Classification of Zinc Die Casting Defects

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DIAGNOSTIC TECHNIQUES: Correct diagnosis is essential if the corrective actions are to be effective. ***Do not rely on a brief examination of the parts. Use the following procedure:***

- Make a careful visual/metallurgical examination using the equipment listed on the right.
- Collect process details (fill time, gate velocity, die temp, final pressure, metal temp, lubrication details, etc.)
- Use this data alongside the physical evidence to make a final diagnosis and decide the corrective action.
- For simplicity, this document shows each defect separately. Under normal conditions more than one defect may be seen on the same casting, often in the same area.

EQUIPMENT and TRAINING (The following equipment is required):

Surface Defects:

- High intensity lighting: 2150 to 2700 Lux (four bare florescent tubes, directly above the worktable).
- Polishing buff or steel wool if the parts are to be plated.
- Magnifier or (preferably) binocular macroscope (10X power).

Internal Defects:

- Sectioning equipment (e.g., a band saw).
- Polishing equipment to 600 grit absolute minimum, preferably
- 3-micron polish – Operator training is important.
- A good lens (20 X) or microscope (100X).
- X-Ray, crack detection or Ultrasonic testing is useful

Category 1 – Laps and Surface Laminations:

These types of defects are very common in die cast components. The effects on the properties are all very similar, but the causes & cures may not be. It is therefore necessary to understand die casting process and design details, such as cavity fill time, die temperature and metal flow to help determine the root causes of these defects

General effects on properties:

- Reduced strength, particularly fatigue strength.
- Esthetic surfaces spoiled.
- Metal flakes may come off in service, affecting the function.
- Fluids may be trapped and cause staining or "bleeding".
- Across parting-line dimensions may be affected.

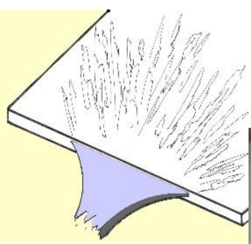
1.1 - Surface Cold shuts:

Appearance:

Laminated discontinuities parallel to the surface in the coldest areas of the die. Usually outlining the flow pattern

Causes and Cures:

- Long cavity fill time (Aim for below 20 ms)
- Low dies temperature (Aim for temperatures between 350ºF – 450ºF)



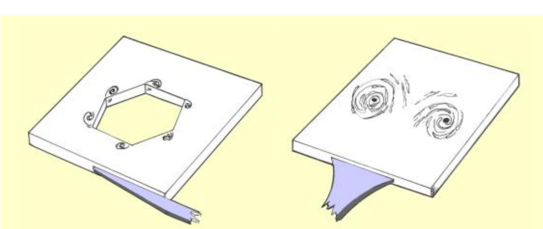
1.2 - Vortexing:

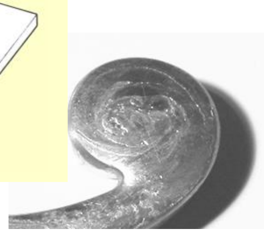
Appearance:

Concentric or spiral laps associated with the filling pattern, or with features in the die such as sharp corners. In severe cased holes may go right through the part

Causes and Cures:

- A combination of long fill time, high gate velocity and jetting action of the metal flowing into the cavity or around a feature in the die
- Consider modifying the feed pattern or the shape of the die cavity to allow smooth filling patterns to occur





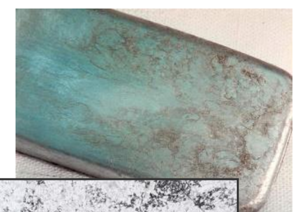
1.3 - Splashing and "Shotting":

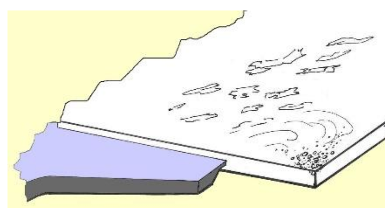
Appearance:

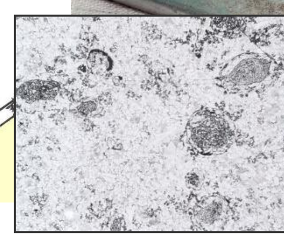
Isolated laps or spherical particles associated with the feed ending up in corners, dead-ends and shadowed areas of the casting. <u>This type of defect can be mistaken for soldering (see section 2.5)</u>

Causes and Cures:

- Long cavity fill time (over 40 millisecs)
- Low dies temperature (below 350ºF)
- Poor control over fill pattern







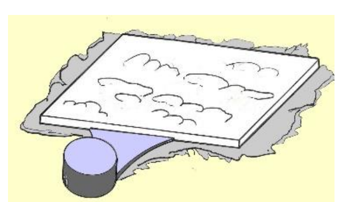
1.4 - Lamination:

Appearance:

Cold-laps are usually more isolated than other types of surface defects and often have a "fish-scale" appearance. They are almost always associated with parting-line flash, and signs of lamination can usually be seen on the flash surface.

Causes and Cures:

- Separation of the two die-halves at the end of cavity fill
- Underlying causes are: insufficient die lock, poor tool support, and high final metal pressure (impact pressure)



Category 2 – Surface Protrusions and Intrusions:

These defects are due to a variety of causes associated with both process control and die/component design. Generally, their effects on properties are similar, but the causes and cures may not be.

General effects on properties:

- Esthetic surface spoiled and finishing costs are increased.
- Across parting-line dimensions may be affected.
- Mechanical properties are normally not seriously affected.

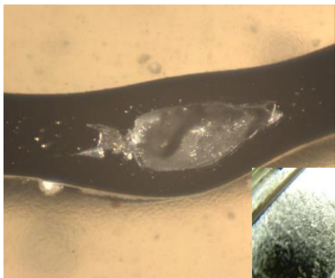
2.1 - Blisters:

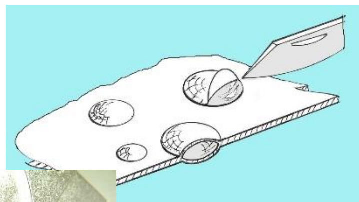
Appearance:

Convex bubbles appear on the surface, usually in the hottest areas or where gasses are likely to be trapped close to the surface

Cause and Cures:

- Excessive die lube, or water in the cavity from cracks in the die
- Low gate velocity (below 100 FPS)
- Inadequate venting will also encourage and exacerbate the effect





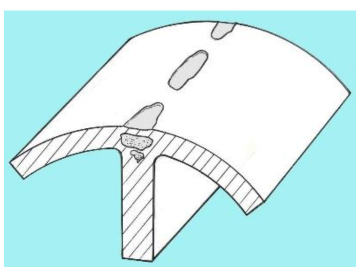
2.2 - Sinks:

Appearance:

These defects appear as concave depressions, usually overlaying thick sections or changes in section associated with ribs etc. Sinks are also often associated with shrinkage porosity.

Causes and Cures:

- Component design contains sudden changes in section thickness
- Insufficient final metal pressure (1500 psi. preferred minimum), or poor pressure transmission from the gate to the affected area



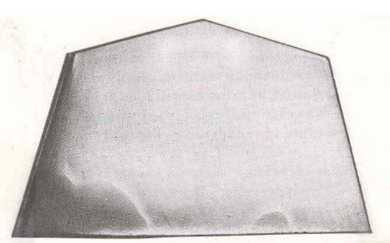
2.3 - Lakes:

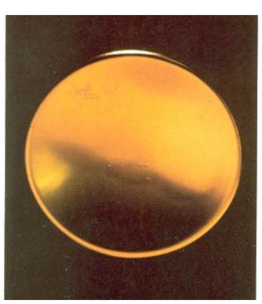
Appearance:

Lakes are very shallow depressions of only 0.001 to 0.003 inches deep**.** They are only visible on smooth surfaces with very good lighting, and usually appear on slightly convex or concave surfaces.

***Causes and Cures*:**

- No definitive cause has been established but the defects are usually associate with poor die temperature control
- Particularly local high temperature gradients, exacerbated by poor cavity filling conditions





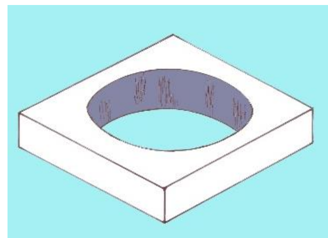
2.4 - Drag-marks and Galling:

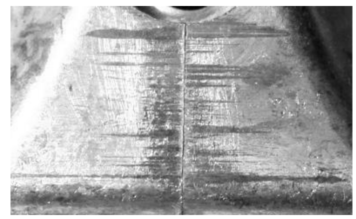
Appearance:

These defects appear as rough protrusions, grooves, and galling parallel to the direction of draw. They are often associated with areas with little or no draft, or where soldering has occurred.

Causes and Cures:

- Check for zero draft or undercuts, sometimes caused by the part shrinking on a core, or bad die alignment
- Insufficient, or ineffective die-lube may also be a factor
- *Die roughness caused by cracks or die soldering - see 2.5*





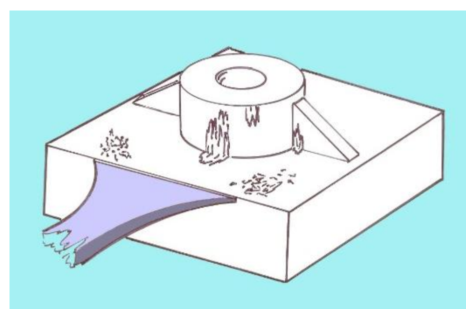
2.5 - Solder or Burn-on:

Appearance:

Rough depressions on the casting caused by metal build-up in the die. In serious cases there may be protrusions caused when the surface of the die has been lost. These defects are usually associated with drags

***Causes and Cures*:**

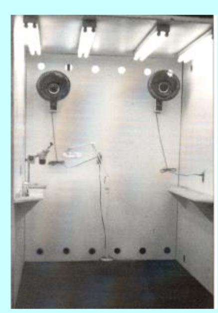
- High die (over 450°F) or metal temperature
- High metal velocity (over 160 FPS)
- Direct metal impact on the die surface
- *Drag and galling may initiate this effect – see 2.4 above*



SURFACE EXAMINATION:

A special area should be available with very good lighting (2700 Lux), polishing equipment, and a magnifier or microscope.

The picture shows a "lightbox with bare florescent tubes which gives very good conditions for examining for these types of defects.



Category 3 – Gas Porosity:

Gas porosity is always present to some extent in die-castings. Since gasses in the cavity becomes mixed with the in-flowing metal and it cannot be separated or escape. In cases of very fine porosity, careful metallurgical polish, to 3 microns or less, and microscopic examination is required.

General effects on properties:

- Mechanical properties will be reduced because the effective section thickness is lessened.
- The spherical shape of the pores does not produce the notch effects and stress concentration effects of other types of porosity.
- Machining problems & drill "wander".

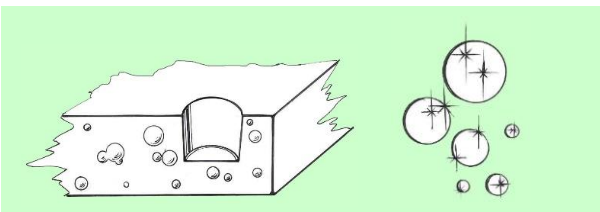
3.1 - Hydrogen Gas Porosity:

Appearance:

This defect only occurs in Aluminum alloys (hydrogen cannot be absorbed by Zinc). It appears as very shiny shperical or almost-spherical pores, usualy well distributed. Section strength is reduced and the appearance of machined surfaces is spoiled, but pressure-tightness may be improved.

Causes and Cures:

- Hydrogen is absorbed by the molten metal (mainly from water in the atmosphere) and is expelled as the metal solidifies
- It may be removed by purging with nitogen or a reactive gas before the casting operation



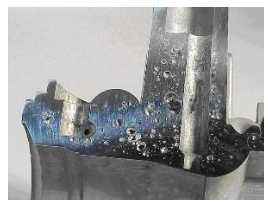
3.2 - Gas Porosity (Oxidizing gasses):

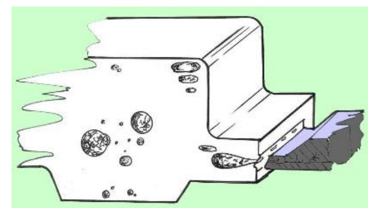
Appearance:

Sherical, oval, or tear-drop shaped cavities, with slightly roughened,darkened surfaces. May congeregate in the center of thick sections, or hot areas of the die. Occasionaly the porosity may be close to the surface and give rise to plating problems or blisters.*- see2.1*

Causes and Cures:

- Excessive die lube (common amount of die lube used ranges between 0.3-0.9 oz of *diluted* lube per pound of finished casting)
- Water in the cavity from cracks in the die
- Low gate velocity (below 100 FPS) and inadequate venting will also encourage and exacerbate the effect





Category 4 – Shrinkage Porosity:

This type of porosity is caused by the shrinkage that occurs as the metal changes from liquid to solid. It occurs in many forms, from roughly spherical, or cubic shapes to thin crack-like defects, depending on the alloy, the section shape, and the process variables.

General effects on properties:

- Mechanical properties are badly affected. The more crack-like the defects, the worse the effect, because of stress concentration.
- Often the porosity is inter-connected which can cause pressure leakage or corrosion problems due to entrapped fluids.

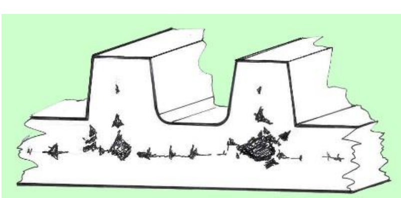
4.1 - Gross Shrink Porosity:

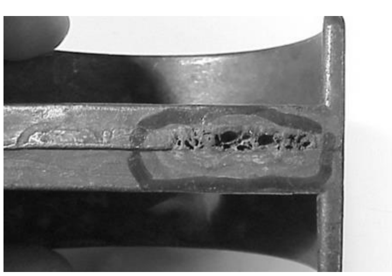
Appearance:

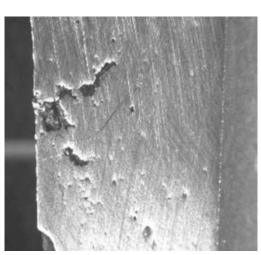
This defect appears as being roughly spherical or cubic shaped and is usually found in the thicker sections (or the "heat center"), which are the last area to solidify. For the same reason this type of porosity sometimes occurs at the gate.

Causes and Cures:

- Poor feeding during solidification due to large changes in section thickness
- Lack of final metal pressure (below 1500 PSI) that may be due to worn plunger rings or sleeve







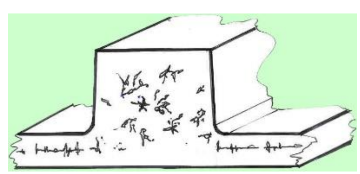
4.2 - Inter-granular (Inter-dendritic) Shrinkage:

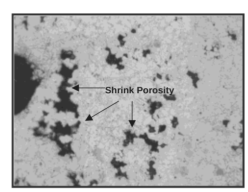
Appearance:

Thread-like filamentary shrinkage, or discontinuities between the grains of the metal. May be found down the centerline of thin sections or at hot spots caused by sharp corners in the tool.

Causes and Cures:

- Poor feeding during solidification due to large changes in section thickness and lack of final metal pressure
- More common in alloys with a long solidification range





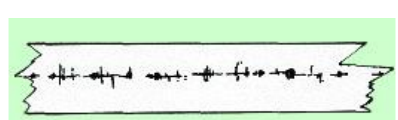
4.3 - Centerline Porosity:

Appearance:

A variant of Inter-granular porosity found down the centerline of relatively thin sections. It may cause a plane of weakness, and leakage. Sometimes they are called "cleavage planes".

Causes and Cures:

- The outer walls extract heat so that the metal solidifies inwards and, unless there is a supply of molten metal to feed it, porosity is left in the center



Category 5 – Hot Tears & Cracks:

These defects may be caused by a combination of shrinkage and stress, or by stress alone, particularly during or just after ejection because of the low strength at elevated temperature. These defects are often very difficult to see and may require crack-detecting equipment to reveal them. In some cases, the cracks may be sub-surface.

General effects on properties:

- Mechanical properties are adversely affected. Long, straight cracks are the worst form of this defect, because of both loss of effective section and stress concentration.
- These can also cause pressure leakage or corrosion problems due to entrapped fluids.

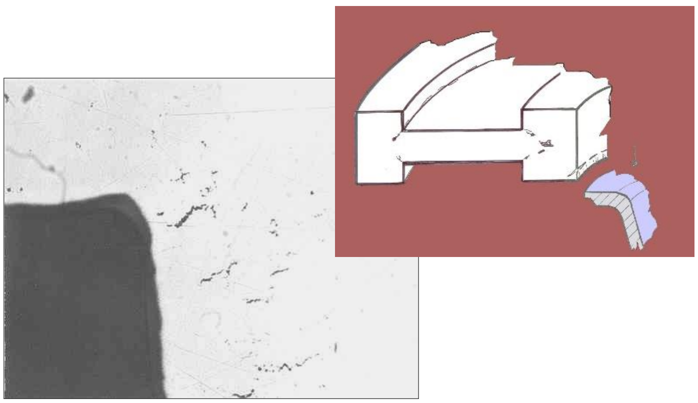
5.1 - Hot Tears:

Appearance:

Hot tears appear as a series of ragged, discontinuous cracks, often associated with other forms of shrinkage defects. They may be below the surface, only visible in carefully examined cross-sections. Cracks become straighter and more continuous as stress levels increase.

Causes and Cures:

- Due to a combination of inter-granular shrinkage and stress caused by the shrinkage contraction, particularly in areas where the casting is held rigidly by things such as cores, or walls with zero taper
- Sharp corners and thin die sections will increase these effects



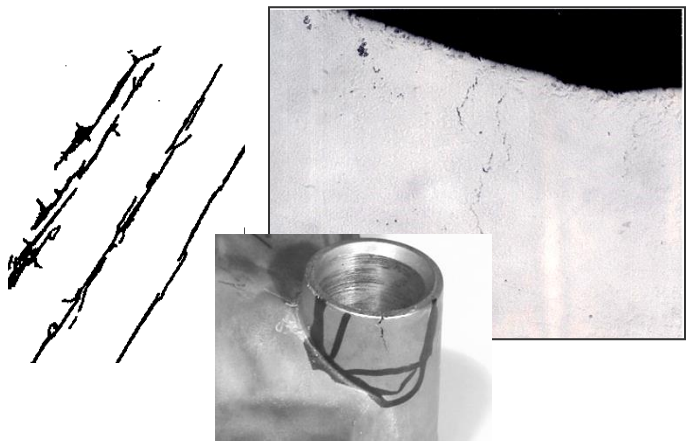
5.2 - Cracks and Hot-Cracking:

Appearance:

Very thin discontinuities, which very seriously reduce the mechanical properties. Often, they cannot be seen without careful preparation of cross-sections and microscopic examination. Dye penetrant or florescent crack-detecting techniques may be preferred.

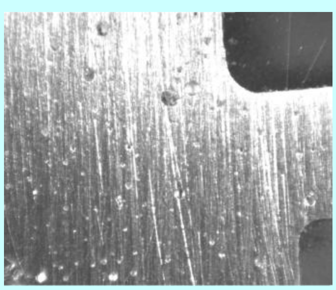
Causes and Cures:

- A combination of shrinkage and stress caused by such things as "hanging-up" in the die, ejection problems and stresses during press trimming
- Cracks formed at high temperature will be more discontinuous and crooked
- Cracks caused at lower temperatures will be straight and more continuous



EXAMINING CROSS-SECTIONS

Cross-sections must be carefully prepared; otherwise, the evidence of internal discontinuities will be destroyed as metal is flowed over by the abrasive. The smaller the defect, the finer must be the polish. It is recommended that cross-sections are polished using gradually finer abrasives to better than 3 microns. The picture on the left has a 280-grit finish. The picture on the right is the same section polished to 3 Micron. Both are at a magnification of about 50X.



NOTES, REFERENCES ETC.:

- This brief document only deals with the most common defects, & does not include non-metallic, or inter-metallic inclusions. The presence of several types of defects in the same casting sometimes markedly changes the appearance of the discontinuities.
- The classification groups defects primarily by their effects on properties, not by causes.
- Where possible we have given rough values for process variables; these are "guidance value" only, further reading is required to define more precise numbers.
- For more detail refer to: - "Die Casting Defects ", W. Walkington, and Published by NADCA. Zinc Die Casting Defects Manual, published by Cominco Ltd., Finishing & Electroplating Die Cast & Wrought Zinc, published by ILZRO.