Atlas of

Casting Defects

Investment Casting Institute

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Introduction

This manual is provided to assist both process engineers and manufacturing personnel to identify defects in castings. It offers suggested remedies to reduce or eliminate the defect.

The manual provides an easy-to-use format. Photos provide a visual of the defect; text provides a list of probable causes and the suggested remedies.

Acknowledgments

The Investment Casting Institute wishes to thank all of the members of the Institute's Publication and Casting Committees who provided information, photographs and valuable resources. This excellent support has made it possible to create this *Atlas of Casting Defects*, an educational tool that will be of great value to the industry now and in the future.

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Defect: Cold Shut

Appearance of Defect: **Linear indication of metal not joined at time of two metal streams meeting.**

Probable Cause

1 Low metal pouring temperature.

2 Poor pouring practice.

3. Improper gating.

4. Low shell permeability.

5. Heavy oxidation of metal increasing surface tension.

6. Low metal fluidity.

Suggested Cure

1. Increase metal and/or mold temperature.

2. Increase head pressure and/or rate of pour; avoid splashing.

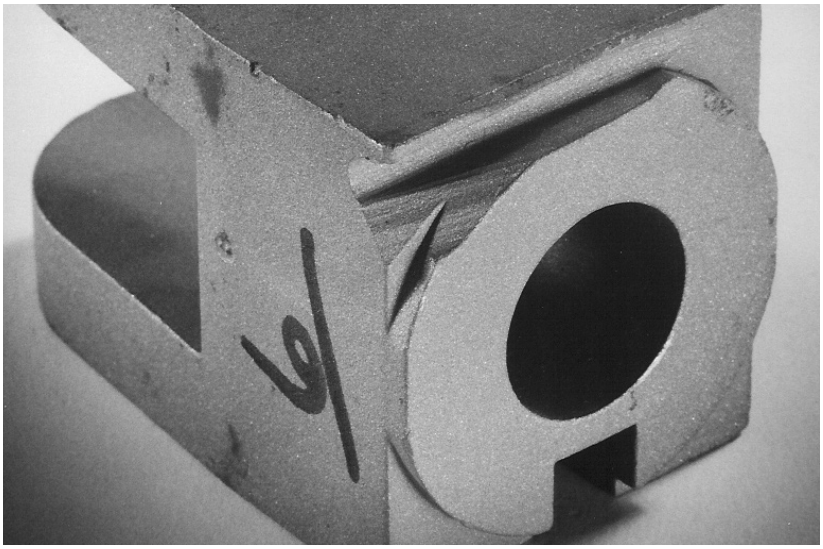
3. Improve gating to enhance mold fill.

4. Increase shell permeability and/or add vents.

5. Melt under controlled atmosphere or vacuum conditions.

6. Modify alloy composition to enhance fluidity.

Defect: Cut Off Damage



Appearance of Defect: **Metal removed during gate cut-off with evidence of abrasive wheel and/or saw damage to casting.**

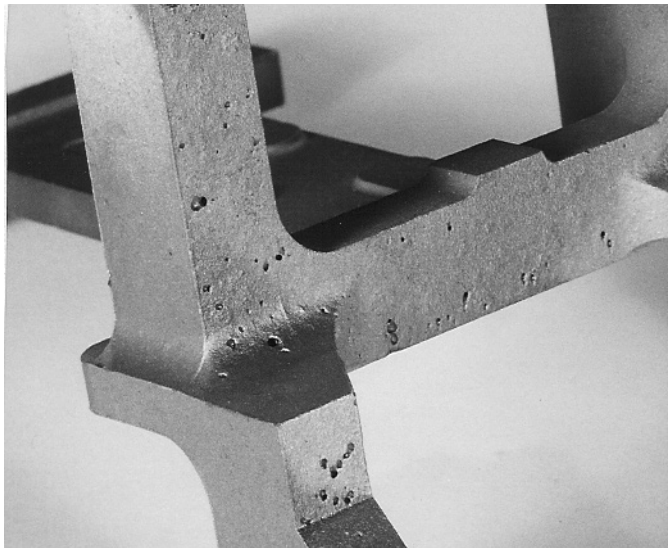
Probable Cause

1. Improper design of casting tree.
2. Worn and/or dull saw blades.
3. Improper fixturing by operating personnel.

Suggested Cure

1. Ensure sufficient clearance for necessary blade thickness while removing castings from tree, lengthen the gate.
2. Maintain cutting edges on blades and abrasive wheels to prevent walking.
3. Improve fixturing to minimize mistake and improve safety.

Defect: Gas



Appearance of Defect: **Generally spherical or teardrop shaped cavities which may or may not contain evidence of oxidation.**

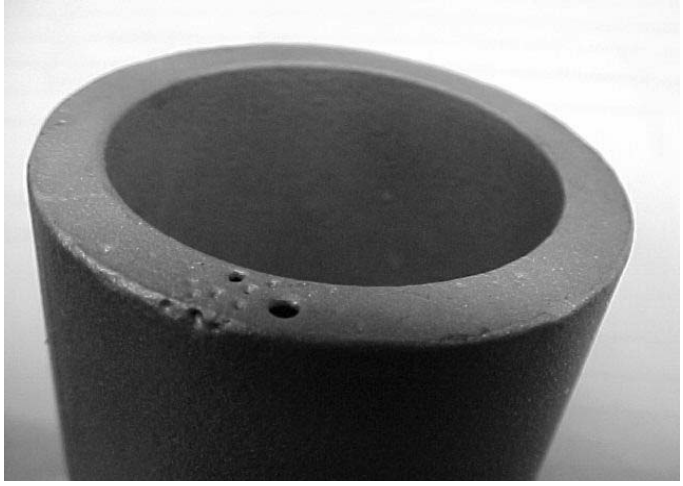
Probable Cause

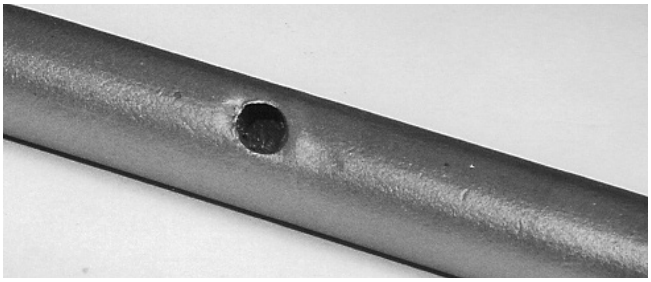
1. Improper or insufficient deoxidation.
2. Metal held at superheat temperatures for extensive length of time.
3. Dirty, wet or contaminated (rusty) charge materials along with possible moist ladles and furnace linings.
4. Low shell permeability.
5. Improper burnout.

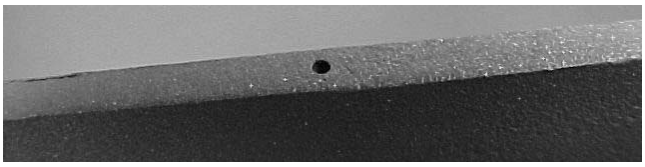
Suggested Cure

1. Revise or increase deoxidation technique.
2. Control time at temperature and cast at lowest temperature possible.
3. Clean all materials charged. Be sure moisture is removed from refractory materials.
4. Improve permeability by using fewer coats and increasing size of refractory particles.
5. Increase burnout time, increase oxidizing atmosphere in burnout furnace, increase burnout temperature.

Defect: Gas (Air Entrapment)







Appearance of Defect: **Rounded smooth walled cavities which may exhibit a slightly oxidized surface.**

Probable Cause

1. Turbulent metal flow.

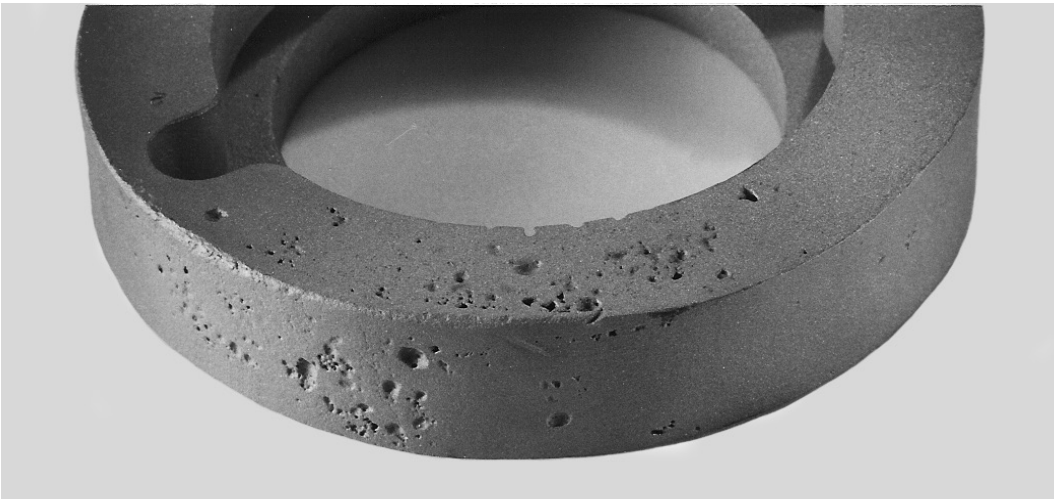
2. Low shell permeability.

Suggested Cure

1. Reduce pouring height between vessel and mold. Modify gating to reduce turbulence, possibly establish a self venting feeding system and also bottom feeding.

2. Use coarser refractory particles, use fewer coats, vacuum assist during pour, increase sprue height.

Defect: Slag



Appearance of Defect: **A series of cavities of irregular and symmetrical shape indicative of slag and/or refractory particles producing the irregular shapes and gas producing the symmetrical shapes.**

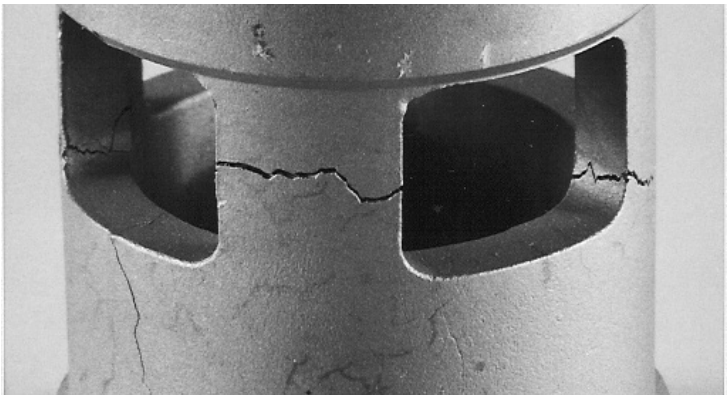
Probable Cause

1. Improper deoxidation.
2. Metal held at superheat temperatures for extensive lengths of time.
3. Dirty, wet or contaminated (rusty) charge materials along with possible moist ladles and furnace linings.
4. Impurities within metal being melted (i.e. slag, refractories, rust on surface, etc.).
5. Particles of refractory from furnace ladle, furnace lip and ladle lip.
6. Improper slagging practice.
7. Incorrect deoxidation practices.

Suggested Cure

1. Revise deoxidation technique.
2. Reduce time at temperature and cast at lowest temperature possible.
3. Clean all materials charges. Be sure moisture is removed from refractory materials.
4. Use clean melt stock.
5. Ensure lips of furnace and ladle are free of refractory particles prior to use.
6. Ensure adequate supply of slag bars and training to melter. Use cobalt blue glasses while slagging. Additions of ceramic/cloth filter reduces inclusions.
7. Reduce/optimize superheated and melt temperature.

Defect: Hot Tears



Appearance of Defect: **Intergranular crack exhibiting oxidized fracture interface.**

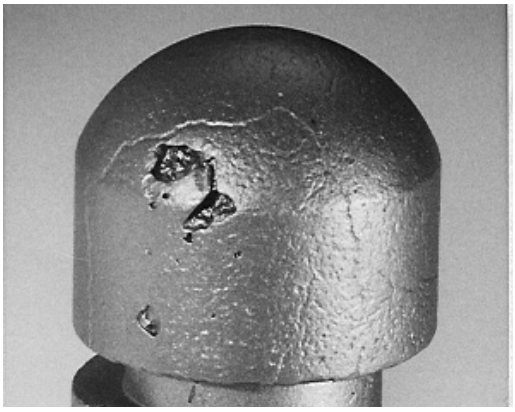
Probable Cause

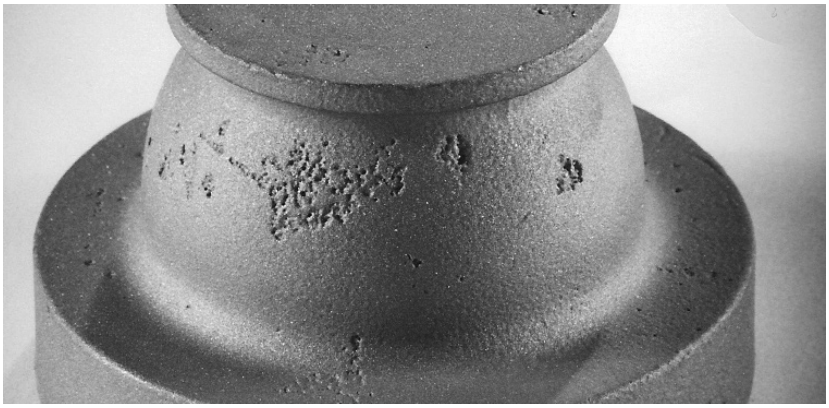
1. Restrained by gating.
2. Shell too strong.
3.. Sharp inside corners.
4. Bad casting design.
5. Movement of shell before alloy solidified.
6. Improper metal or shell temperature.
7. Faster cooling rate after pouring (during solidification).
8. Improper chemistry of alloy.

Suggested Cure

1. Modify the gating.
2. Reduce shell strength.
3. Increase generously all radii.
4. Eliminate thick, thin sections.
5. Allow sufficient time for solidification before moving the mold.
6. Establish and control to proper temperature.
7. Reduce the cooling rate by insulating the mold.
8. Modify chemistry of alloy.

Defect: Inclusion





Appearance of Defect: **Irregular cavities possibly containing traces of refractory and/or slag particles.**

Probable Cause

1. Sand/refractory particles in shell.
2. Dirty melt stock.
3. Foreign material from crucible/ladles.
4. Poor wax assembly of gate to sprue in wax room.
5. Refractory contained in melting stock.
6. Slag entrapped during pouring.

Suggested Cure

1. Clean shell prior to pour (vacuum or turn upside down and empty).
2. Remove rust, foreign surface contaminants, check for surface slag and/or sand clusters.
3. Use proper refractory and keep free from contaminants (i.e. good slag practice, etc.).
4. Seal all undercuts to prevent flashing and chipping of shell interior.
5. Use clean melting stock.
6. Use adequate deoxidation and slagging practices. Modify runner system to reduce turbulence. Use teapot spout ladle.

Note: Use of ceramic cloth filter reduces inclusion related defects.

Defect: Ceramic Inclusion

Appearance of Defect: **Generally a smooth sided irregular shape of indefinite size possibly containing traces of refractory material.**

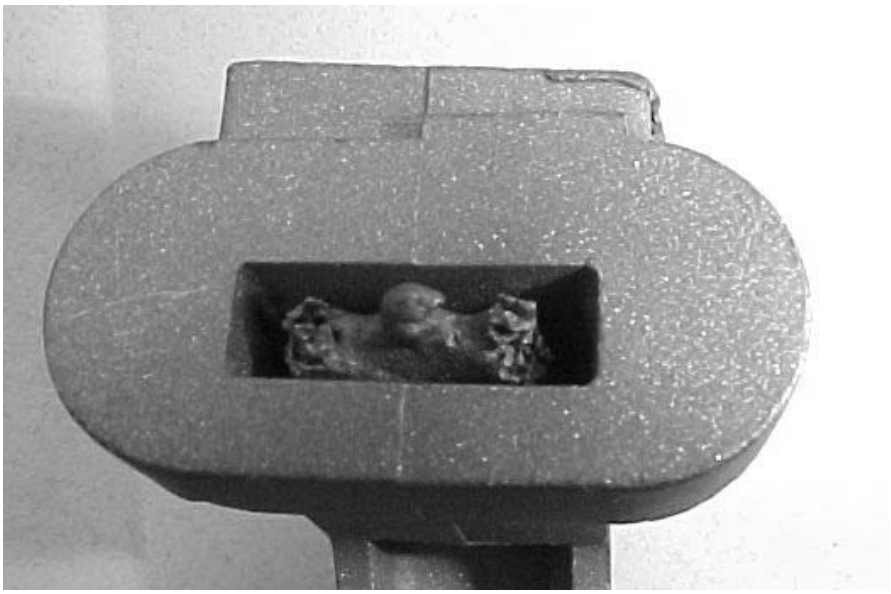
Probable Cause

1. Mold, shell backup refractories, uncontrolled mold process conditions.
2. Refractory contained in melt stock.
3. Improperly sintered furnace and transfer ladle refractories.

Suggested Cure

1. Observe and correct improper mold build-up techniques with proper instruction and care.
2. Ensure supply of refractory-free melt stock.
3. Ensure furnaces and ladles are free of loose refractories prior to melting or metal transfer.

Defect: Excessive Metal From Shell Failure



Appearance of Defect: **Generally a smooth sided irregular shape of indefinite size possibly containing traces of ceramic material with angular irregular shape in vicinity of shell failure.**

Probable Cause

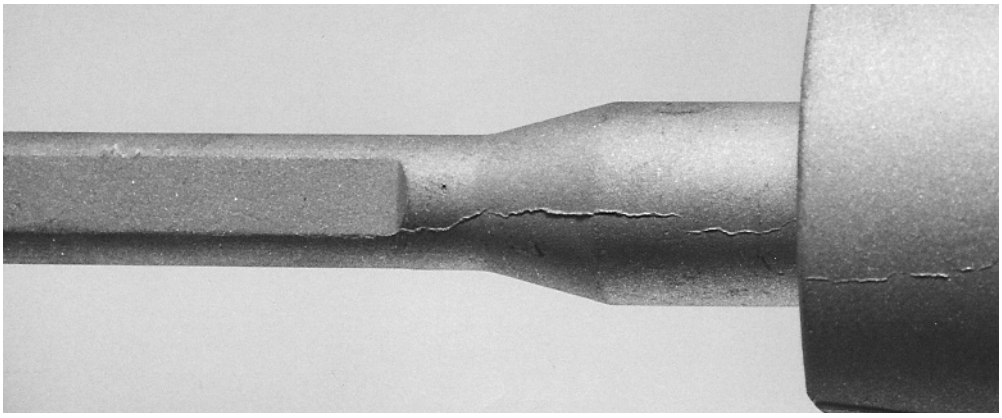
1. Mold, shell backup refractories, uncontrolled mold process conditions.

Suggested Cure

1. Observe and correct improper mold build-up techniques with proper instruction and care.

   Refer to *Atlas of Shell Defects.*

Defect: Mold Cracking, Finning



Appearance of Defect: **Surplus metal following contour of crack in shell mold.**

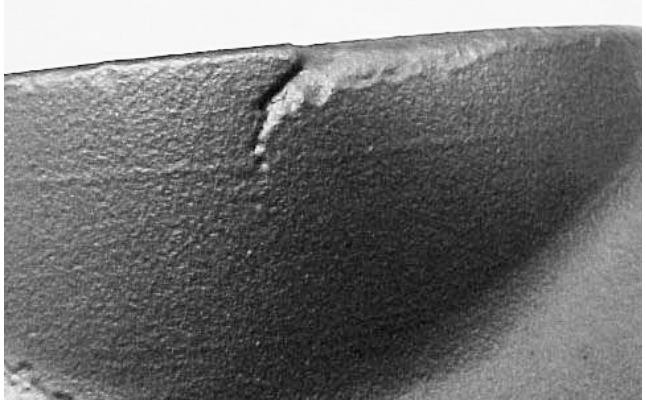
Probable Cause

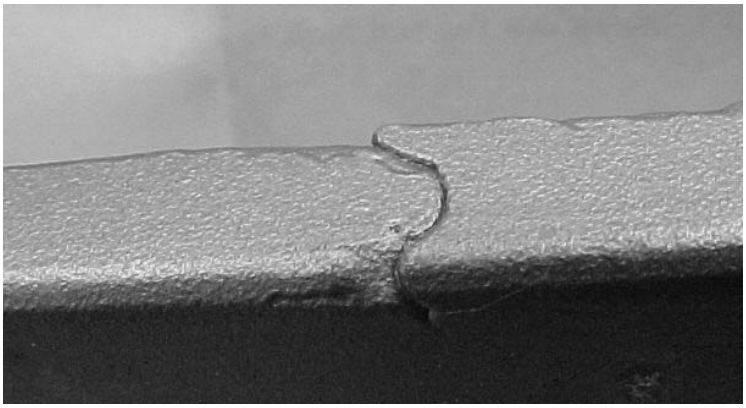
1. Cracks during dewaxing operation.
2. Excessive drying rate during drying of primary coats.
3. Different coefficients of expansion between primary and subsequent shell coats.
4. Low shell strength.

Suggested Cure

1. Improve dewax method.
2. Reduce drying rates. Refer to *Atlas of Shell Defects.*
3. Use compatible refractories.
4. Increase green shell strength.

Defect: Non-fill/Misrun





Appearance of Defect: **Incomplete casting with rounded edges where casting is not completely filled.**

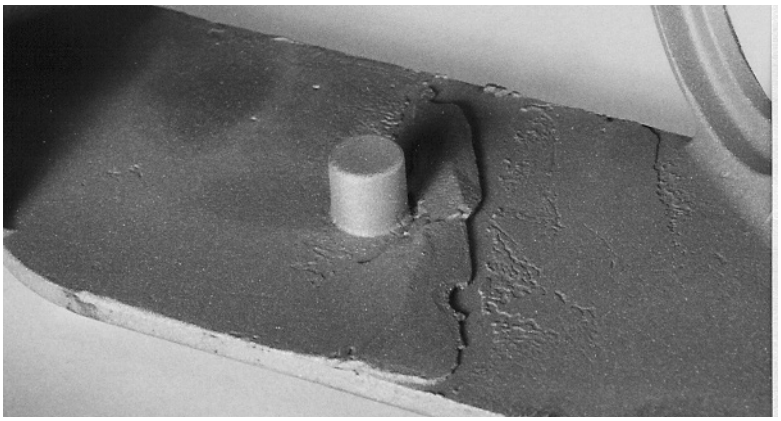
Probable Cause

1. Low shell or metal pour temperature.
2. Lack of fluidity.
3. Interrupted pour.
4. Rate of pour too slow.
5. Thin sections.
6. Low shell permeability and absence of vents.

Suggested Cure

1. Increase gate and sprue size and height.
2. Increase shell and/or alloy temperature. Modify chemical composition to improve fluidity.
3. Pour without interruption.
4. Increase pouring rate.
5. Increase metal section, extend thin section then cut back to drawing dimension.
6. Increase permeability by using coarser refractory, fewer coats, or addition of vents.

Defect: Primary Coat Buckle



Appearance of Defect: **Island of surplus metal on surface of casting, often associated with flash at the casting edge.**

Probable Cause

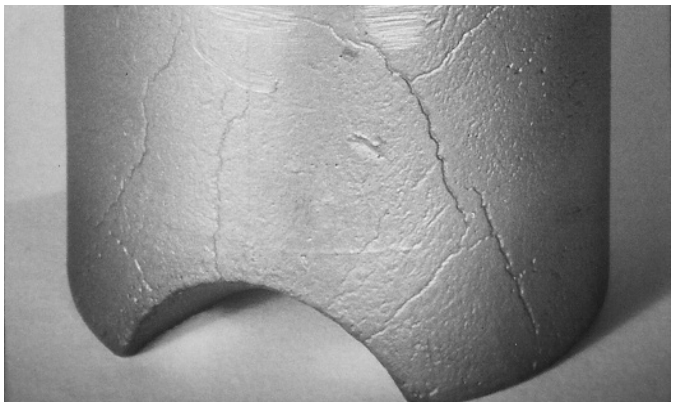
1. Cracking of primary coat allowing back-up slurry to penetrate between pattern and the primary coat faces; probably caused by an uneven primary coat thickness, giving rise to variable rates of drying.
2. Drying of primary coat before application of refractory sand.
3. Primary slurry coat draining from areas too quickly presenting a tendency for variations in thickness.
4. Primary slurry coat too viscous.
5. Age of slurry mixture.

Suggested Cure

1. Ensure patterns are washed sufficiently and that the primary coat has good wetting properties. Ensure that refractory particles are adhering to the entire area of the primary coat and that any surplus is completely removed.
2. Control temperature and humidity through entire shell manufacture cycle.
3. Ensure proper viscosity of slurry along with uniform coverage and drainage.
4. Reduce viscosity.
5. Check pH and age of slurry.

Refer to *Atlas of Shell Defects.*

Defect: Rat-Tailing/Oxidation Crazing



Appearance of Defect: **Shallow rounded grooves on the surface of the casting with radial pattern (oxide may be evident in the grooves prior to cleaning).**

Probable Cause

1. High shell temperature and excessive time during preheat.
2. Shell cracking permitting quantities of air to oxidize vicinity of cracks during cooling.

Suggested Cure

1. Reduce shell temperature.
2. Can-cover the shell immediately after casting. Addition of carbonaceous material (i.e. sugar, dried wood chips, wax, etc.) before applying can cover also helps.

Defect: Shell Buckle

Appearance of Defect: **Metal penetration in area designed for core along with evidence of mold cracking prior to casting (note small fin).**

Probable Cause

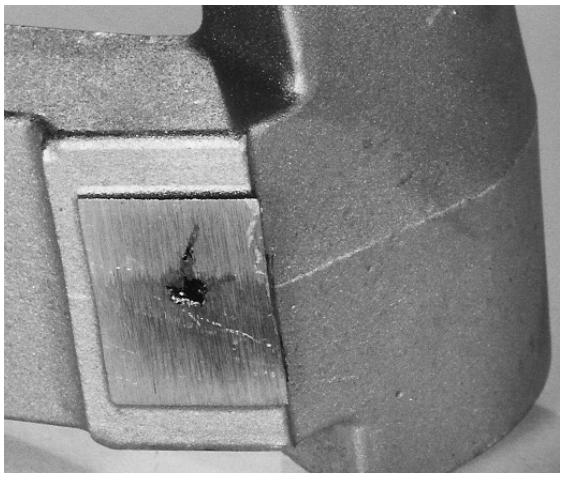
1. Pattern not sufficiently rigid to support necessary dipping and refractory coating operations.
2. Wax expansion during mold build-up and/or drying.
3. Inadequate mold strength.
4. Large flat surface.

Suggested Cure

1. Support pattern in additional areas to sprue.
2. Avoid temperature fluctuations during mold build-up and drying. Avoid excessive rate of drying of primary coat. Ensure proper dewaxing methods.
3. Increase shell strength with additional coats or adjustment of binder.
4. Break the flatness by using ribs, dimples, etc.

   Refer to *Atlas of Shell Defects.*

Defect: Shrink in Gate Area



Appearance of Defect: **Large internal irregular cavities usually exposed on removal of gate.**

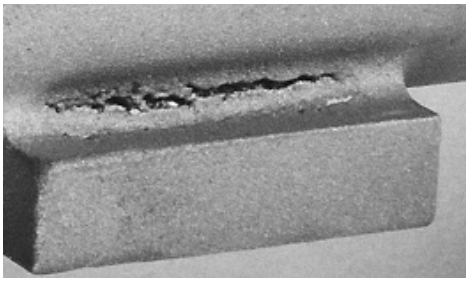
Probable Cause

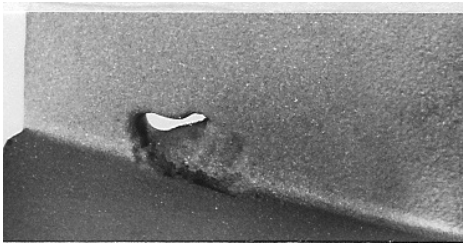
1. Improper gate design.
2. Inadequate feeding.
3. Higher pour temperature and gas content.

Suggested Cure

1. Adjust gate size and/or taper all locations.
2. Use larger feed bars and greater head pressure to promote directional solidification. Insulate wrappings of tree gate. Also use of exothermic in pour cup.
3. Reduce pour temperature and gas content.

Defect: Shrinkage (Surface)





Appearance of Defect: **Surface depression or irregular cavities exhibiting oxidized surfaces.**

Probable Cause

1. Localized mold hot spots.

2. Metal and/or shell temperature too high.

Suggested Cure

1. Improve pattern spacing and avoid refractory build-up in completing molds.

2. Reduce and/or adequately control metal or mold temperature. Do not move molds until metal is completely solidified.

Defect: Wax Flow Line

Appearance of Defect: **Casting shows irregular smooth shallow grooves reproducing detail of pattern lines.**

Probable Cause

1. Excessive use of die lubricant during wax injection.

Suggested Cure

1. Check type, quantity and quality of lubricant used. Refer to *Atlas of Wax Pattern Defects*.

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