Incomplete (or Lack of) Fusion

- Definition: Where weld metal does not form a cohesive bond with the base metal.
- Cause: Low amperage, steep electrode angles, fast travel speed, short arc gap, lack of preheat, electrode too small, unclean base metal, arc off seam.
- Prevention: Eliminate potential causes.
- Repair: remove and re-weld, being careful to completely remove the defective area. This is sometimes extremely difficult to find.

Lack of Fusion

INCOMPLETE FUSION

Arc Strike

- Definition: A localized coalescence outside the weld zone
- Cause: Carelessness.
- Prevention: In difficult areas, adjacent areas can be protected using fire blankets.
- Repair: Where applicable, arc strikes must be sanded smooth and tested for cracks. If found, they must be remove and repaired using a qualified repair procedure and inspected as any other weld.

Inclusions

- Slag
- Wagon-tracks
- Tungsten

Slag Inclusion

- Definition: Slag entrapped within the weld
- Cause: Low amperage, improper technique, Trying to weld in an area that is too tight. Slow travel in Vertical Down
- Prevention: Increase amperage or preheat, grind out tight areas to gain access to bottom of joint.
- Repair: Remove by grinding. Reweld.

Slag


QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Wagon Tracks (non-standard)

- Definition: Slang term for a groove left at the toe of a root pass which becomes filled with slag and is trapped in the weld.
- Cause: The contour of the root pass is too high, or the weld toe is not bonded to the base metal
- Prevention: Use proper technique to deposit the weld root.
- Repair: Best repaired before applying the hot pass. Carefully grind the root pass face flat. be careful not to gouge other areas on the weldment.

Tungsten Inclusion

- Definition: A tungsten particle embedded in a weld. (Typically GTAW only)
- Cause: Tungsten electrode too small, amperage too high, AC balance on +, Upslope too high, electrode tip not snipped, electrode dipped into the weld pool or touched with the fill rod, electrode split.
- Prevention: Eliminate the cause
- Repair: Grind out and reweld

Tungsten Inclusion

- Very hard entrained particle
- Imparts local mechanical and thermal stresses

Inclusions

- Fix when you see it (welder)
- Otherwise grind out & fix

Whiskers

- Typically GMAW, can be GTAW
- Unconsumed weld-wire passes or pushes through weld joint and is caught in root penetration
  - Unsightly
  - Inhibits material flow in piping
  - Can break off in pipes and damage equipment downline
  - Considered inclusions

Spatter

- Definition: Small particles (droplet) of weld metal expelled from the welding operation which adhere to the base metal surface.
- Cause: Long arc length, severe electrode angles, high amperages.
- Prevention: Correct the cause. Base metal can be protected with coverings or hi-temp paints.
- Repair: Remove by grinding or sanding. Sometimes must be tested as if it were a weld.

SPATTER

Arc Craters

- Definition: A depression left at the termination of the weld where the weld pool is left unfilled.
- Cause: Improper weld termination techniques
- Prevention: Improve technique or use equipment function
- Repair: If no cracks exist, simply fill in the crater. Generally welding from beyond the crater back into the crater.

Cracks

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Cracks

- Longitudinal
- Transverse
- Crater
- Throat
- Toe
- Root
- Underbead and Heat-affected zone
- Hot
- Cold or delayed

Longitudinal Crack

- Definition: A crack running in the direction of the weld axis. May be found in the weld or base metal.
- Cause: Preheat or fast cooling problem. Also caused by shrinkage stresses in high constraint areas.
- Prevention: Weld toward areas of less constraint. Also preheat to even out the cooling rates.
- Repair: Remove and reweld

Toe Crack

- Definition: A crack in the base metal beginning at the toe of the weld
- Cause: Transverse shrinkage stresses. Indicates a HAZ brittleness problem.
- Prevention: Increase preheat if possible, or use a more ductile filler material.
- Repair:

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Throat Crack

- Definition: A longitudinal crack located in the weld throat area.
- Cause: Transverse Stresses, probably from shrinkage. Indicates inadequate filler metal selection or welding procedure. May be due to crater crack propagation.
- Prevention: Correct initial cause. Increasing preheat may prevent it. be sure not to leave a crater. Use a more ductile filler material.
- Repair: Remove and reweld using appropriate procedure. Be sure to correct initial problem first.

Crater Crack

- Definition: A crack, generally in the shape of an “X” which is found in a crater. Crater cracks are hot cracks.
- Cause: The center of the weld pool becomes solid before the outside of the weld pool, pulling the center apart during cooling
- Prevention: Use crater fill, fill the crater at weld termination and/or preheat to even out the cooling of the puddle
- Repair:

Transverse Crack

- Definition: A crack running into or inside a weld, transverse to the weld axis direction.
- Cause: Weld metal hardness problem
- Prevention:
- Repair:

Root Crack

- Definition: A crack in the weld at the weld root.
- Cause: Transverse shrinkage stresses. Same as a throat crack.
- Prevention: Same as a throat crack
- Repair:

Underbead Crack

- Definition: A crack in the un-melted parent metal of the HAZ.
- Cause: Hydrogen embrittlement
- Prevention: Use Lo/Hi electrodes and/or preheat
- Repair: (only found using NDT). Remove and reweld.

Hot Crack

- Definition: A crack in the weld that occurs during solidification.
- Cause: Micro stresses from weld metal shrinkage pulling apart weld metal as it cools from liquid to solid temp.
- .

Cold Crack

- Definition: A crack that occurs after the metal has completely solidified
- Cause: Shrinkage, Highly restrained welds, Discontinuities
- Prevention: Preheat, weld toward areas of less constraint, use a more ductile weld metal Repair:
- Remove and reweld, correct problem first, preheat may be necessary.

Repairs to Cracks

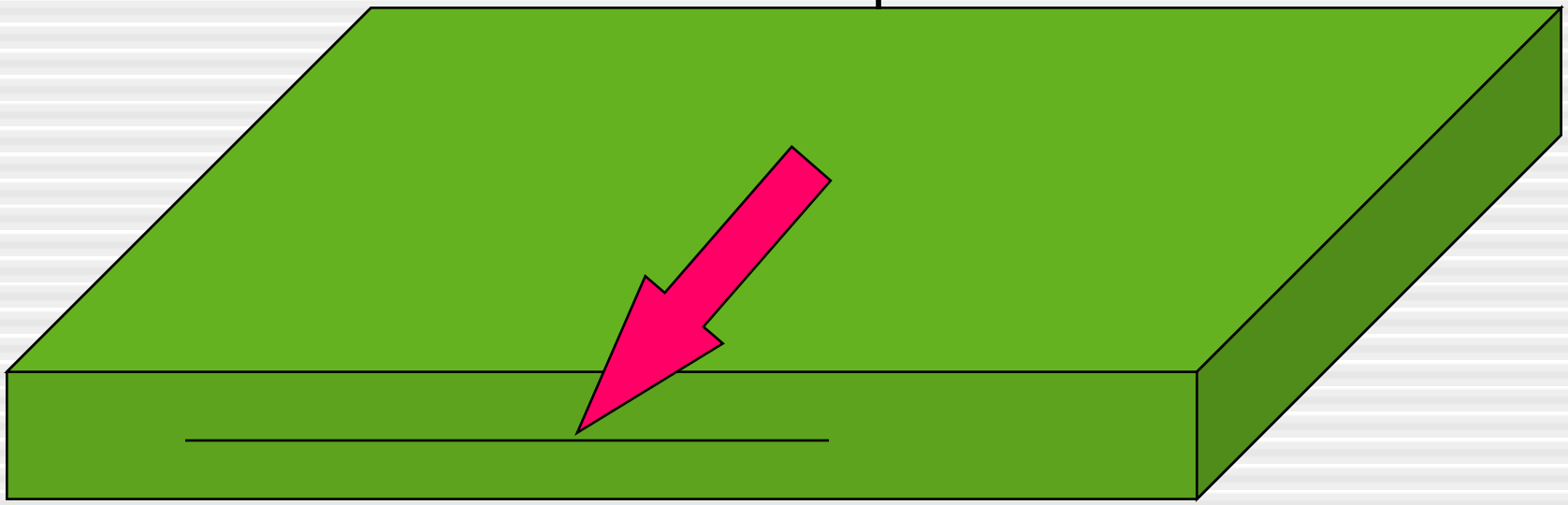
- ***Determine the cause***
  - A crack during application of a welding process is an indicator of a bigger ***PROCESS PROBLEM***
- Correct the problem
- Take precautions to prevent reoccurrence
- Generally required to repair using a smaller electrode

Base Metal Discontinuities

- Laminations and De-laminations
- Lamellar tearing
- Laps and Seams

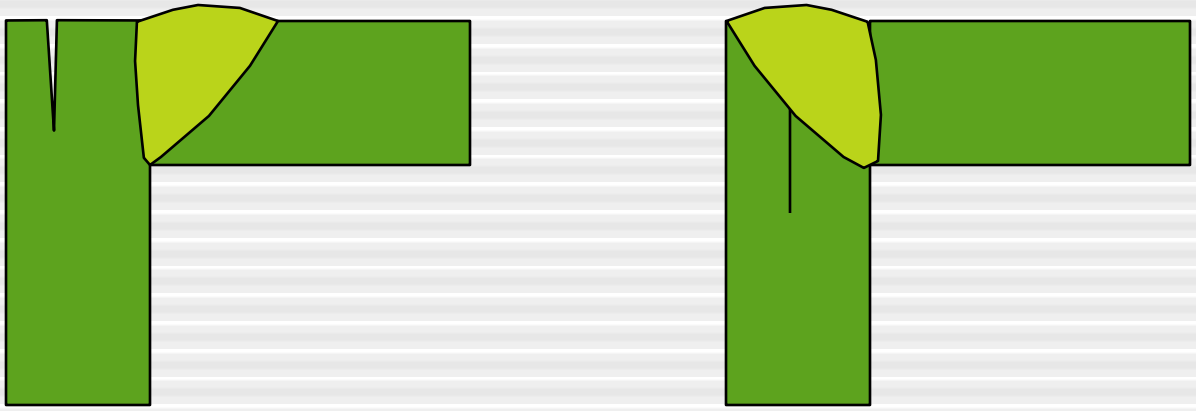
Laminations

- Base Metal Discontinuity
- Typical of rolled plate and strip
- May require repair prior to welding
- Formed during the milling process
- De-lamination - a lamination opened under stress



Effect

- Lamination effects can be reduced by joint design:



Laps and Seams

- A mill-induced discontinuity resulting from a lump of metal being squeezed over into the surface of the material.
- If beyond acceptable limits, must be removed and repaired or discarded.

Porosity

- Single Pore
- Uniformly Scattered
- Cluster
- Linear
- Piping

Single Pore

- Separated by at least their own diameter along the axis of the weld

Uniformly Scattered Porosity

- Typically judged by diameter and proximity to a start or stop
- often caused by low amperage or short arc gap or an unshielded weld start

Cluster Porosity

- Typically viewed as a single large discontinuity

Linear Porosity

- being linear greatly affects the severity of this discontinuity

Piping Porosity

- Generally has special allowable limits

POROSITY

Porosity

- Preheat will help eliminate
- May need an electrode with more deoxidizers
- Use run-on/run-off taps
- Restart on top of previous weld and grind off lump

Hammer marks

- Stress risers
- Unsightly
- Unnecessary

Heat-affected zone microstructure alteration

- Metallurgical change in HAZ - may include
  - grain refinement
  - grain growth
  - hardened areas
  - softened areas
  - precipitate suseptable areas.

Defect vs. Discontinuity

- Discontinuity - if it renders the part unusable, it is a defect.
- Defect - it is outside the allowable limit, it renders the part unusable.
- Design must recognize - things don't have to be perfect, just within acceptable tolerance.
- Perfection is time consuming and costly

REPAIR TECHNIQUES

- May involve:
  - different process
  - different procedure
  - different preheat/PWHT
  - different electrode
  - smaller electrode

Repairs

- Only repair defects.
- Discontinuities are, by definition, acceptable.
  - Discontinuity pair is unnecessary and not cost effective.