WELDING DEFECTS

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OBJECTIVES

To:

- Understand the definition & cause of weld defects
- Solve the problem
- Suggest possible remedies associated with individual weld defects.

INTRODUCTION

- Performance of welded structure in service depends on:
  - the presence or absence of defects in weld joints.
- Not possible for the welds to be completely sound
- Improper welding parameters & wrong welding procedures intoroduce defects in the weld metal and HAZ
- Defects impair the strength of weld joints
- A defective weldment fails under service conditions & causes damage to property & loss of human lives

DEFINITION OF WELDING

Definition:

"Process of joining two similar or dissimilar metals by heat or by pressure or by both using a filler metal to achieve a defect less joint having the physical properties similar to that of parent metal".

Dissimilar metal means:-

- Those that are chemically different (steel,Cu, Al, etc).
- Those that are metallurgically different (MS, SS, etc).

*Dissimilar metal imparts galvanic cell corrosion

Commonly welded base metals:-

- Ferrous-[WI, CI, C-steel (low, med, high), alloy steel, SS]
- Non-ferrous-(Al, Cu ,Mg, Ni, Zn & their alloys)

WELDING & ALLIED PROCESSES

Arc welding: (the most popular process)

- SMAW or MMAW
- FCAW
- TIG welding or GTAW
- MIG welding or GMAW
- MAG welding or CO_2 welding
- SAW
- Plasma arc welding
- ESW
- EGW

Gas welding:

- Oxy-acetylene welding
- Oxy hydrogen welding
- Air acetylene welding

Resistance welding:

- Spot welding
- Seam welding
- Resistance butt welding
- Flash butt welding

Solid state welding

- Diffusion welding
- Forge welding
- Friction welding
- Ultrasonic welding

Thermo chemical welding

- Thermit welding
- Atomic hydrogen welding

Radiant energy welding

- Plasma welding
- Laser beam welding
- Electron beam welding

Allied process

- Soldering
- Brazing
- Adhesive welding

WELDING PROCESSES MAINLY USED ON IR

- MMAW
- SAW/MIG/MAG
- Gas welding
- Thermit welding
- Flash butt welding
- Gas pressure welding
- Brazing

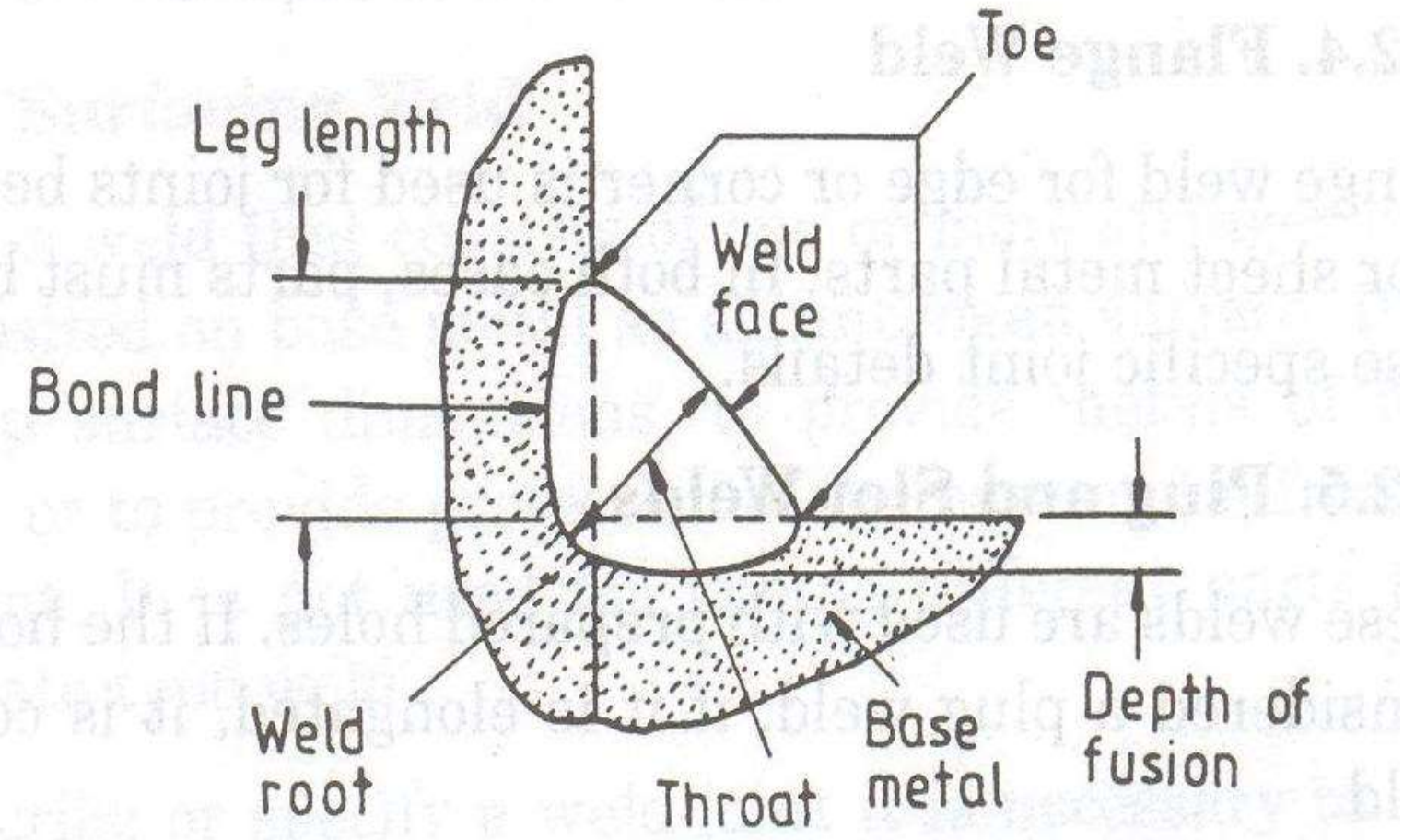
WELDING PROCESSES USED ON IR

PROCESS	USES ON IR
MMAW	1. For repair of Rly comp like coaches, wagons, Bridge girders, Bogies of diesel & electric locos 2. For fabrication of above Rly components, the process was replaced by MIG/MAG & SAW 3. For reclamation & reconditioning of worn out Rly components like Rly points & crossings, hangers, eq beam of trimount bogies, gas inlet casing of diesel locos, etc
SAW	1. Used for fabrications of Rly components like bridge girders, diesel engine block, wagons, fabricated bogies 2. For reclamation of worn out wheel flanges of C & W (both cast & rolled forged
MIG/MAG	1. Used for fabrications of Rly components like bridge girders, C& W, fabricated bogies 2. For reclamation of worn out Rly components like Rly points & crossings, equiliser beam of trimount bogies, etc

WELDING PROCESSES USED ON IR

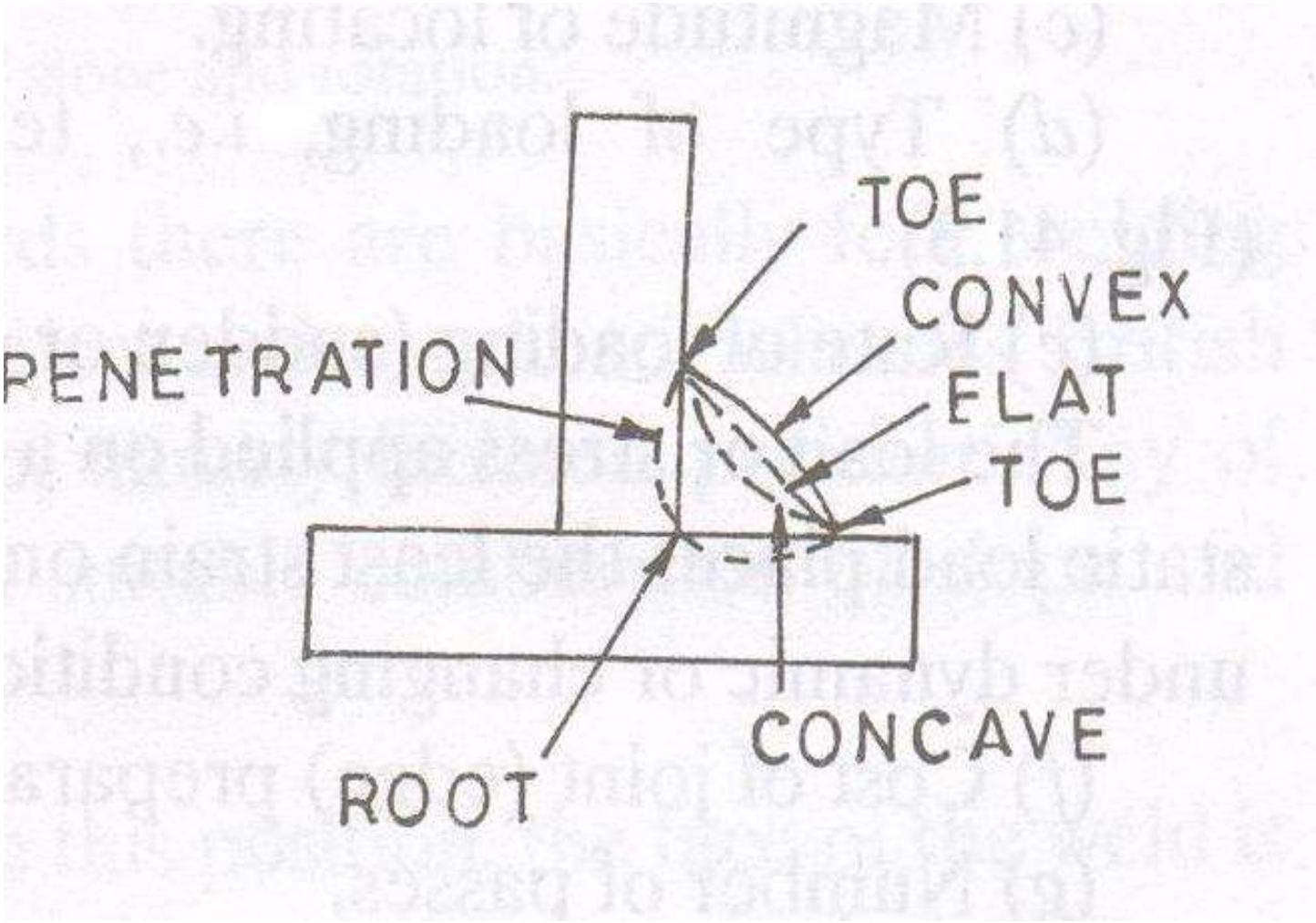
PROCESS	USES ON IR
Gas welding	Presently limitetd on IR. However, used for repair of small defects for general purposes. Also used for joining of some non-ferrous comp
Brazing	Mainly used for joining of electrical comp of E & D locos. Also used for joining of Al & Cu tubes of AC coaches
Thermit welding	Most widely used for joining of rails of IR (70% of rails joining)
FBW	Used for joining rails
GPW	Limited for joining of rails

NOMENCLATURE OF A FILLET WELD

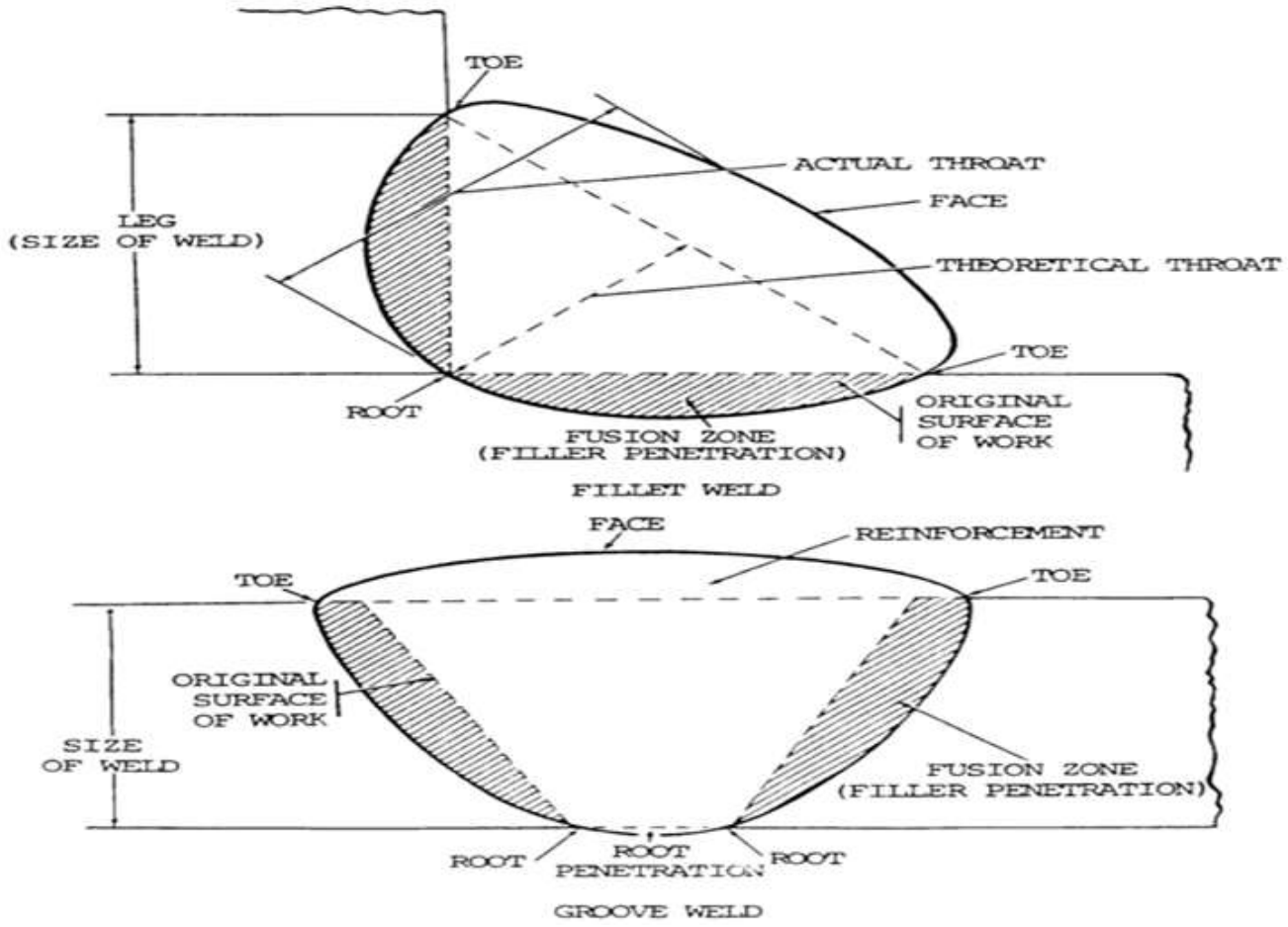


*concave fillet weld has higher tensile stress on the face than the convex fillet weld

NOMENCLATURE OF A FILLET WELD



NOMENCLATURE OF A FILLET WELD



WELDING DEFECTS

WELDING DEFECTS & ITS EVALUATION

Definition of welding defects:-

"Defects introduced during welding beyond the acceptance limit that can cause a weld to fail".

- All discontinuities are not defects. Discontinuities are rejectable only if they exceed spec requirements

Radiographic standards used for evaluation of weld defects:-

- IIW standards
- ASTM standards

*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:-:
  - 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
  - Cracks

ASTM STANDARDS

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

- Defects not allowed:-
  - Shrinkage /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

- One of the IIW documents classifies all welding defects into six groups according to their appearance.-

➢ Crack- includes all types of cracks such as crater cracks, hot cracks, cold cracks, etc

➢ Cavity- includes blow holes, porosities, shrinkage, pipes, etc

➢ Incomplete fusion & penetration- includes lack of fusion, lack of penetration, etc

CLASSIFICATION OF WELDING DEFECTS

- Solid inclusion- includes slag, metal oxides, tungsten, wagon track, etc
- Imperfect shape -under cut, under fill, over lap, excessive penetration, improper bead shape, etc
- Miscellaneous defects – includes arc strike, excessive spatter, rough surface, uneven ripples, etc

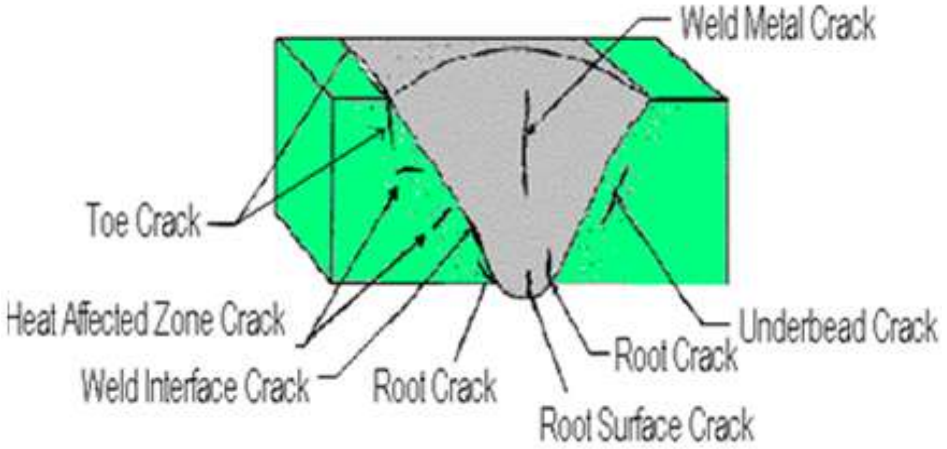
CLASSIFICATION OF WELDING DEFECTS

All these defects fall under two categories-

- Visual defect /Surface weld defect/External defect
  - surface cracks
  - over laps
  - under cuts
  - under fills
  - excessive penetration
  - surface porosity
  - excessive spatter
  - Arc strike, etc
- Hidden defect/sub surface weld defect/Internal defect
  - lack of fusion
  - lack of penetration
  - sub surface blow holes/ porosity
  - shrinkage cavity
  - slag inclusion
  - tungsten inclusion, etc.

CRACKS

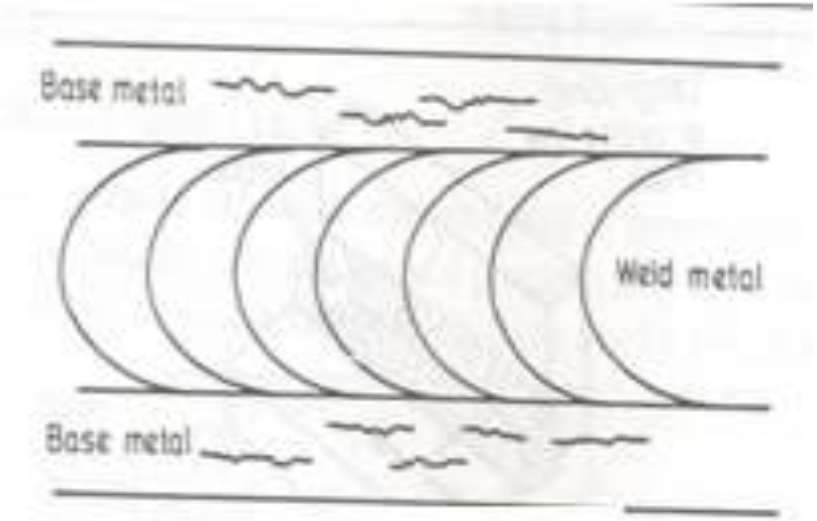
- A hair line separation in the BM/BM-WM-bdy / WM/HAZ
- May appear:
  - at the root or
  - middle or
  - In the crater
  - surface or
  - subsurface



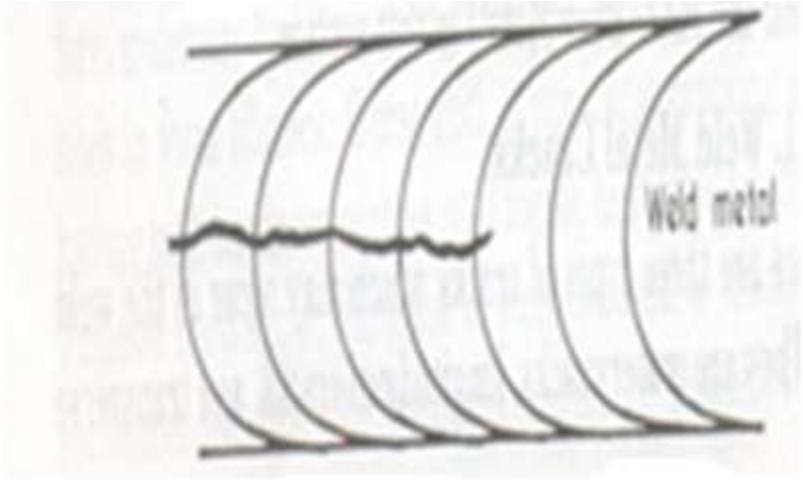
- Most dangerous of all defects
- Occurs in the WM when localized stresses exceed the UTS of material.
- May be of microscopic or macroscopic sizes.

CRACKS

Long crack in HAZ parallel to weld bead



Long crack in weld metal running through centre of the weld



CRACKS

Cause:-

- Poor ductility of base metal
- High C & S- content of BM/WM
- High contraction stresses
- Electrode with high hydrogen content

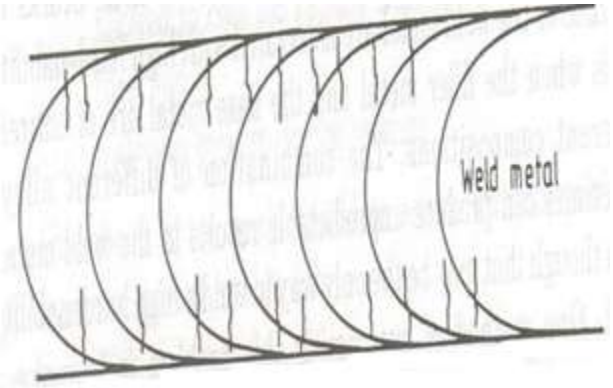
Remedy:-

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

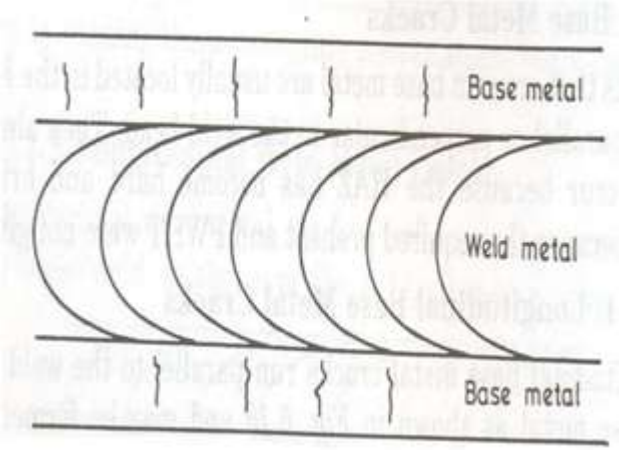
Classification:-

Cracks may be grouped mainly into two categories-

- Hot crack
- Cold crack



transvethe rse weld crack running across weld bead

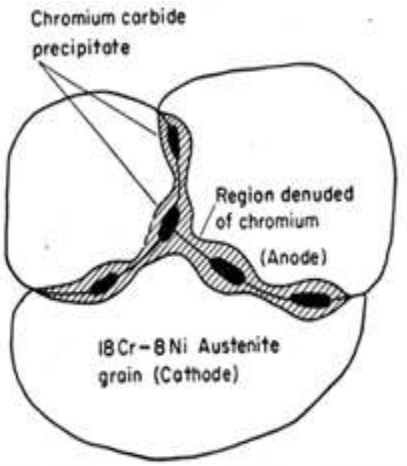


transverse base metal crack generally in high strength steel

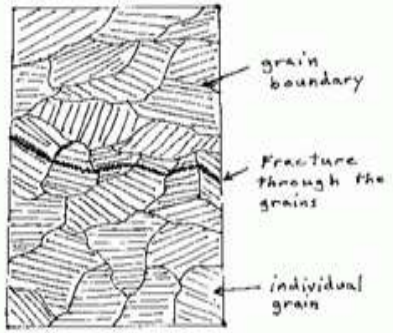
HOT CRACKS

- Crack in the weld that occurs just after the welds are completed and sometimes while the welds are being made.
  - Develops at high temperatures
  - Propagates between the grains of the material (intercrystalline)
  - Occurs in the weld metal & sometimes in HAZ.
    - "solidification crack " (weld metal)
    - "liquation crack" (HAZ)

Intercrystalline crack



Transcrystalline crack



HOT CRACKS

Cause:-

- High residual stresses in weld metal
- Low weld ductility
- Too high welding current
- High thickness of work piece (thicker the work piece, faster the cooling rate)
- high ratio of S &P with low Mn content, high C & Ni content (high harden ability

HOT CRACKS

Prevention:

- Controlling composition of the metal (S<0.007%) to be welded
- Using filler metal with proper composition & low tensile strength
- Pre- heat
  - reduces rate of cooling
  - not essential for Aus.SS (martensite does not occur).

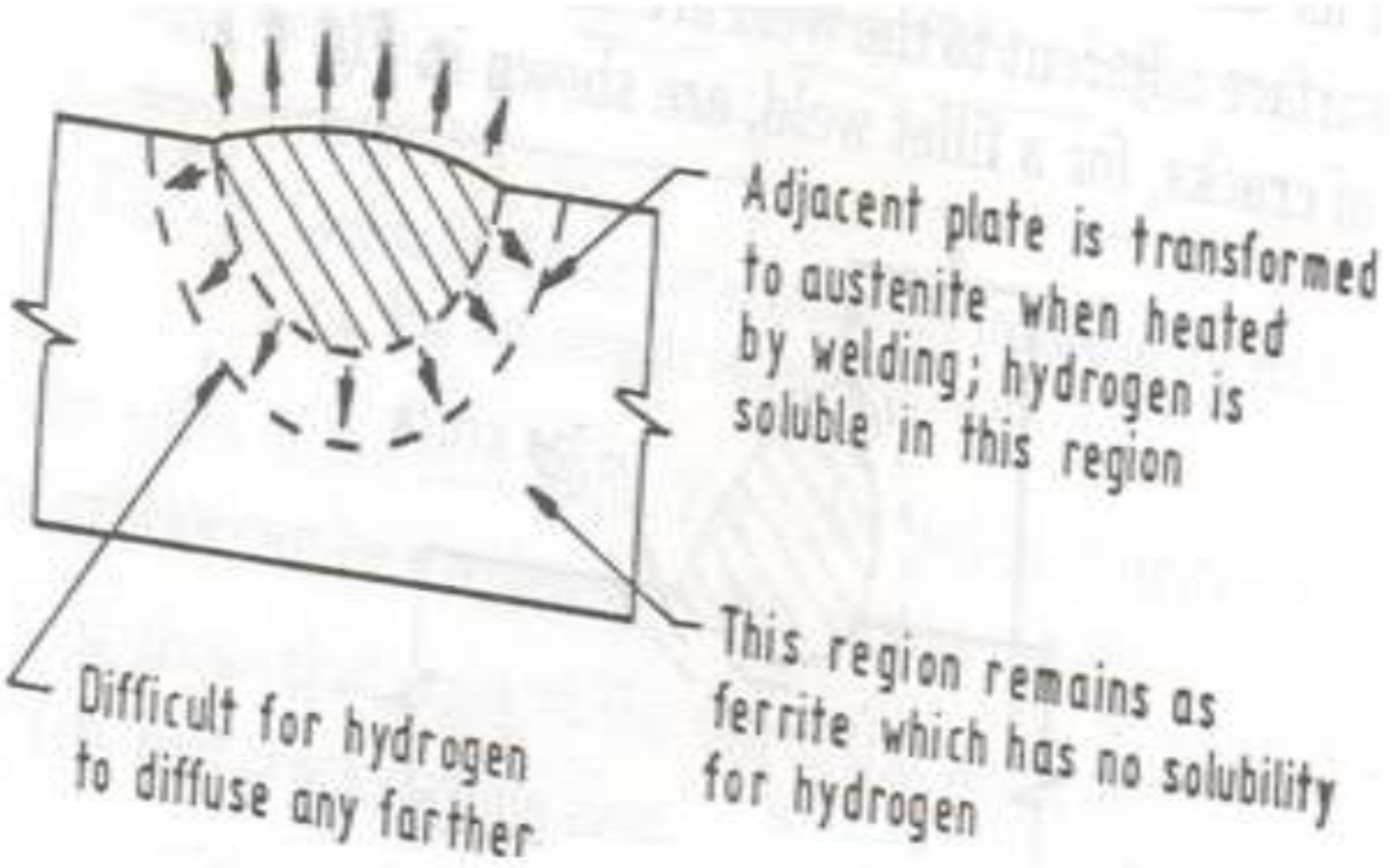
Repair:

- Remove and re-weld

COLD CRACK

- Occurs after the metal has completely solidified (at temp -100^{0}C to 200^{0}C)
- Can occur several days after weld
- Occurs in C-steel, low & high alloy steel
  - propagates both between grains and through grains.
  - often associated with non-metallic inclusion (elongated MnS).
  - occurs in both weld metal and HAZ but generally in HAZ

COLD CRACK



movement of H_2 during arc welding

COLD CRACK

Cause-

- Hydrogen pick up during welding
  - Source of hydrogen:-
    - Moisture in base metal & welding electrodes
    - Surface contaminated with organic substances
    - Surrounding atmospheres
- Phase changes (e.g. formation of martensite) during cooling

Prevention:

- Controlling welding parameters:-
  - proper pre-heating:
    - reduces diffusion of H_2
    - ensures no moisture
  - Post-welding treatment:
    - stress relief.

COLD CRACK

- Clean joint from rust
- Use proper welding processes and consumables:
  - Low strength filler metals.
  - Use low hydrogen type baked electrode

Repair:

- Remove and reweld.

CRATER CRACK/STAR CRACK

"A depression left in weld metal where the arc was broken or the flame was removed or electrode was changed".

- They are hot cracks
- Occurs at the crater of the weld
  - usually star shaped, but may have other shapes.
  - most frequently found in austenitic SS(high thermal coeff).

CRATER CRACK/STAR CRACK

Cause:

- The center of weld pool becomes solid before the outside, pulling the center apart during cooling.
- High current (deep crater)

Prevention:

- can be minimised by filling craters to a slightly convex shape prior to breaking the welding arc.
- may be avoided through improved welding skill

Repair:

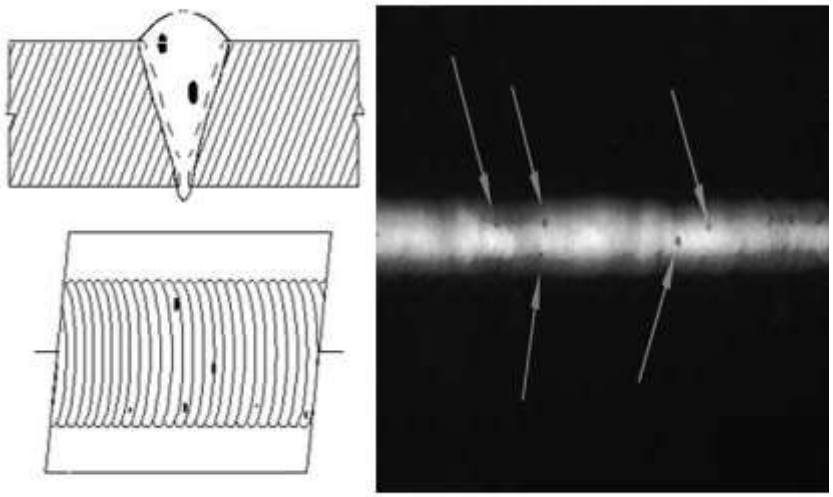
  - remove and reweld using appropriate procedure.

POROSITIES/BLOW HOLES

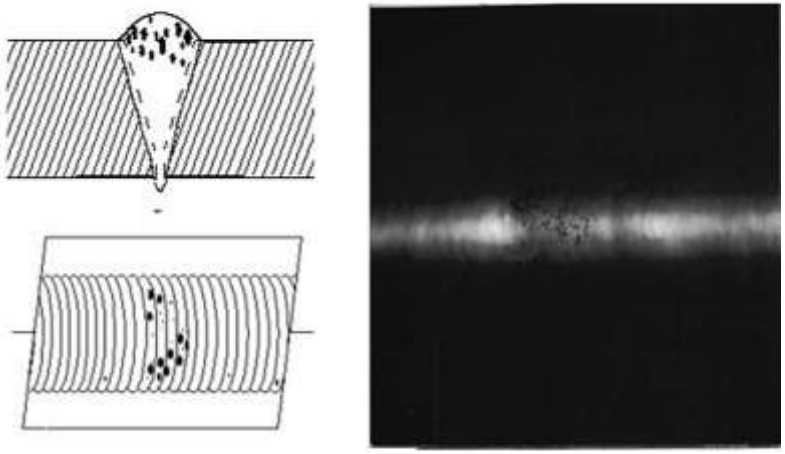
"Porosity is a group of small voids, where as blow holes are comparatively bigger hole or cavity caused by entrapment of gases [gases:H_2,CO,CO_2,N_2 &O_2 from coating ingredients in the electrode or moisture, oil, grease, rust,etc on BM]within the solidified weld".

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

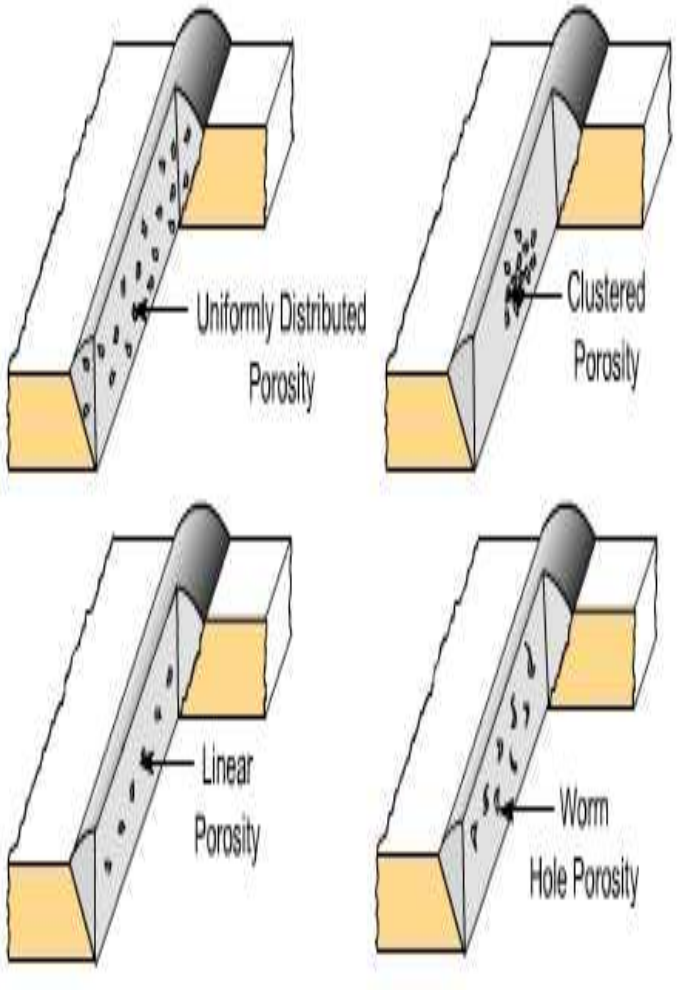
POROSITIES / BLOW HOLES



Gas porosity or blow holes



cluster porosity



BLOW HOLES / POROSITIES

Cause:

- Work piece or electrode contains/contaminated with:-
  - High sulphur & carbon
  - Excessive moisture, rust or scale, oil, grease, etc
- Atmospheric gases [N_2, excessive O_2 (Al-welding)]
- Anodising coating on Al (contains moisture)
- Long arc
- Fast solidification rate

Prevention:

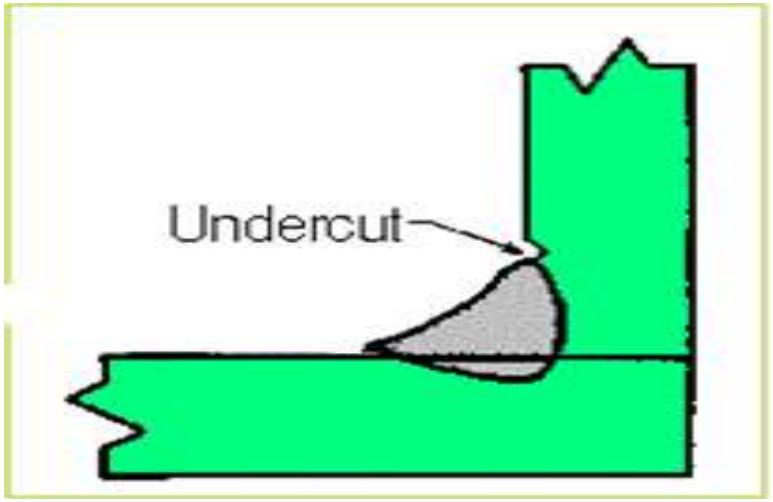
- Preheat
- Maintain proper arc length
- Use low hydrogen electrode
- Use recommended procedure for baking & storing electrodes
- Clean joint surfaces & adjacent surfaces

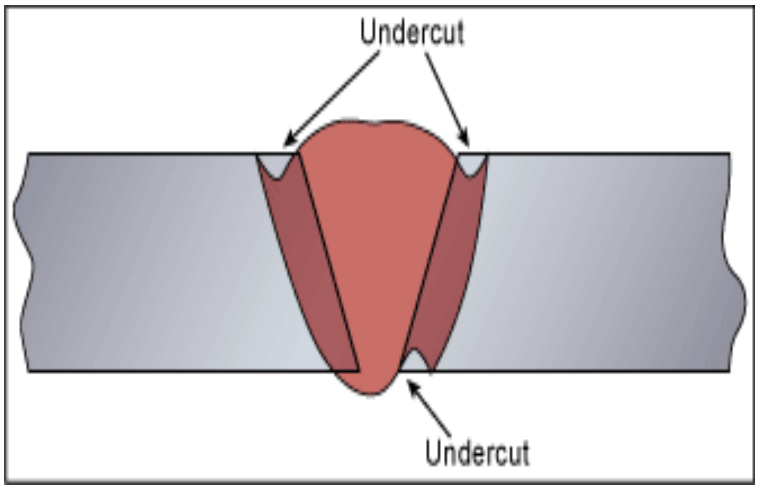
UNDER CUT

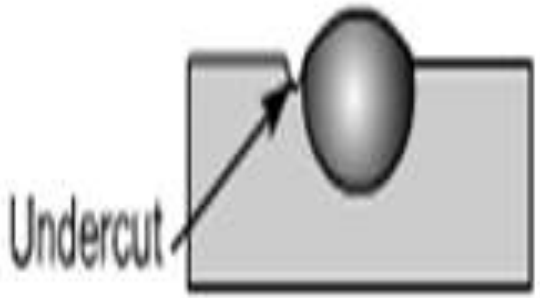
"Grooves formed in the BM adjacent to the toe of a weld & left unfilled by the weld metal".

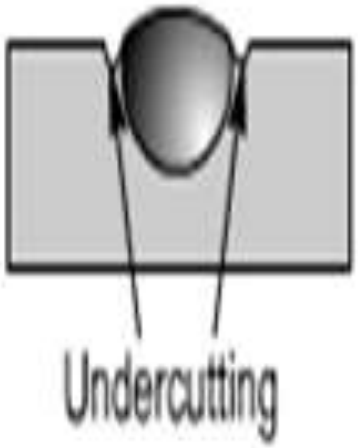
- Generally located parallel to the junction of weld metal & base metal at the toe or root of the weld
- Reduces the cross-sectional thickness of the base metal
- Acts as stress raiser in fatigue loading

UNDER CUT









UNDER CUT

Cause:

- High welding current & arc voltage
- 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.

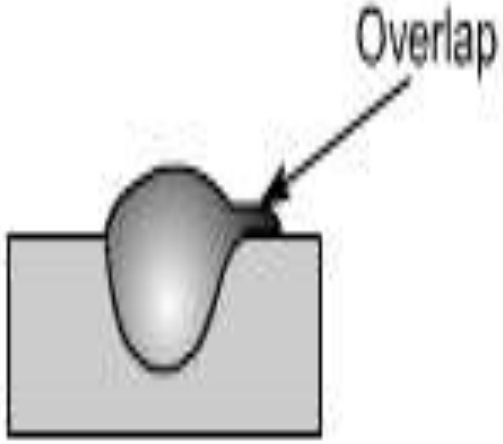
Repair:

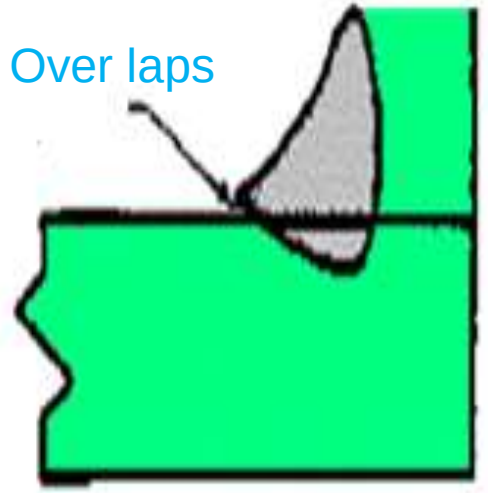
- Gouge & weld with low hydrogen electrode

OVER LAPS

"Occurs when molten metal from the electrode flows over the parent metal surface & remains without getting properly fused"(protruded weld metal beyond the toe)

- Just reverse to undercutting
- 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





OVER LAPS

Cause:-

- current too low
- Too large deposition in a single run
- Longer arc
- slow arc travel speed.

Prevention:

- Proper welding technique
- Use proper size of electrode

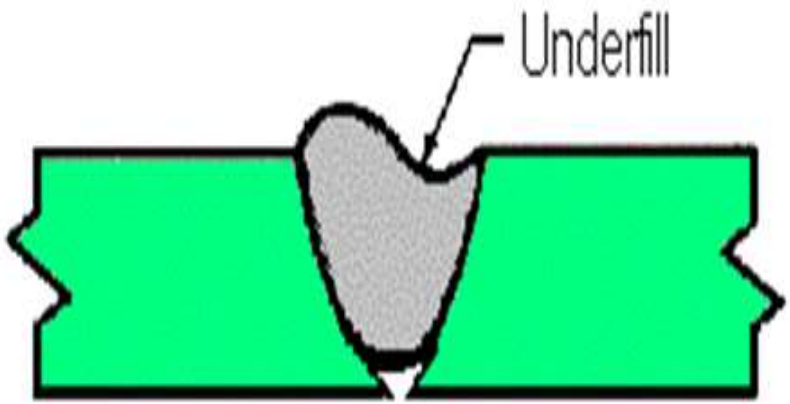
Repair:

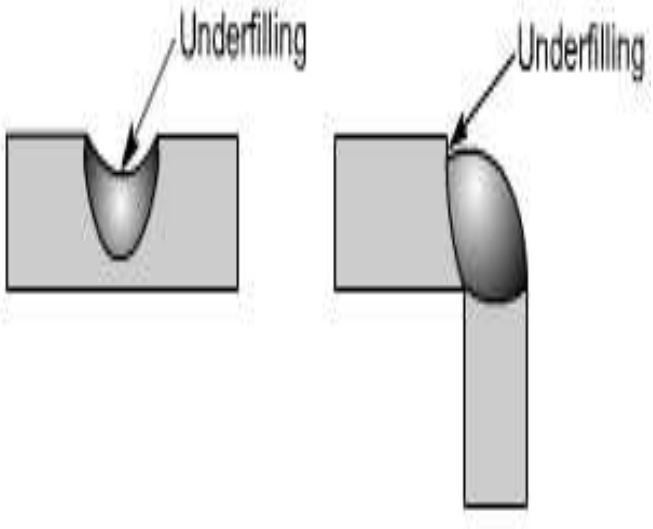
- Overlap must be removed to blend smoothly into the base metal.

UNDER FILL /SUCK BACK

"A depression on the face of a weld or the root surface".

- Reduces the cross sectional area of the weld
- Occurs when the welder or welding operator fails to fill the weld joint to the level required by the welding procedure spec.





UNDER FILL /SUCK BACK

Cause:-

- Low current
- Small size of electrodes
- Excessive travel speed

Prevention:

- Apply proper welding techniques

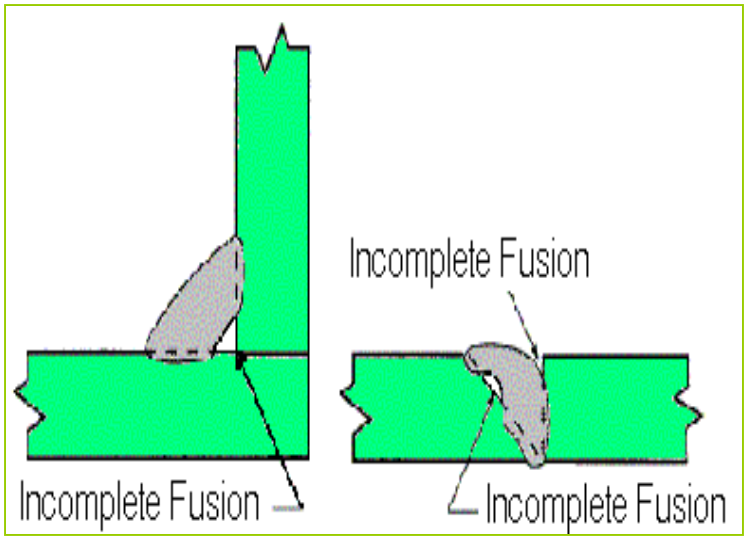
Repair:

- Simply weld to fill
- May require preparation by grinding.

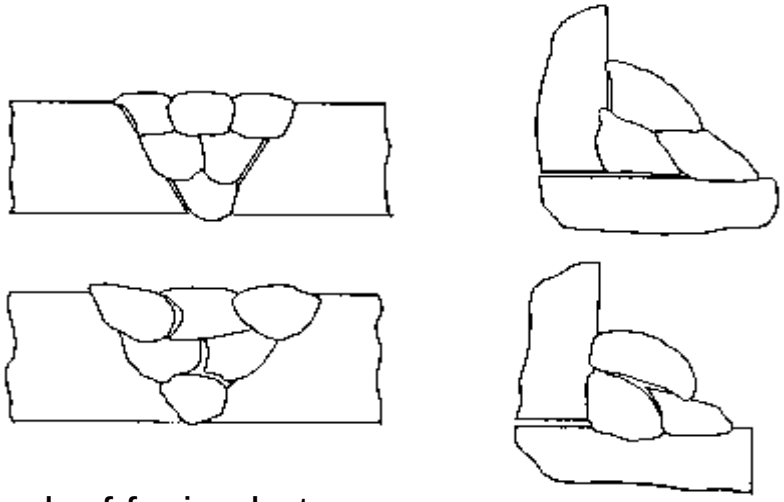
LACK OF FUSION

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

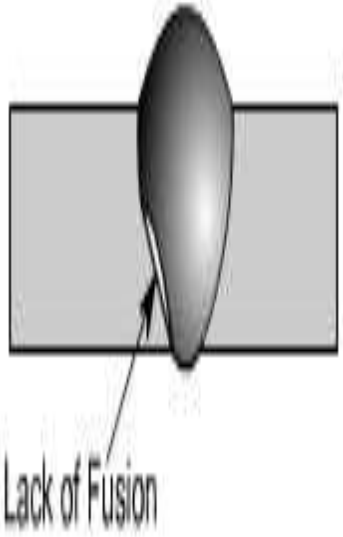
- May be at the root, sides or between two runs.
- Reduces the strength of welds & makes welded structures unreliable

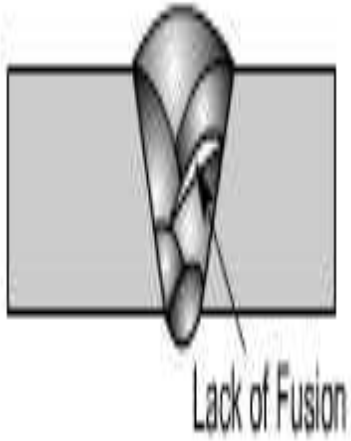


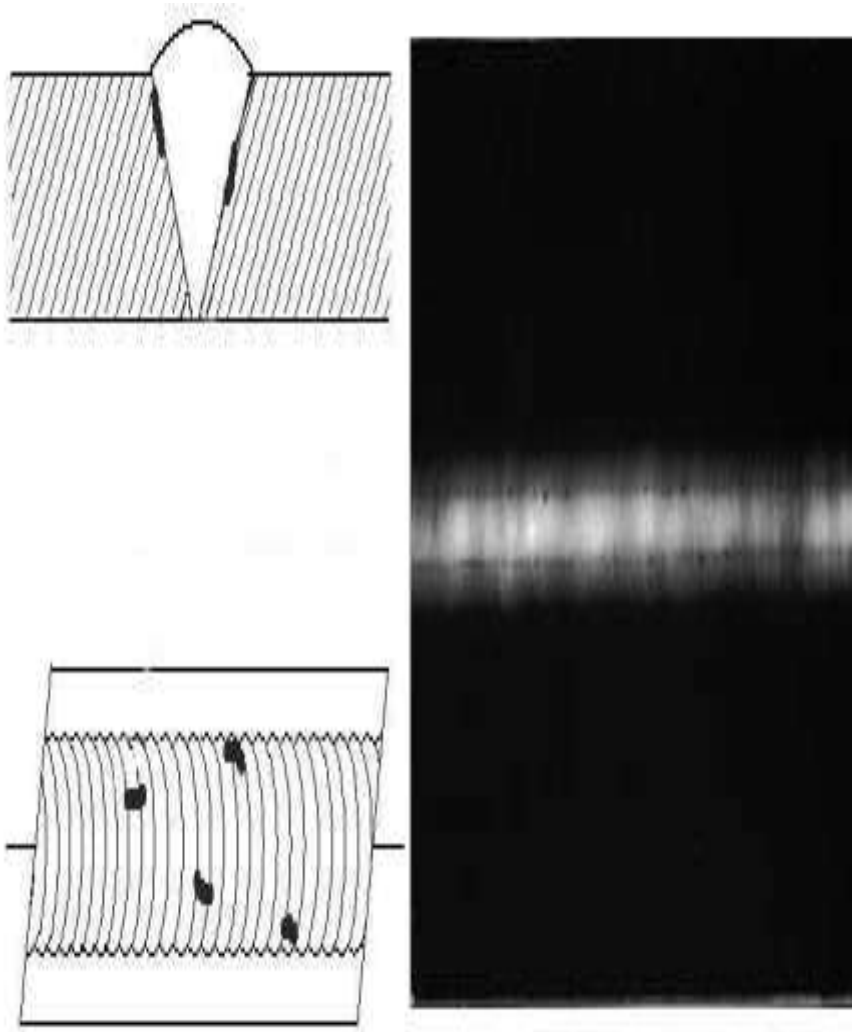
LACK OF FUSION



lack of fusion between passes







LACK OF FUSION

Cause:

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

Prevention:

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

Repair:

- Chipping back & re-welding

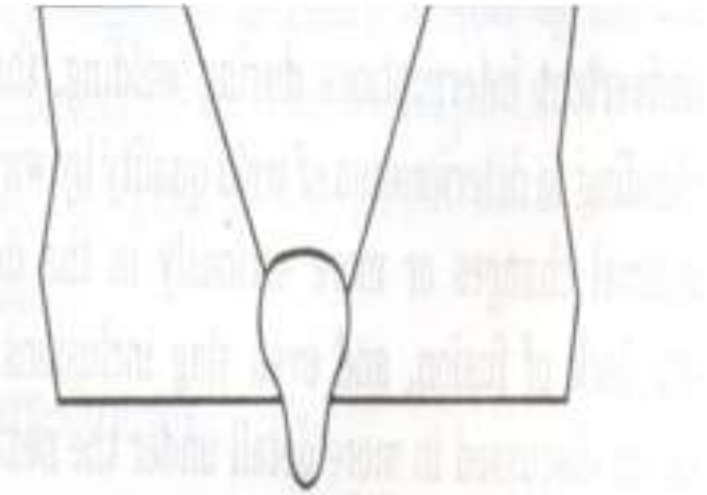
EXCESSIVE PENETRATION/ICICLES

"Weld metal lying outside the plane joining the toes"

- Makes notches that create stress concentration.
- An economic waste

Cause :-

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



Excessive penetration in root run of a groove butt weld.

EXCESSIVE PENETRATION/ICICLES

Prevention:

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

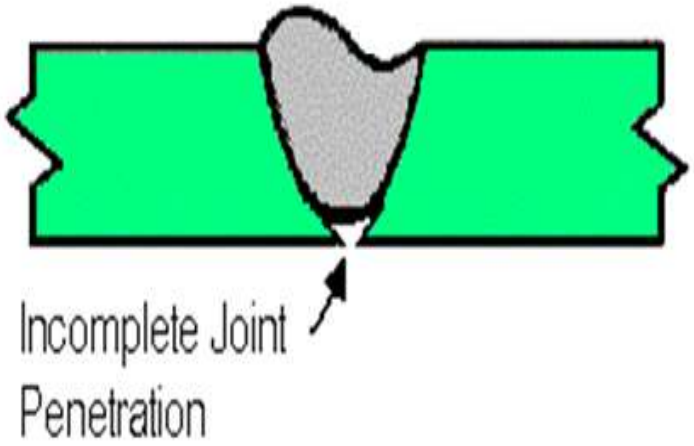
Repair:-

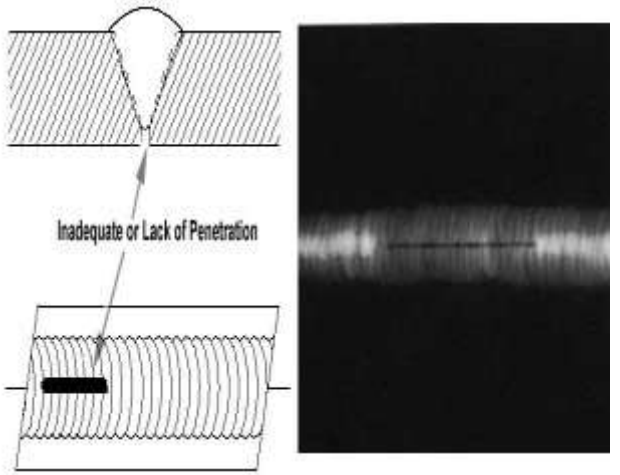
- Remove and re-weld

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"

- Acts as stress riser from which a crack may propagate





LACK OF PENETRATION

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:

- Back gouge and back weld or remove and reweld.

SPATTER

"Small globular metal drops **/** particles thrown out during welding & stick to the BM surfaces along its length".

- Metal lost
- Do not form part of the weld.
- Excessive spatters unacceptable.

SPATTER

Cause –

- Excessive arc current
- Excessive long arc
- Improper shielding gas
- Electrodes coated with improper flux ingredients
- Damp electrodes

Prevention:

- Correct welding current for type & size electrode used.
- Correct proper arc length & use correct arc voltage
- 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:

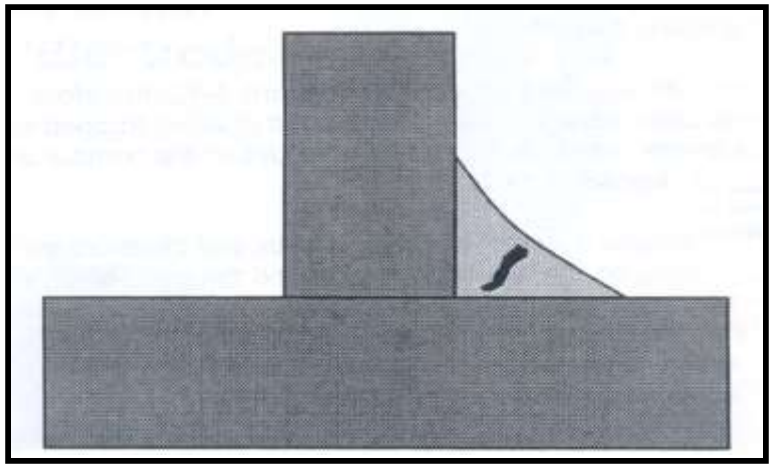
- Remove by grinding or sanding.

INCLUSION

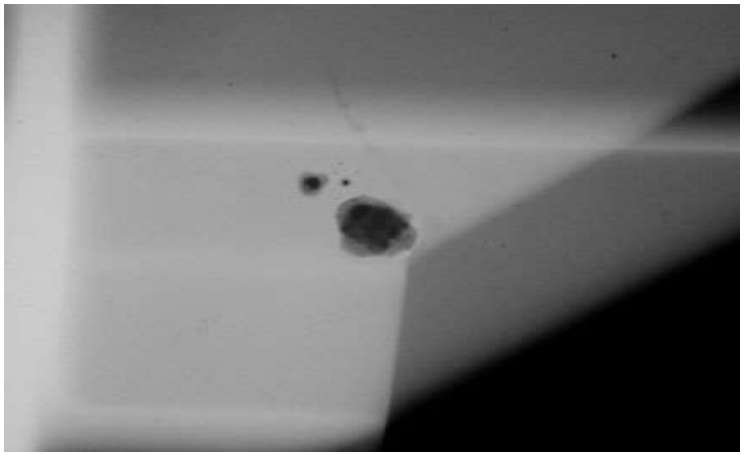
"Metallic or nonmetallic solid material entrapped within the WM, between weld passes or between WM & BM".

- May be in the form of slag or any other foreign material, which does not get a chance to float on the surface of the solidifying WM
- H_2: the most undesirable inclusion (causing: cold crack)
- Lowers the strength of joint & make it weaker
- Non- metallic inclusion:-
  - Most dangerous
  - May be sulphide, oxide, silicate or aluminate type
  - Acts as stress raiser
- Slag inclusions are elongated or globular pockets of metallic oxides and other solid compounds.

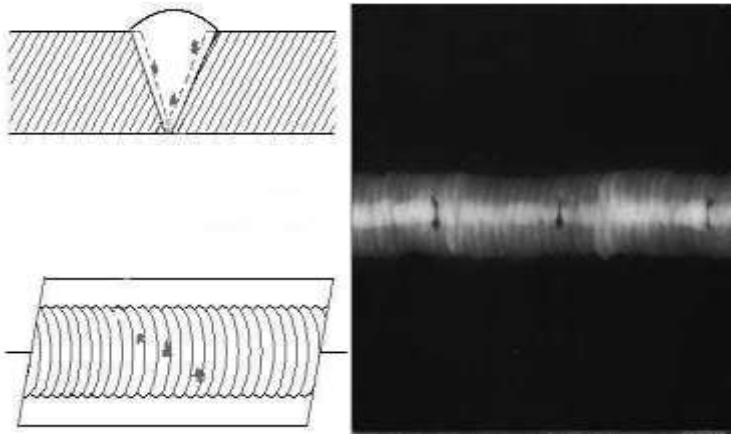
INCLUSION



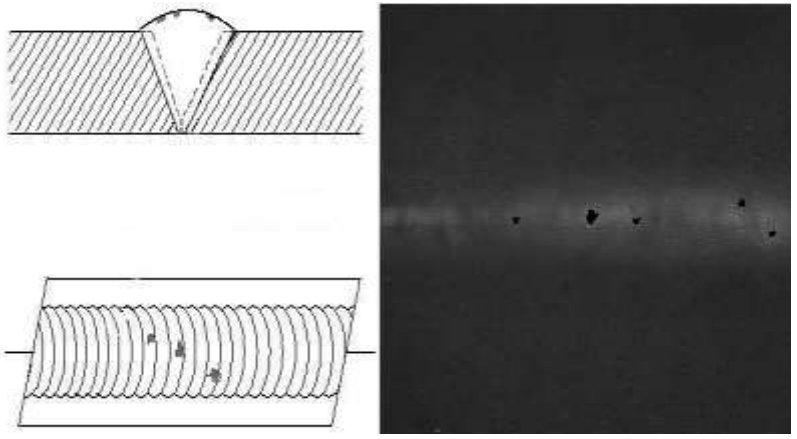
Slag inclusion



Sand inclusions



Slag inclusion



Oxide inclusions

INCLUSION

Possible causes for slag inclusion:

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

Prevention:

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

Repair:

- chip back & re-weld

METALLIC INCLUSION

Entrapped droplets of tungsten in welds in TIG welding.

– extremely brittle & can fracture easily under stress.

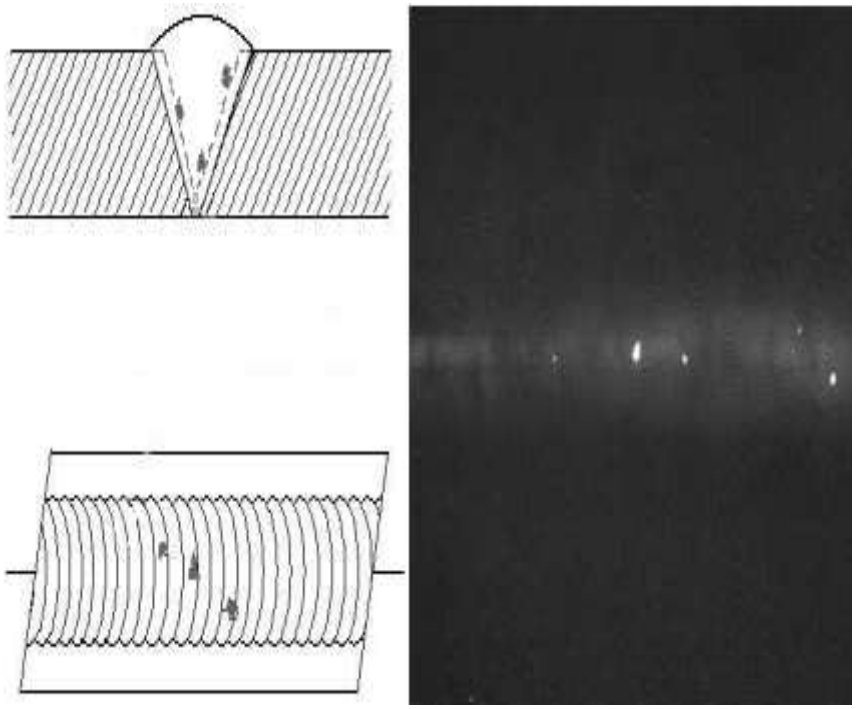
Cause –

- Dipping of tungsten electrode into molten weld pool
- Use of heavy current
- Over heating & melting of W- electrode
- Use of oxygen contaminated shielding gas

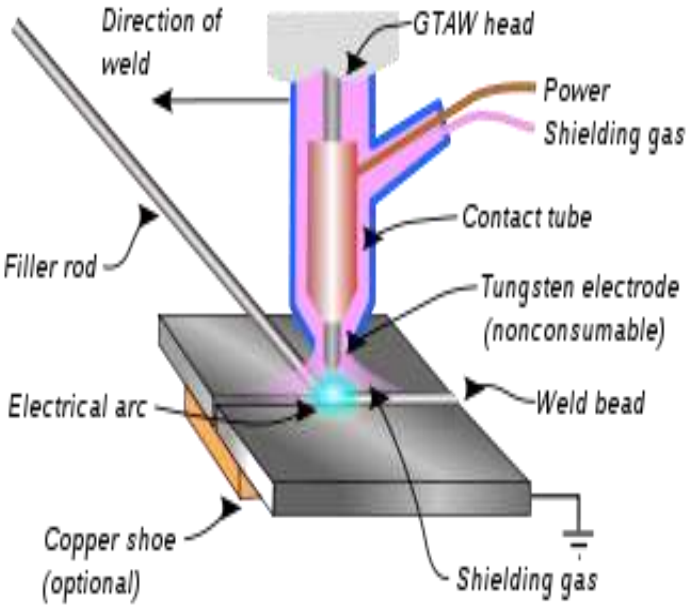
Prevention:

- Avoid contact between the electrode & the work
- Use larger electrode
- Repair: Grind out and re-weld

METALLIC INCLUSION



W-inclusion



TIG WELDING

WAGON TRACK

"Linear slag inclusions along the axis of weld"

Cause:

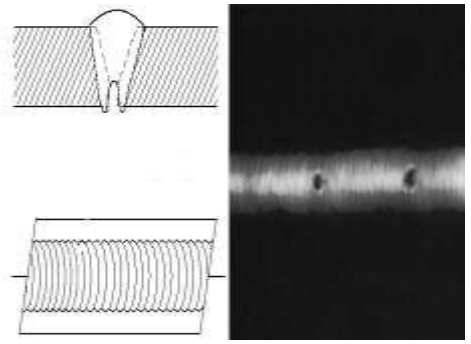
– Improper technique

Prevention:

– remove slag from previous passes.

BURN-THROUGH

"The holes burned through the parent metal in a single pass weld or the root run in multi run welds"



- seldom occurs

Cause:-

- Excessive welding current with low welding speed
- Insufficient root face
- Excessive root gap

Repair:

- Remove and re-weld
- PWHT

ARC STRIKE

"Localised HAZ"

When a welder accidently strikes the electrode or the electrode holder against the work, usually adjacent to the weld, causing an unwanted arc. Such spots are referred to as "arc strikes" which can initiate failure in bending or cyclic loading

- Must be avoided
- The repair of such damage may be difficult & costly, involving chipping & pre heating before re welding
- If this is not an option then the arc spot can be post heated

SHRINKAGE CAVITY or CONTRACTION CAVITY

"A cavity formed by shrinkage of weld metal during its solidification".

– Seldom occurs

Shrinkage cavity


THANK YOU