WELDING DEFECTS

WELDING DEFECTS

- Defects introduced during welding beyond the acceptance limit that can cause a weld to fail
- All discontinuities are not defects. Discontinuities are rejected only if they exceed specification requirement
- Improper welding parameters, base metal and welding procedures introduce defects in weld metal & around

- Radiographic standards:
  - IIW standard
  - ASTM standard

*Acceptance standards vary with service requirements

IIW STANDARDS

Five IIW standards:

- Black
- Blue
- Green
- Brown
- Red

IIW STANDARDS

Black

- A homogeneous weld or a weld with a few small scattered gas cavities

Blue

- Very slight variation from homogeneity in the form of one or more of the following defects:-:
  - Gas Cavity
  - Shrinkage cavity
  - Slag inclusion
  - Undercut

Green

- Slight variation from homogeneity in the form of one or more of the following defects:-
  - Gas cavity
  - Shrinkage cavity
  - Slag inclusion
  - Undercut
  - Incomplete penetration

IIW STANDARDS

Brown

- Marked deviation from homogeneity in the form of one or more of the following defects:-
  - Gas cavity
  - Shrinkage cavity
  - Slag inclusion
  - Undercut
  - Incomplete penetration
  - Lack of fusion

Red

- Gross deviation from homogeneity in the form of one or more of the following defects:-
  - Gas cavity
  - Shrinkage cavity
  - Slag inclusion
  - Undercut
  - Incomplete penetration
  - Lack of fusion
  - Cracks

ASTM STANDARDS

Specified welding defects level as per ASTM E- 390 Vol-II

- Defects not allowed:-
  - Crack
  - Lack of Fusion
  - Burn through
  - Elongated Porosity
- Defects allowed:-
  - Incomplete Penetration up to level-II
  - Slag Inclusion up to Level-III
  - Undercut up to level-IV
  - Porosity:
    - Coarse scattered Porosity up to level-II
    - Cluster Porosity up to Level-III
    - Fine scattered Porosity up to Level-IV

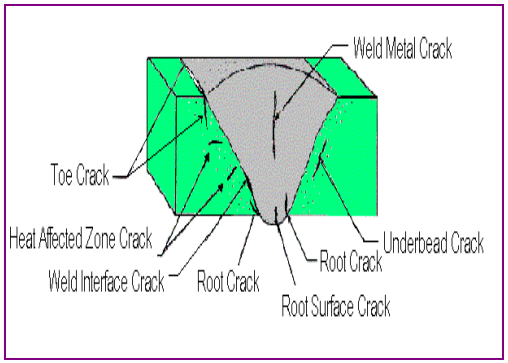
CLASSIFICATION OF WELDING DEFECTS

- IIW classifies welding defects into six groups.

- Crack- hot crack, Cold crack, Crater crack
- Cavity- Blow holes, Porosities, Pipes
- Incomplete fusion & Penetration
- Solid inclusion- slag, metal oxides, tungsten, wagon track
- Imperfect shape -Under cut, Under fill, Over lap, Excessive penetration, Improper bead shape
- Miscellaneous defects – Arc strike, Excessive spatter

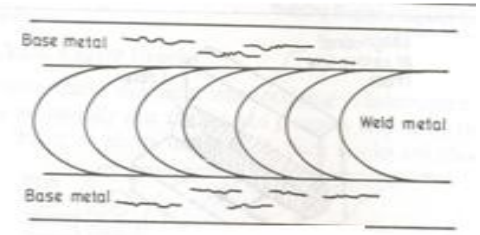
CRACKS

"A hair line separation in the weld metal/parent metal /HAZ at the root or in the middle or on the surface or subsurface"

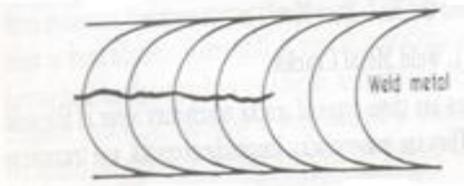


- Most dreaded among all welding defects.
- Occurs when localized stress exceed the UTS of base metal.

Long crack in HAZ parallel to weld bead



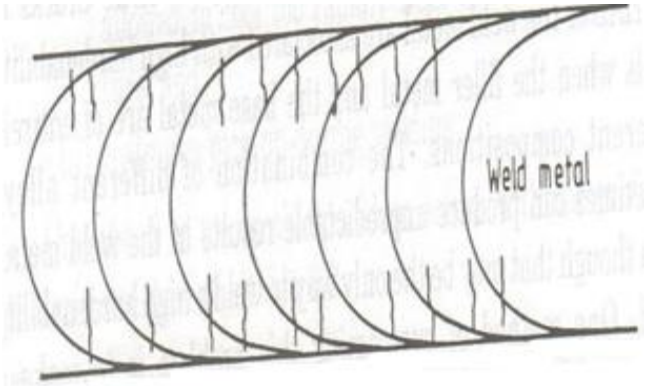
Long crack in weld metal running through centre of the weld



CRACKS

Cause:-

- High residual stresses
- Electrode with high hydrogen content

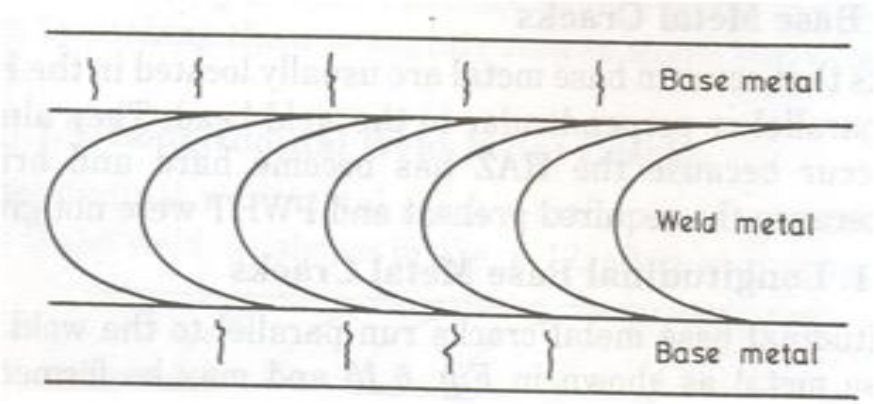


transverse weld crack running across weld bead

Remedy:

-

- Pre- heating
- Mn/S ratio : 18 min
- Use low H_2 electrode
- Avoid rapid cooling



transverse base metal crack generally in high strength steel

HOT CRACKS

- Crack in the weld during welding or just after welding
- Propagates along the grain boundary
- Occurs in the weld metal and sometimes in heat affected zone (HAZ)

Types of Hot cracks:

- Solidification crack (weld metal)
- Liquation crack (HAZ)

HOT CRACKS

Cause:-

- Weld metal composition having wide freezing range
- Impurities such as S & high C or Ni which form low freezing point liquid film
- High residual stresses in weld metal
- Low weld ductility
- Too high welding current
- High thickness of work piece

(thicker work piece-faster cooling rate)

Prevention:

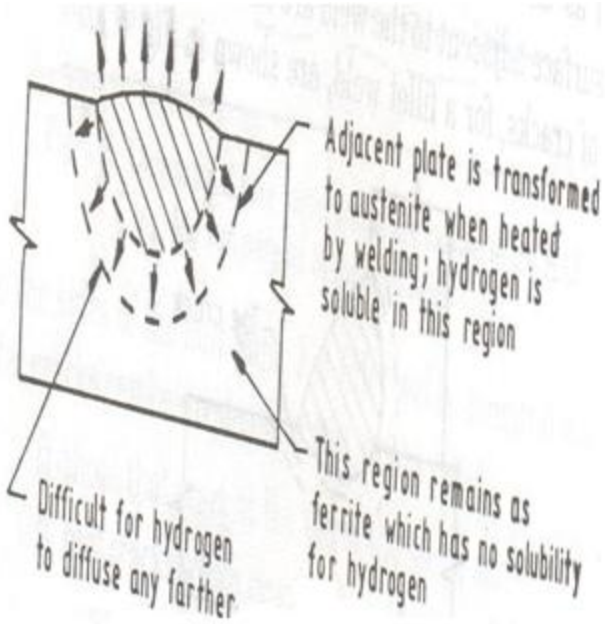
- filler metal of proper composition & low tensile strength
- Pre- heat (reduces rate of cooling)

Repair:

- Remove & re-weld

COLD CRACK

- Occurs after the metal has completely solidified
- Can occur several days after welds are made
- Occurs in C-steel, low & high alloy steel
- Propagates both between grains and through grains.
- Often associated with non-metallic inclusion
- Occurs in both weld metal and HAZ but generally in HAZ



movement of H_2 during arc welding

COLD CRACK

Cause-

- Hydrogen pick up during welding
- High stresses
- Phase changes (e.g. formation of martensite) during cooling
- High welding speed

Prevention:

- Controlling welding parameters:-
  - proper pre-heating:
    - reduces diffusion of H_2
    - ensures no moisture
  - Post-welding treatment:
    - stress relief.
- Clean joint from rust
- Use proper welding processes and consumables:
  - Low strength filler metals.
  - Use low hydrogen type baked electrode

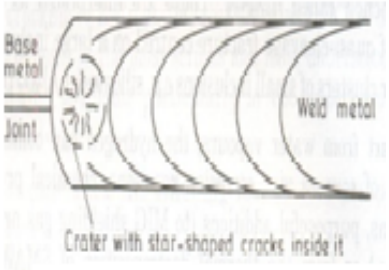
Repair:

- Remove and re-weld.

CRATER CRACK

"Cracks formed with a depression either in the weld or at the end of a weld"

- Occurs when the arc was broken or the flame was removed or electrode was changed
- They are hot cracks
- Usually star shaped, but may have other shapes
- Most frequently found in Austenitic Stainless Steel (due to high thermal coefficient)



Cause:-

- Center of weld pool becomes solid before the outside, pulling the center apart during cooling.

Prevention:-

- Can be minimized by filling craters to a slightly convex shape prior to breaking the welding arc.
- May be avoided through improved welding skill

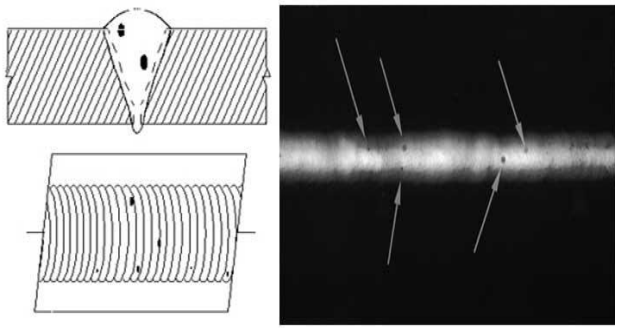
Repair:

  - Remove and re-weld

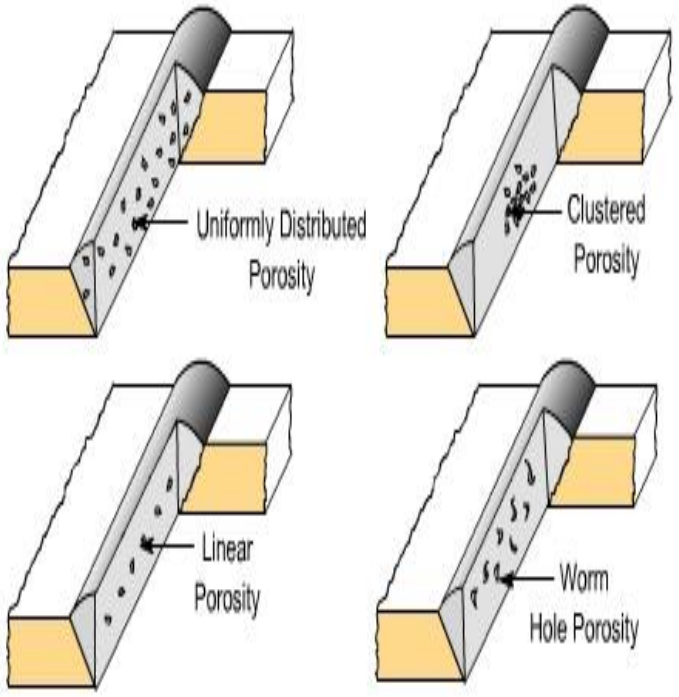
POROSITIES/BLOW HOLES

"Porosity is a group of small voids, where as blow holes are comparatively bigger hole or cavity caused by entrapment of gases (H_2, CO, CO_2,N_2 & O_2) within the solidified weld".

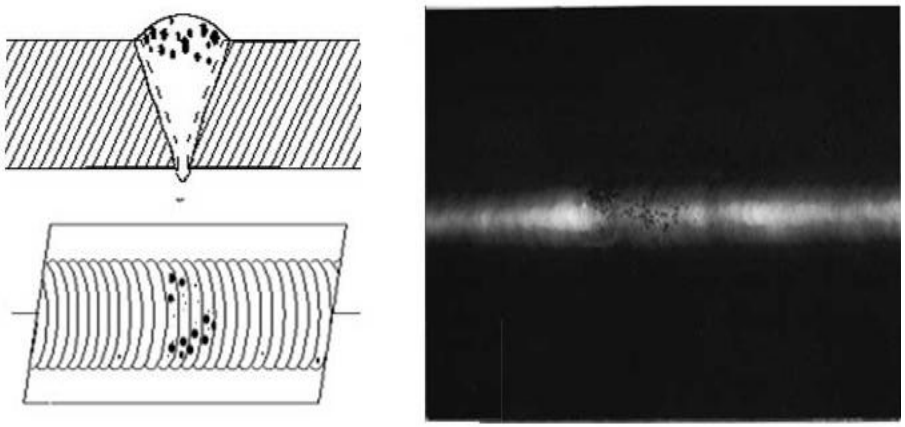
- Porosity can occur on or just below the surface of a weld.
- Porosity in the weld and HAZ may lead to cracking.



Gas porosity or blow holes



Cluster porosity



BLOW HOLES / POROSITIES

Cause –

- Work piece or electrode contains/contaminated with:-
  - Excessive moisture, rust or scale, oil, grease, etc
- Atmospheric gases [N_2, excessive O_2]
- Long arc
- Fast solidification rate

Prevention:-

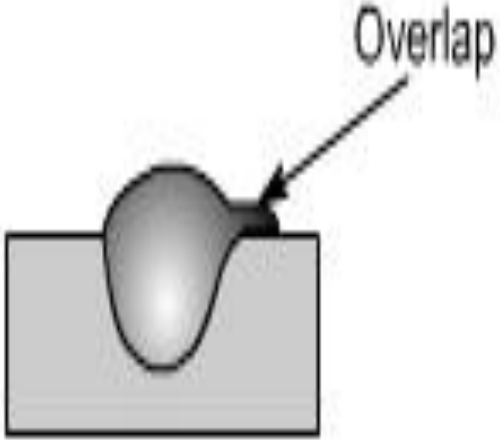
- Preheat
- Maintain proper arc length
- Use low hydrogen electrode
- Use recommended procedure for baking & storing electrodes
- Clean joint surfaces & adjacent surfaces

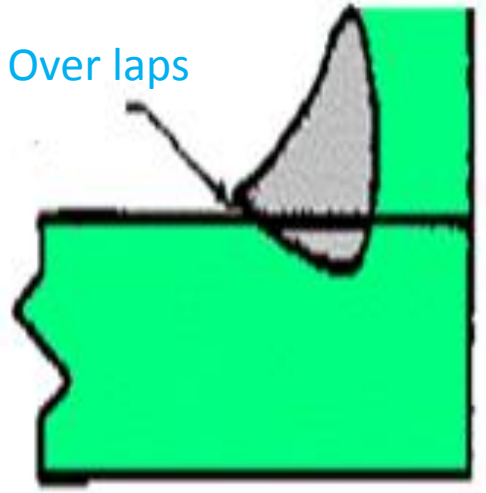
OVER LAPS

"Occurs when molten metal from the electrode flows over the parent metal surface & remains without getting properly fused"

- Tends to produce mechanical notch

- Starts a crack at the sharp point where the weld metal and base metal come together at the over-lapped surface





CONTD------

Cause:-

- Too large deposition in a single run
- Slow arc travel speed.

Prevention:

- Proper welding technique
- Use proper size of electrode

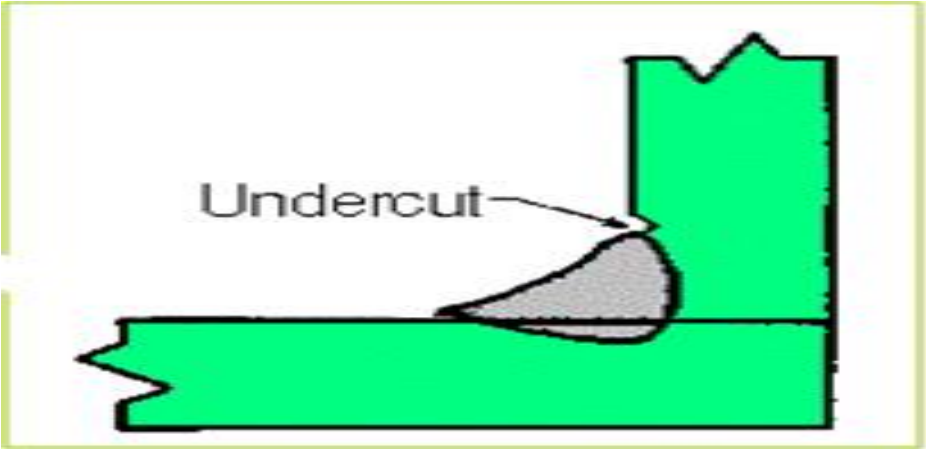
Repair:

- Overlap must be removed to blend smoothly into the base metal.

UNDER CUT

"A groove formed in the parent metal adjacent to the toe of a weld ".

- Generally located at the junction of weld metal & base metal in the toe or root of the weld
- Acts as stress raiser in fatigue loading
- Reduces the cross-sectional thickness of the base metal



CONTD---

Cause:

- Excessive welding current
- Too large electrode dia
- Incorrect electrode angle
- Longer arc length

Prevention:

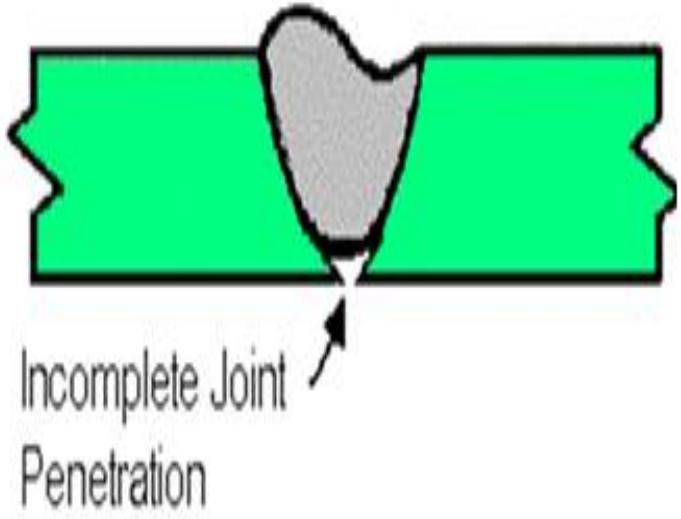
- Use prescribed welding current for electrode size.
- Adjust electrode angle to fill undercut area.
- Correct travel speed, arc length, etc.

Repair:

- Gouge & weld with low hydrogen electrode

LACK OF PENETRATION

"Improper penetration of weld metal through the thickness of joint or weld metal not extending to the required depth into the joint root"



Cause –

- Root gap too small
- high welding speed
- Low heat input
- Too large electrode dia.

Prevention:

- Proper joint preparation
- Proper heat input & welding speed
- Use suitable size of electrode

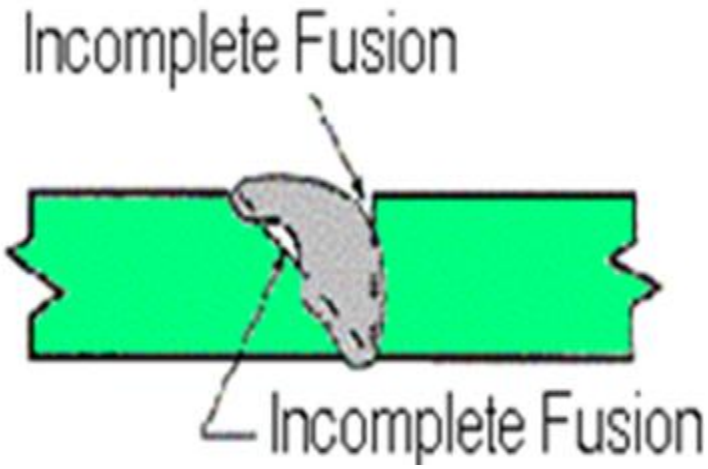
Repair:

- Remove and re-weld.

LACK OF FUSION

"Lack of complete melting/fusion of some portion of the weld metal in a joint"

- May be at the root, sides or between two runs.
- Reduces the strength of welds & makes welded structures unreliable



Cause:-

- Low welding current
- Excess welding speed
- Unfavorable heat input

Prevention:-

- Maintain proper current & welding speed
- Proper cleaning of each bead

Repair:-

- Chipping back & re-welding

EXCESSIVE PENETRATION

Weld metal lying outside the plane joining the toes.

- Makes notches that create stress concentration.

Cause:

- Too wide a root gap
- Too high welding current
- Slow travel speeds

Prevention:

- Correct root opening and root face
- Reduce wire-feed speed

Repair:

- Remove and re-weld

SPATTER

"Small globular metal drops / particles thrown out during welding which stick to the base metal surface".

- Metal lost
- Excessive spatters unacceptable.

SPATTER

Cause –

- Electrode coated with improper flux ingredients
- Damp electrode
- High welding current
- Excessive long arc

Prevention:

- Proper baked electrode
- Correct welding current .
- proper arc length
- Spatter cure SC-07(Non-toxic, non- pollutant, water based inorganic anti-spatter flux)
- Can easily be removed either by hair brush or by washing.

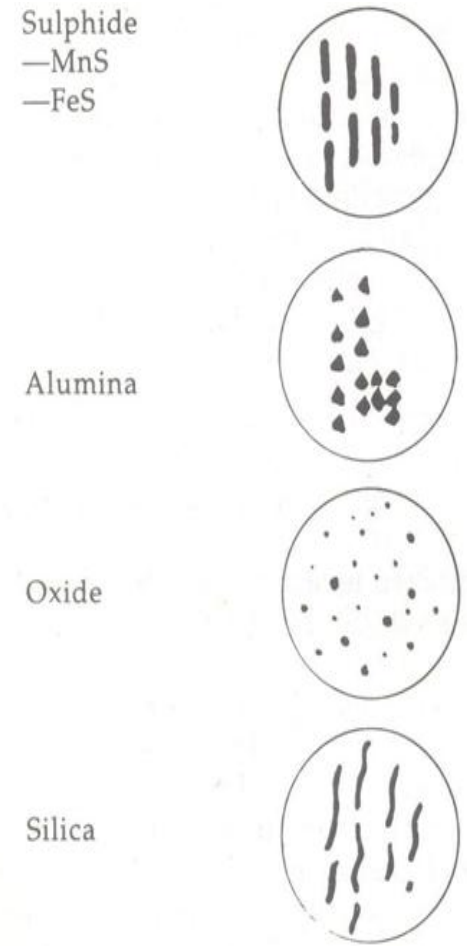
Repair:

- Remove by grinding or rubbing with sand paper.

INCLUSION

Entrapment of foreign solid material (slag, flux, W, oxides).

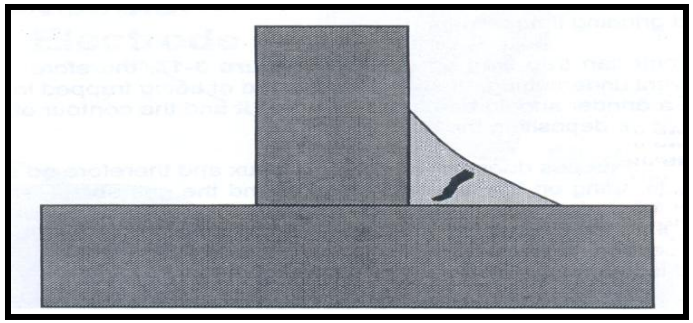
- Inclusions can be continuous or intermittent.
- Impairs the ductility of welds
- Non- metallic inclusion:-
  - sulphide, oxide, silicate or alumina
  - Acts as stress raiser



INCLUSION

Possible causes for slag inclusion:

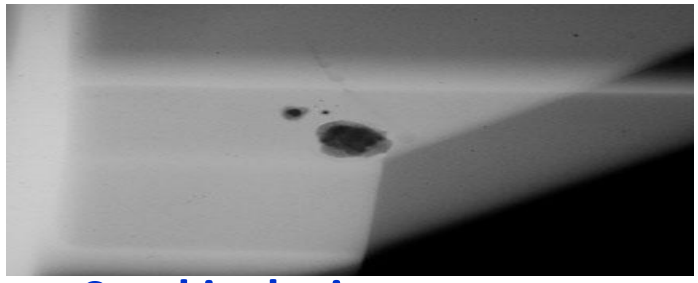
- Inadequate cleaning of weld metal between passes
- Rapid rate of welding
- Too large electrode
- improper current
- Long arcs



Slag inclusion

Prevention:-

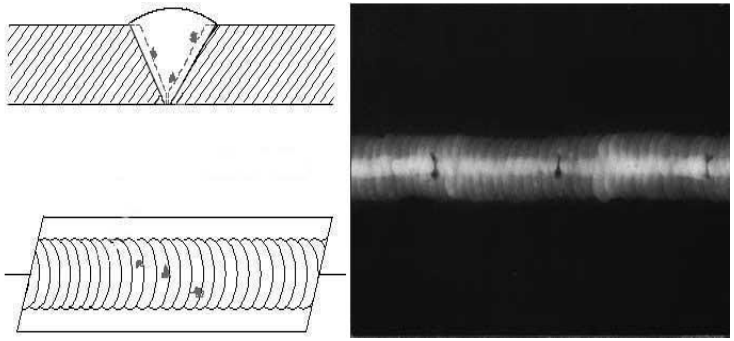
- Maintain proper current & heat input
- Proper cleaning of weld



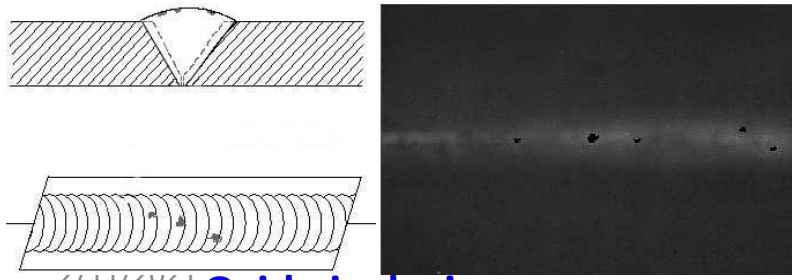
Sand inclusions

Repair:

- Chip back & re-weld



Slag inclusion

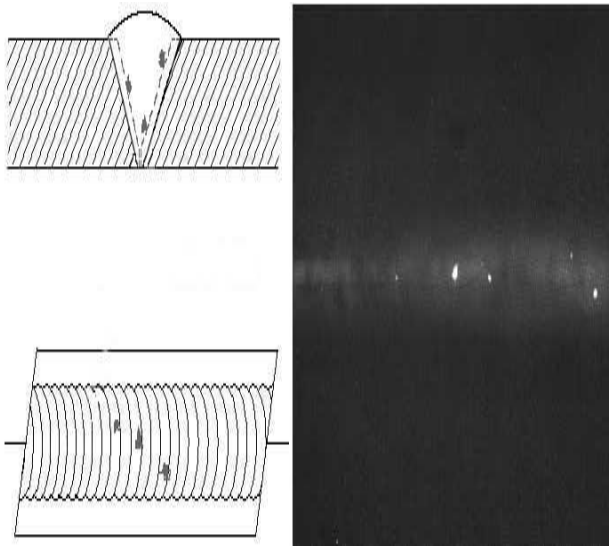


Oxide inclusions

TUNGSTEN INCLUSION

Entrapment of tungsten in welds in TIG welding.

- extremely brittle & can fracture easily under stress.

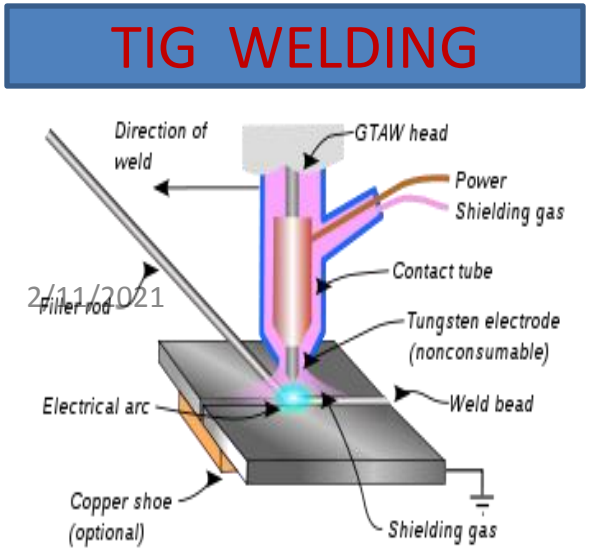


Cause:

- Dipping of tungsten electrode into molten weld pool
- Use of heavy current
- Over heating causes disintegration W- electrode

Prevention:

- Eliminate the above causes
- Repair: Grind out and re-weld



WAGON TRACK

"Linear slag inclusions along the axis of weld"

Cause:

- Improper welding technique

Prevention:

- Remove slag from previous passes.

ARC STRIKE

When a welder strikes the electrode or the electrode holder against the work, usually adjacent to the weld,

- Must be avoided
- If the arc is struck outside of the weld groove then it must be welded over to prevent the cracking.
- If this is not an option then the arc spot can be post heated

EXAMPLE OF ARC STRIKE

Welding Distortion

- *Undesirable change in dimension of a fabricated structure*
- *Caused due to unequal expansion of the parent metal during heating followed by its solidification shrinkage during cooling*
- *Under normal conditions, stress developed after welding remains as residual stress which may be removed by subsequent heat treatment*
- *If* **stress is high enough, contraction may take place, which pulls base metal out of alignment and cause distortion.**
- **Structures in I R susceptible to welding distortion**
  - **Bogie frame of loco, coach, frame of wagon, bridge girder etc.**

Undesirable Effects of Welding Distortion

- Mismatching problem.
- Aesthetics of the component is lost.
- Functional requirement of the component is affected.
- Additional expenditure to correct its dimensions.
- Component may have to be rejected due to fitment problem

Common types of Welding Distortion

- **Longitudinal distortion**
- **Transverse distortion**
- **Angular distortion**

Longitudinal Distortion

When a weld is deposited lengthwise on a light , narrow and perfectly flat strip of material that is neither clamped or held in any way , the strip will tend to bow upwards in direction of the welding bead due to longitudinal contraction of the weld metal as it cools after welding.

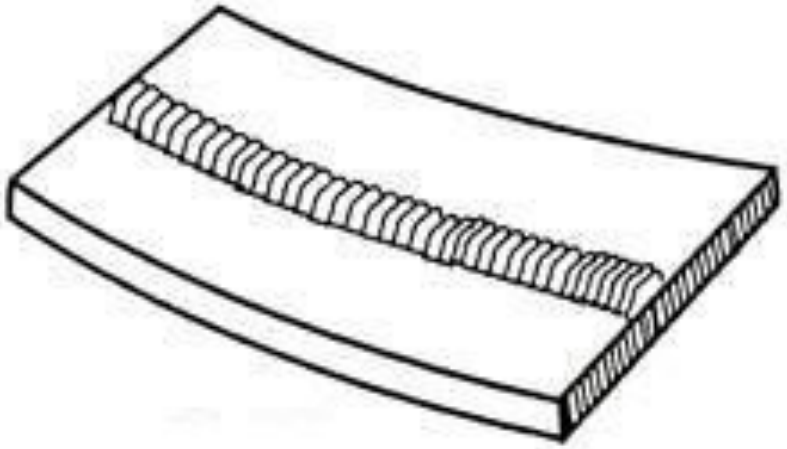
Longitudinal contraction is maximum along the weld centre line and decreases towards the edge.

This phenomenon is called Longitudinal distortion.

Longitudinal distortion depends upon:

- **Contraction forces**
- **Stiffness of the section being welded.**
- **Distance between the centroids of weld & section.**

Longitudinal Distortion

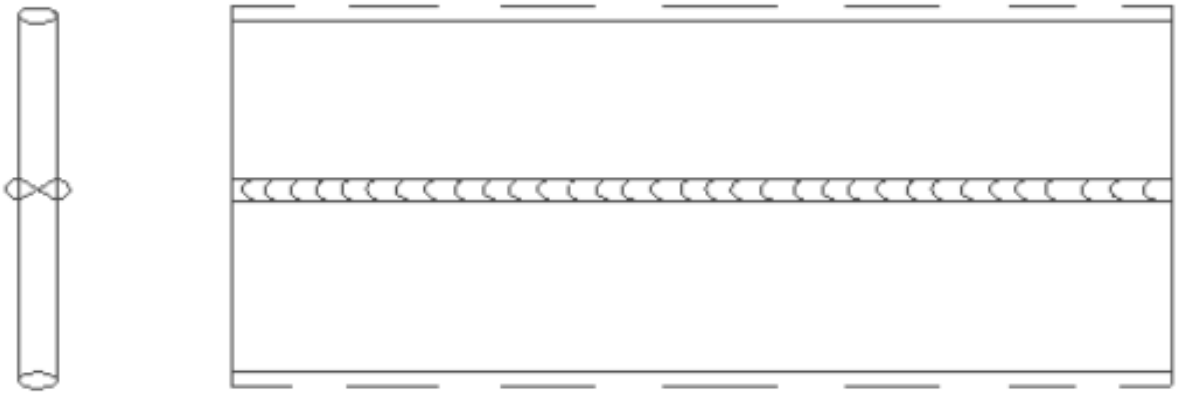


Transverse Distortion

- **When two plates butt welded together are neither too heavy nor held together and are thus free to move , they will be drawn closer together by the uneven contraction of weld metal. This phenomenon is called Transverse distortion.**

- **Transverse distortion depends upon the extent of permanent contraction of the weld Zone.**

Transverse Distortion

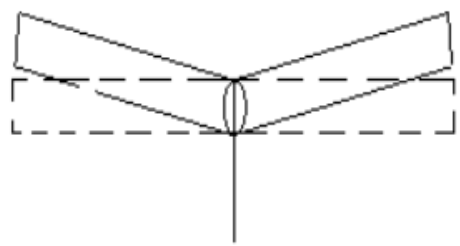


(A) TRANSVERSE SHRINKAGE IN A BUTT JOINT

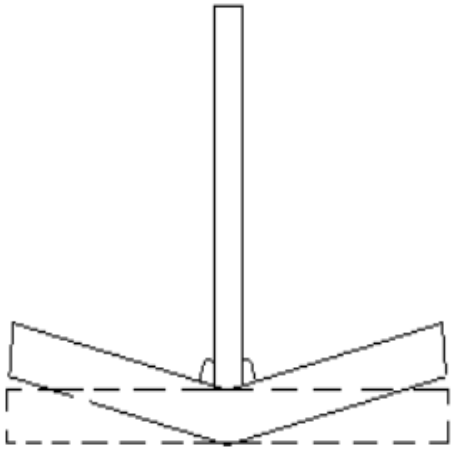
Angular Distortion

When two beveled plates are welded , it is found that the plates are pulled out of line with each other. Since the opening at the top of the single V groove is greater than at the bottom. A greater portion of the weld portion is deposited there and thus the drawing or pulling is greater at that side of the joint.

Angular Distortion



(C) ANGULAR CHANGE IN A BUTT JOINT



(D) ANGULAR CHANGE IN A FILLET WELD

Control of Welding distortion

- ❑ Joint Design
- ❑ Assembly weld
- ❑ Preheating
- ❑ Elastic pre-straining
- ❑ Pre-setting
- ❑ Back step welding
- ❑ Welding Sequence

Joint Design

- Economic design
  - fewest number of parts
  - minimum welding.
- For minimum weld metal use.
  - Use double ‘V’ preparation instead of single ‘V’.
  - Use J or U preparation.
  - Root gap should be minimum.
  - For fillet weld, weld size shall be smallest that meets the design requirement.
  - Avoid over welding.

Assembly weld

- Large weldment can be broken into small sub assemblies which can be welded without restraint. In this manner, distortion error can be rectified and finally, sub assemblies are welded together using fixtures to form the main integrated structure.

- In this case, only the final welding is carried out under condition of restraint. Hence distortion is minimised.

» Pre-Heating:

- Preheating helps in reducing distortion by reducing temperature gradient.

» Elastic Pre-straining:

- Here the plates are bent elastically.
- Angular change can be reduced significantly after removal of the restraint.
- Shrinkage force is balanced with opposing force.

Back Step Weld

- Weld bead increments are deposited in the direction opposite to the progress of the weld Due to small weld length degree of residual stress formed is much less.

WELDING SEQUENCE

It is the order of making welds in a complex job involving a number of welds.

» An incorrect sequence causes distortion & sometimes cracks in the weldment due to stress concentration at some points.

» By using proper welding sequence the distortion can be reduced significantly.

» Proper welding sequence depend on the component being fabricated and therefore should be treated on it's own merit & established by experiment.

WELDING SEQUENCE(Contd.)

Some of the general rules:

1. Weld outward from a central point i.e. towards free ends.
2. Place weld metal at different points about a structure so that shrinkage balance each other.
3. In a complicated structure try to weld diagonally opposite locations simultaneously.
4. Small welds shall be completed first before long continuous weld.
5. In case of double fillet weld, try to weld both sides simultaneously in small increments.

To summarize

- Minimise heat input. Use largest possible diameter of electrode.
- If the application allows it, use intermittent welds.
- Use as few weld passes as possible. The shrinkage from each pass tends to be cumulative.
- Weld as close to the neutral axis as possible. There is less leverage for the shrinkage forces to pull the plates.
- Use Back-step weld when possible
- Make shrinkage work to your advantage. Use shrinkage during welding to pull distorted parts back into alignment.
- Peening during welding helps to neutralise stresses & hereby reduces distortion.

To summarize (Contd.)

- Prebending or pre-springing the part before welding will help counteract the shrinkage forces.
- Use opposing forces to balance the shrinkage forces. Restraining forces can be imposed with clamps, jigs or fixtures, or by the arrangement of other members in the assembly. The counterforce can be produced by the gravity action of a sagging member.
- Plan a welding sequence whereby welds are placed at different points on the structure with the intent of counteracting the shrinkage forces of welds already made.
- Welds as quickly as possible and limit heat input to only what is needed. The less heat transmitted to the base metal, the less chance for distortion.

MEASUREMENT OF DISTORTION

- Measurement of distortion is required to decide acceptability i.e. whether the component can be used directly or some corrective action required or rejected.
- Distortion is determined by normal length and angular measuring technique. Sometimes, not all but only key dimensions are taken. Component should be placed on a surface table.
- Use of ‘GO’ & ‘NO GO’ gauges are very useful for small components.
- For vertical structure plumb line can be used. A simple straight edge or a thread can also be very much useful.

CORRECTION OF DISTORTION

It is not always possible to control distortion within acceptable limit. Distortion can be corrected to make the component usable. Distortion can be removed in the final product by producing adequate plastic deformations by Thermal method or Mechanical method.

Thermal method:

Component is heated locally . The heated portion will expand & this expansion is opposed by surrounding cold & relatively strong metal causing it to squeeze. On cooling, this part will shrink & will cause the part to deform in the desired direction.

CORRECTION OF DISTORTION

- Mechanical methods are mostly used.
- In this process the member can be straightened with a press or a jack.
- Application of heat may be required in the localised area by using oxy-acetylene flame.

THANK YOU