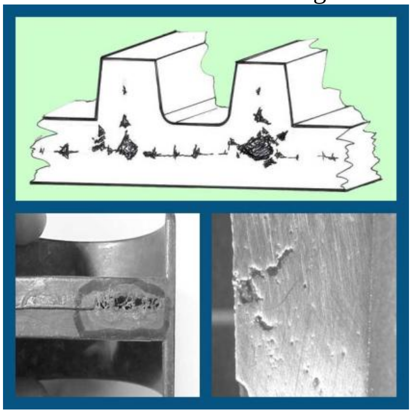

Fig 2.4.1 Gross Shrink porosity

2.4.2 - Inter-Granular (Inter-Dendritic) Shrinkage
Appearance: This defect appears as the discontinuities between grains of the metal or thread like filamentary shrinkage. It may exist at hot spots caused by sharp corners in the tool, or near the centreline of thin sections.
Causes: Lack of final metal pressure and poor feeding due to large change in section thickness.

- This is more common in alloys with long solidification range.

Cures: Additional gating or sprue of proper size, if attached directly to the heavy or thicker sections of the casting can help in filling the cavity and provide necessary feed material to counteract shrinkage as cooling occurs.

- The solidification range can be reduced by ensuring proper cooling techniques and altering the alloy chemistry.

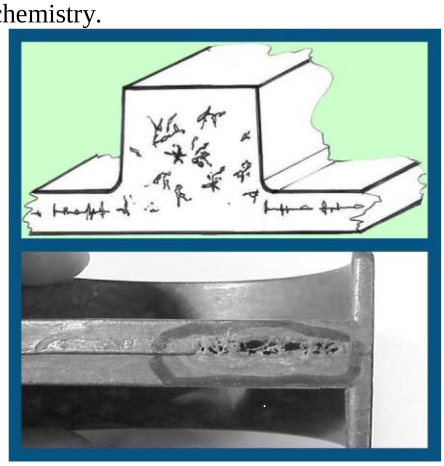

Fig 2.4.2 Inter-Granular (Inter-Dendritic) Shrinkage

2.4.3 - Centreline Porosity
Appearance: This is a variant of inter-granular porosity found in relatively thin sections down the centreline. It weakens the plane and may cause leakage, they are sometimes called "cleavage planes".
Causes: Heat is extracted by the outer walls as a result the metal solidifies inwards, and unless it is fed by sufficient supply of molten metal porosity remains in the centre.
Cures: Same steps as gross shrinkage and inter granular porosity should be taken, along with these sufficient molten metal feed should be ensured to avoid porosity at the centre.

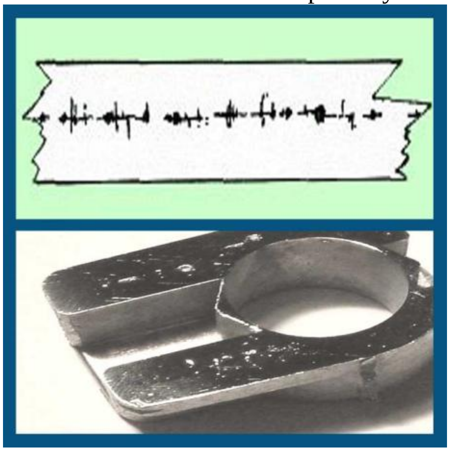

Fig 2.4.3 Centreline Porosity

2.5 - HOT - TEARS AND CRACKS
Description: These defects are caused particularly during or just after ejection by a a combination of shrinkages and stresses, or by stress alone because of the low strength at elevated temperatures.These defects require crack detecting equipment to reveal them as they are often very difficult to see from naked eyes. The cracks may be sub-surface in some cases.
General Effects on Materials
Hot Tears and Cracks adversely affect material properties. The worst form of this defect can be seen as Long cracks as it causes both, loss of effective section and stress concentration. Pressure leakage or Corrosion problems can also occur due to entrapped fluids.

2.5.1 - Hot Tears
Appearance: A series of ragged, discontinuous cracks are called Hot Tears, they are often associated with other forms of shrinkage defects. They are only visible in careful examination of the cross section as they may be below the surface. As stress levels increase, cracks become straighter and more continuous.
Causes: Shrinkage contraction causes a combination of inter-granular shrinkage and stress, particularly in areas where things like cores, walls with zero taper hold the casting rigidly.
These effects are increased by sharp corners and thin die sections.
Cures: Modify casting design to avoid sharp corners, Increased radii abolishes sharp inside corner.
Use refractory materials that provide low non-flexural strength.

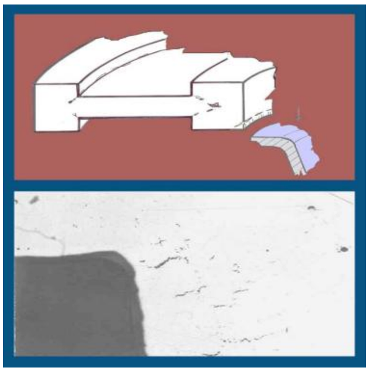

Fig 2.4.5 Hot Tears

2.5.2 - Cracks and Hot Cracking

Appearance: This discontinuities are very thin and seriously reduce the mechanical properties. Often, without careful preparation of cross-section and microscopic examination they cannot be seen. The preferred techniques are Dye Penetrant or florescent crack-detecting techniques.

Causes: Things such as "hanging-up" in the die cause a combination of shrinkage and stress, press trimming also gives rise to ejection problems and stresses.

- More discontinuities and crookedness are found in cracks that form at high temperatures.
- Cracks that are formed at lower temperatures are straight and more continuous.

Cures: Faster cooling rate should be reduced by mold insulation or use of insulating refractories.

Selection of proper alloys or altering alloy chemistry and giving proper gating is helpful.

Fig 2.4.5 Cracks and Hot-Cracking

III. CONCLUSION

In this research work different casting defects related to NON-FERROUS ALLOY CASTINGS are studied. By referring different research papers and resource material available from leading industry experts causes and cures for most of the defects are listed. These will be helpful for manufacturers and quality control department of non-ferrous casting industries for analysis of casting defect. This study will definitely be helpful in improving the productivity and yield of the casting. The study done so far will be useful to readers and learners in a number of ways, this work can be carried further by going into the details of each defects and looking for better preventive measures to avoid defects. As for the human nature is considered there will always be a room for imperfections but advanced research can bring more cost effective ways to cure defects caused in the casting processes. Defects leads to part rejection, etc causing huge material wastage which cannot be afforded in today's world where resources are depleting at a much higher pace.

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