

Materials for Automobiles

Lec 13

Welding

12 Oct 2011

Types of Welding

Fusion Welding

Use heat to melt the base metals and may add a filler metal

Solid-State Welding

Uses heat and pressure, or pressure alone, to join the metals; the temperature does not reach the melting point

Arc Welding

The main method employed for structural steelwork is arc welding
Principles – Electrode or filler wire melts due to passage of welding current through the filler wire, Arc (plasma) & back to the power source via the earthed component Typically arc temperature is 5000 to 30000K
The melt is transferred across the arc – several mechanisms – droplets, spray etc.

1 – Shielded Metal Arc Weld (SMAW):

Most popular welding technique (stick welding).

The electrode coating performs the following:

A – Produce gaseous shield to exclude oxygen.

B – Introduce deoxidizer material to improve grain.

C – Produce a blanket of slag to retard cooling and oxidation.

The SMAW process is designated by AWS as “E6OXX” or “E7OXX”

e.g. E7018

E indicates electrode. 70 indicates 70,000 psi tensile strength

1 indicates use for welding in all positions, 8 indicates low hydrogen

- Older, simple technology
- The electrode is also the filler rod
- Strong welds if done properly (but often not)
- Very high heat input: good for thick parts, bad for grain growth and distortion

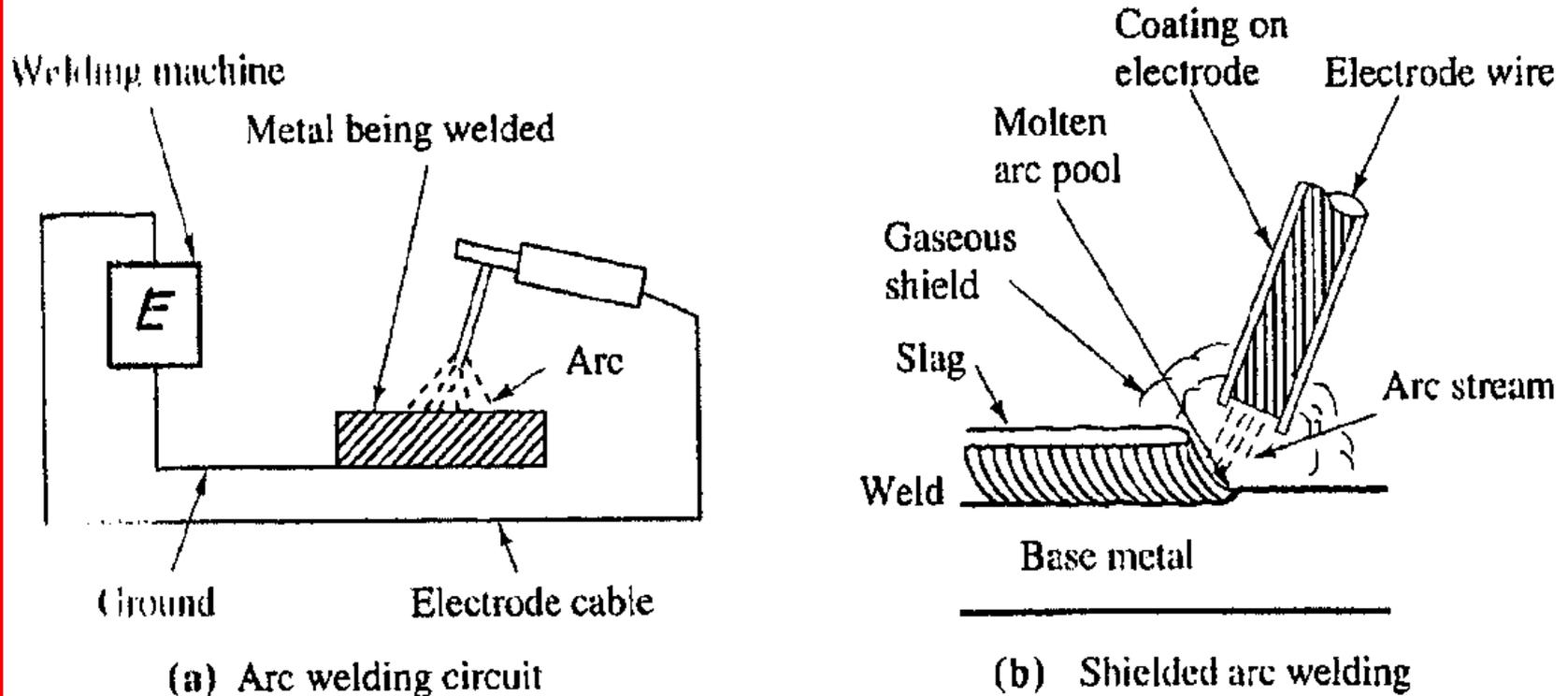


Figure 5.2.1 Shielded metal arc welding (SMAW).

Coating Materials -Partial List

Arc Stabilizers : Titania TiO_2

Gas-Forming Materials: Wood Pulp, Limestone CaCO_3

Slag-Forming Materials: Alumina Al_2O_3 , TiO_2 , SiO_2 , Fe_3O_4

Slipping Agents to Aid Extrusion: Clay, Talc, Glycerin

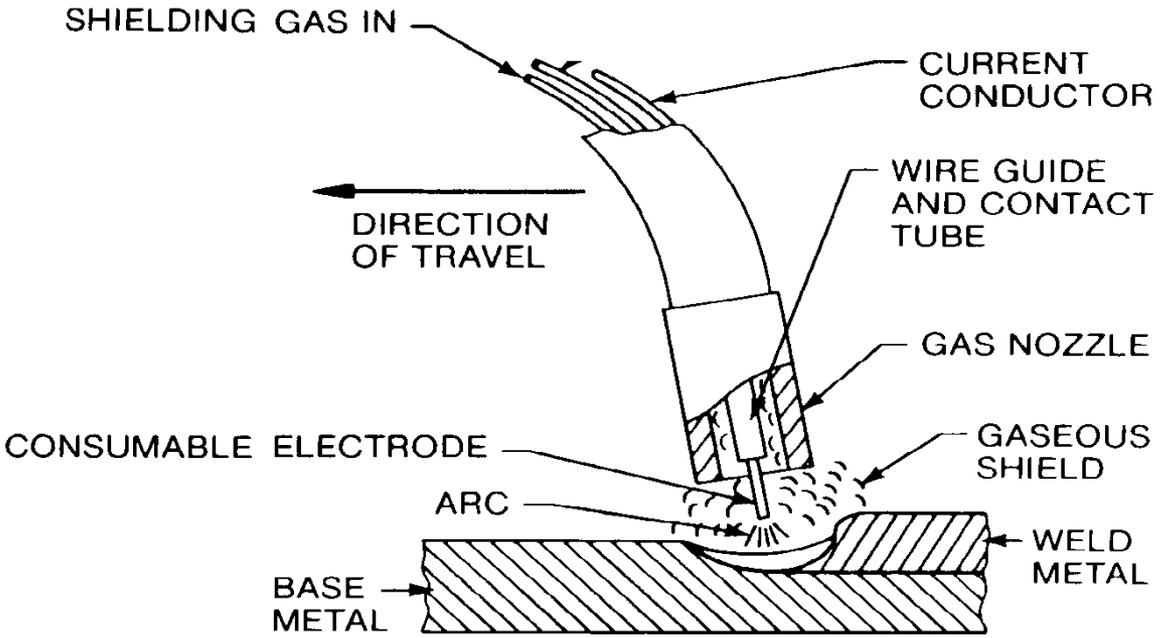
Binding Agents: Sodium Silicate, Asbestos, Starch, Sugar

Alloying and Deoxidizing Elements: Si, Al, Ti, Mn, Ni, Cr

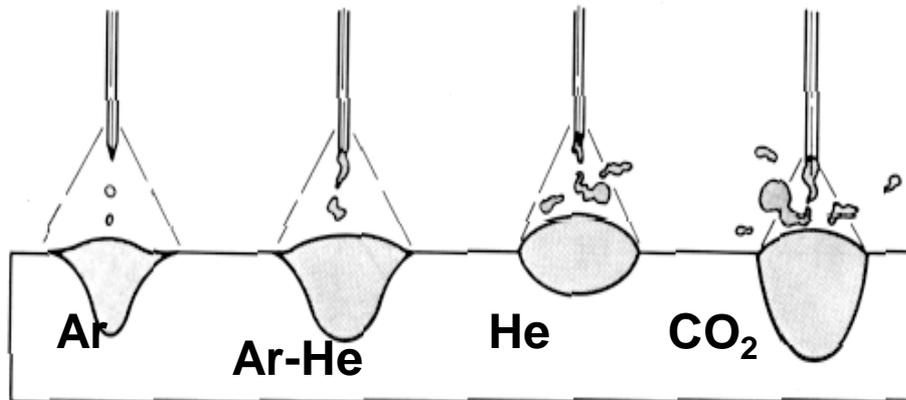
SMAW

Adv	<p>Equipment relatively easy to use, inexpensive, portable</p> <p>Filler metal and means for protecting the weld puddle are provided by the covered electrode</p> <p>Less sensitive to drafts, dirty parts, poor fit-up</p> <p>Can be used on carbon steels, low alloy steels, stainless steels, cast irons, copper, nickel, aluminum</p>
Quality Issues	<p>Discontinuities associated with manual welding process that utilize flux for pool shielding</p> <ul style="list-style-type: none">Slag inclusionsLack of fusion <p>Other possible effects on quality are porosity, and hydrogen cracking</p>
Limitations	<p>Low Deposition Rates</p> <p>Low Productivity</p> <p>Operator Dependent</p>

Gas Metal Arc Welding (GMAW or MIG or CO2 Welding)



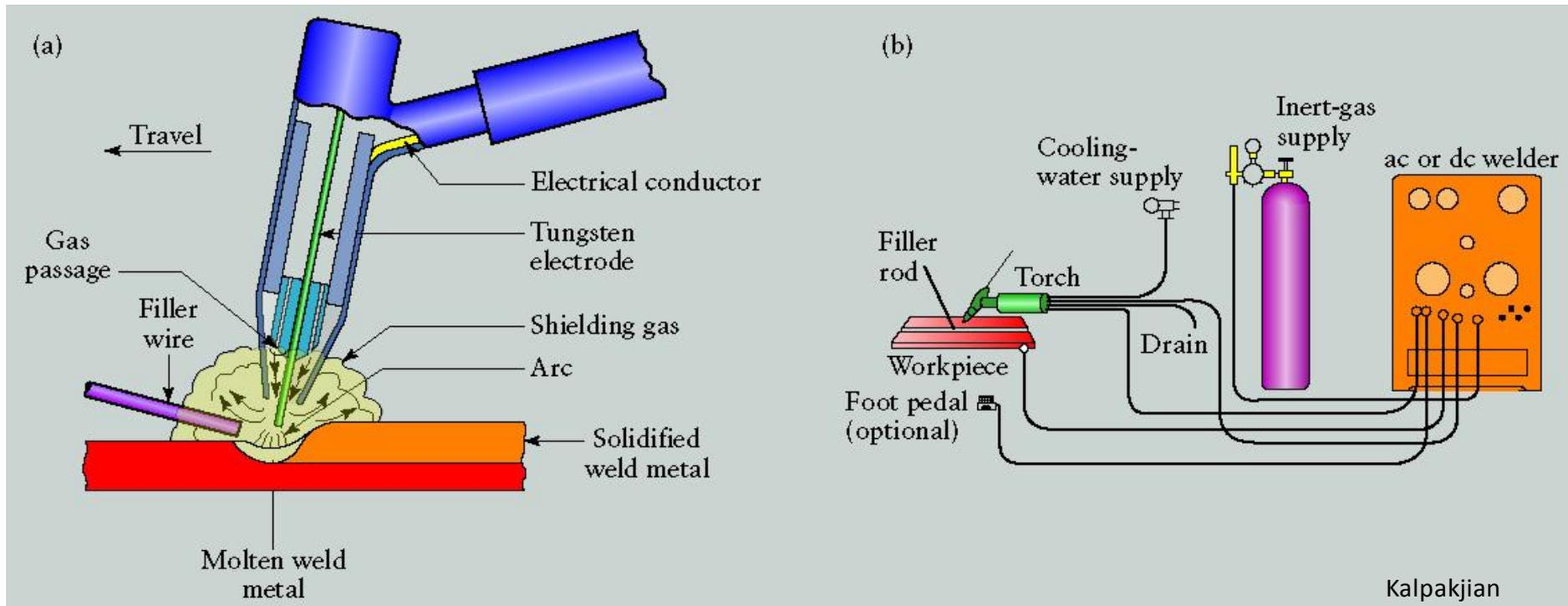
Shielding Gas



- Shielding gas can affect
 - Weld bead shape
 - Arc heat, stability, and starting
 - Surface tension
 - Drop size
 - Puddle flow
 - Spatter

Gas Tungsten Arc Welding (GTAW): “TIG” (Tungsten-Inert-Gas)

- The electrode is tungsten (not consumed)
- The filler rod is separate and fed manually
- High skill level required to achieve good weld
- Difficult to automate
- Low heat input and small weld bead: distortion and grain growth are minimized



GMAW

Advantages	Deposition rates higher than SMAW Productivity higher with no slag removal & continuous welding Easily automated
Quality Issues	Spatter Droplets of electrode material that land outside the weld fusion area and may or may not fuse to the base material Porosity Small volumes of entrapped gas in solidifying weld metal
limitations	<ul style="list-style-type: none">• Equipment is more expensive and complex than SMAW• Process variants/metal transfer mechanisms make the process more complex and the process window more difficult to control• Restricted access<ul style="list-style-type: none">• GMAW gun is larger than SMAW holder

Role of Welding Flux and Shielding gas

Welding Flux

Three forms

Granular

Electrode wire coating

Electrode core

Fluxes melt to form a protective *slag* over the weld pool

Other purposes

Contain scavenger elements to purify weld metal

Contain metal powder added to increase deposition rate

Add alloy elements to weld metal

Decompose to form a shielding gas

Shielding Gas

Shielding gas forms a protective atmosphere over the molten weld pool to prevent contamination

Inert shielding gases, argon or helium, keep out oxygen, nitrogen, and other gases

Active gases, such as oxygen and carbon dioxide, are sometimes added to improve variables such as arc stability and spatter reduction



Argon



Helium

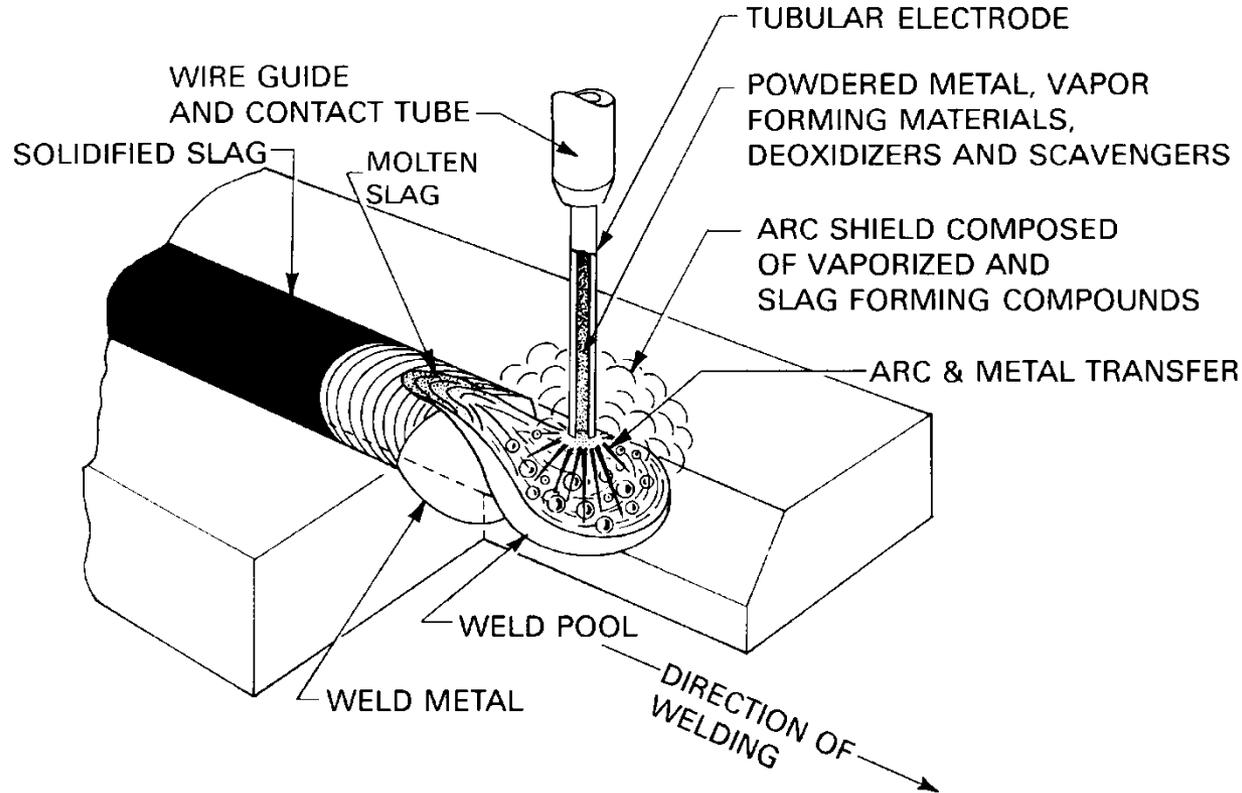


Oxygen



Carbon Dioxide

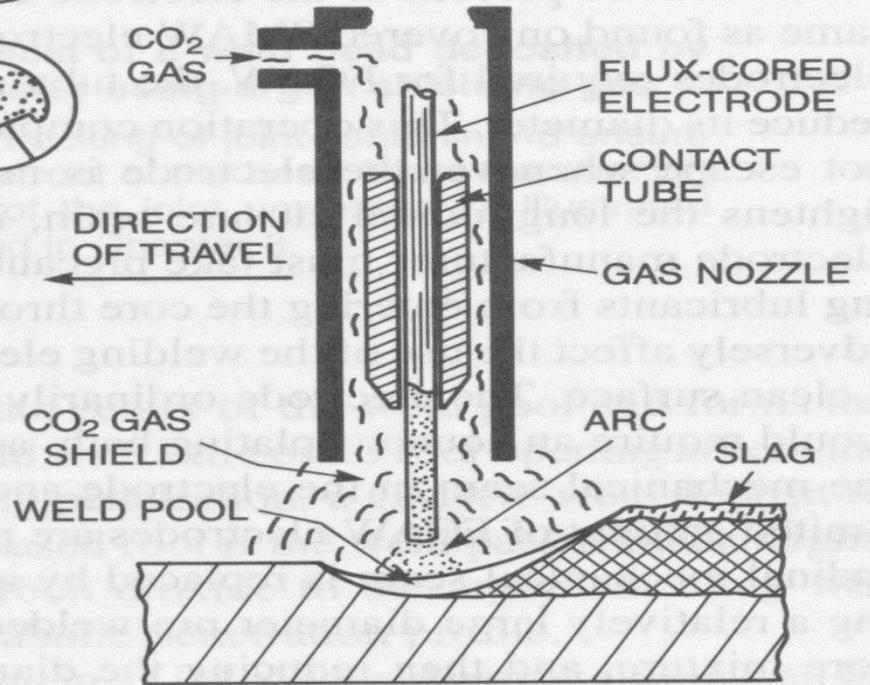
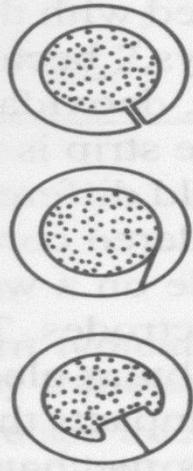
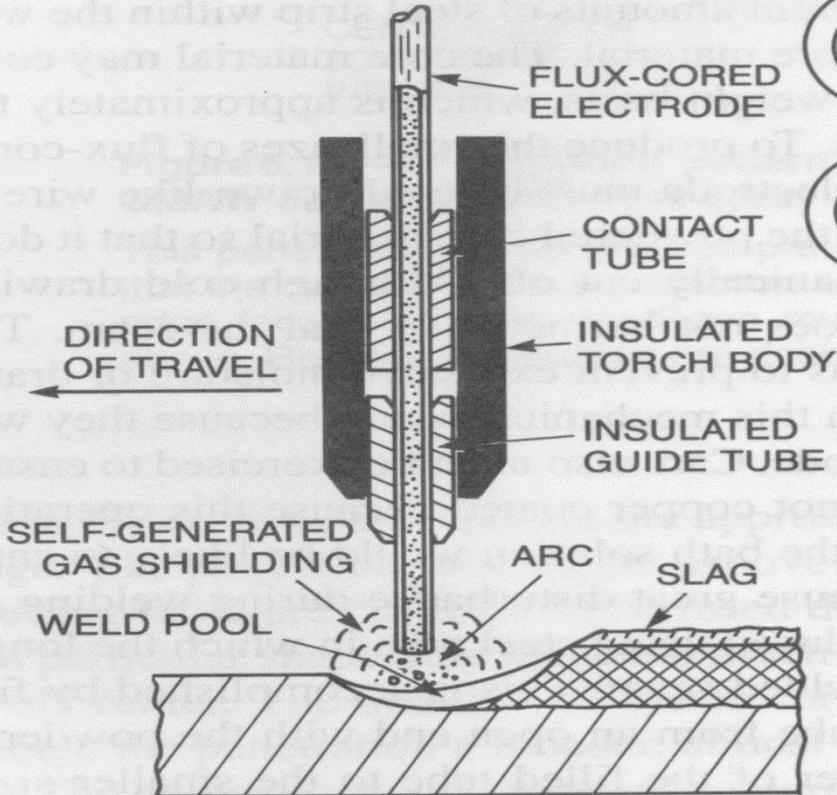
Flux Cored Arc Welding (FCAW)



FCAW WITH SELF-SHIELDED ELECTRODE

EXAMPLES OF CROSS-SECTIONS OF FLUX-CORED ARC WELDING ELECTRODE

FCAW WITH GAS SHIELDED ELECTRODE



FCAW

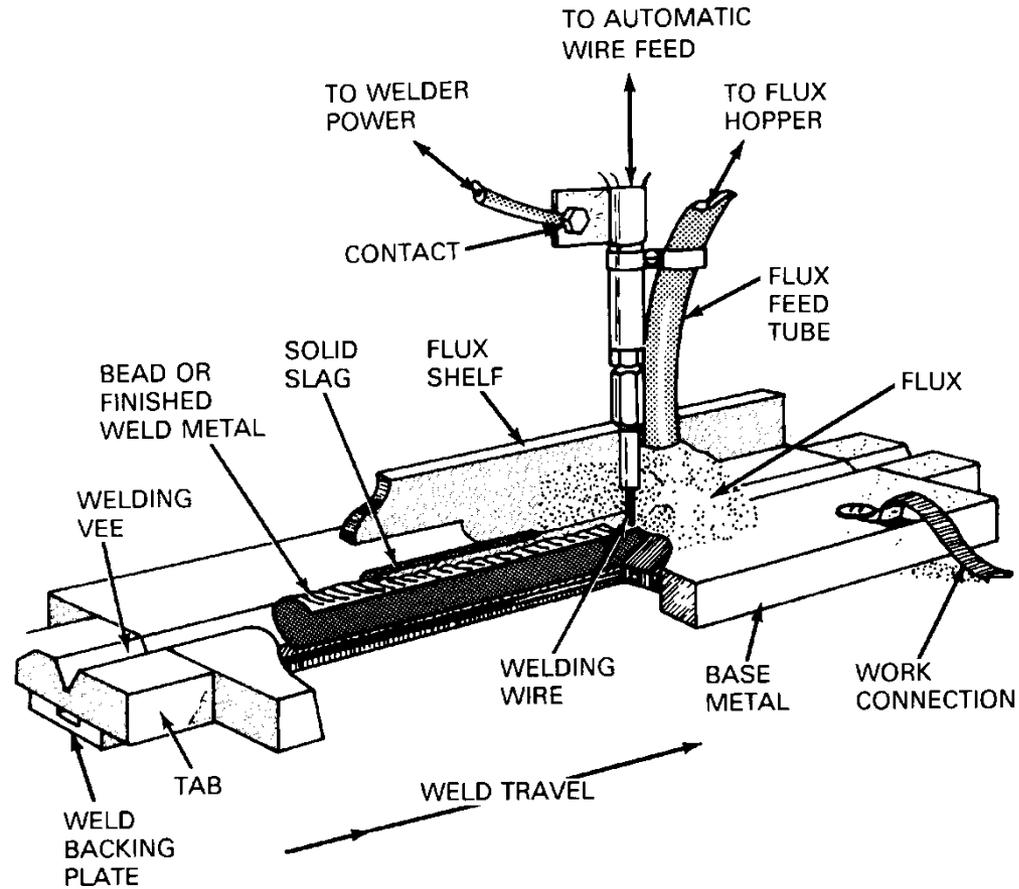
Advantages

- High deposition rates
- Deeper penetration than SMAW
- High-quality
- Less pre-cleaning than GMAW
- Slag covering helps with larger out-of-position welds
- Self-shielded FCAW is draft tolerant.

Limitations

- Slag must be removed
- More smoke and fumes than GMAW and SAW
- Spatter
- FCAW wire is more expensive
- Equipment is more expensive and complex than for SMAW

Submerged Arc Welding



Submerged Arc Weld (SAW)

In this process the automatically fed arc (spool) is protected by a blanket of granular material called “flux”. This flux material acts to improve weld quality and to protect it from the air. Most (SAW) processes are used in welding shops and not at site.

Advantages

- High deposition rates
- No arc flash or glare
- Minimal smoke and fumes
- Flux and wire added separately - extra dimension of control
- Easily automated
- Joints can be prepared with narrow grooves
- Can be used to weld carbon steels, low alloy steels, stainless steels, chromium-molybdenum steels, nickel base alloys

Limitations

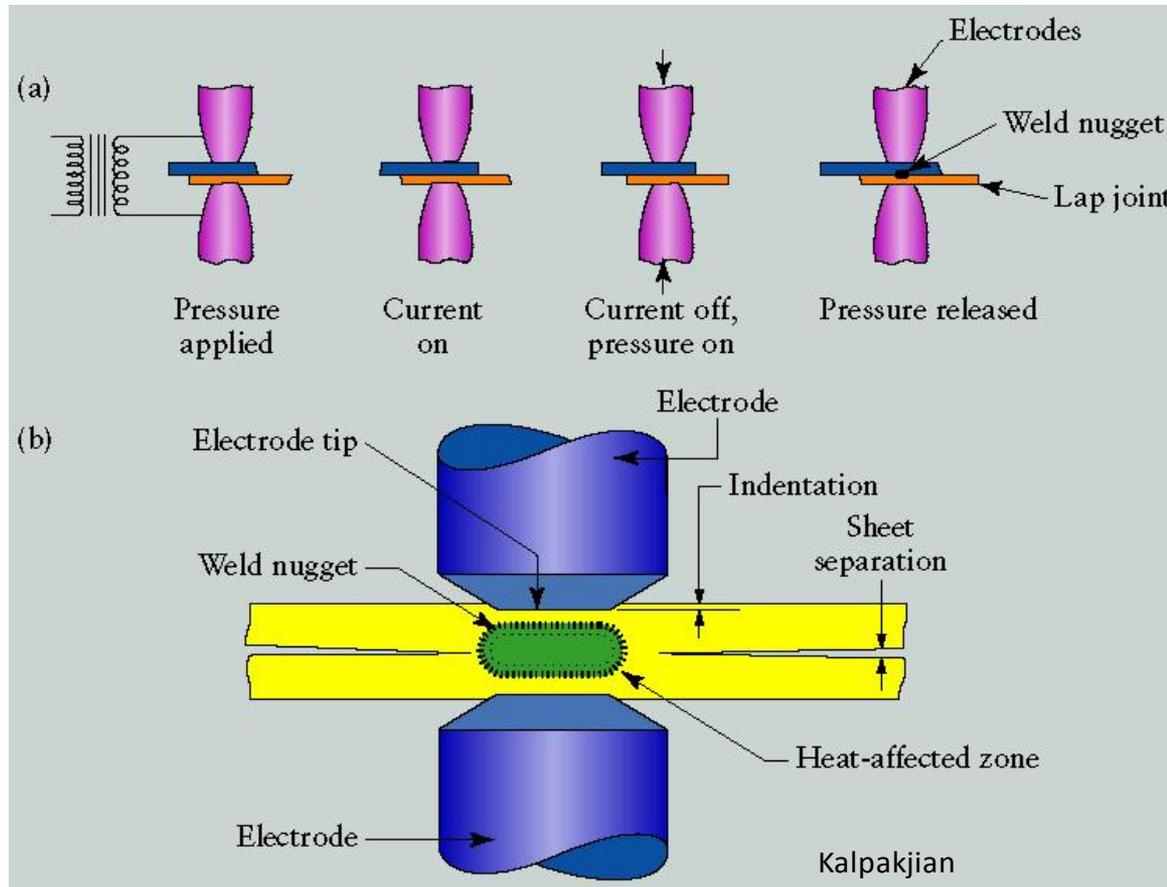
- Flux obstructs view of joint during welding
- Flux is subject to contamination \Rightarrow porosity
- Normally not suitable for thin material
- Restricted to the flat position for grooves - flat and horizontal for fillets
- Slag removal required
- Flux handling equipment

Resistance Welding

- Developed in the early 1900's
- A process in which the heat required for welding is produced by means of electrical resistance across the two components
- RW does not **requiring the following:**
 - Consumable electrodes
 - Shield gases
 - Flux

Resistance Spot Welding (RSW): “Spot Welding”

- No filler rod: electrical current is passed through metal under pressure
- Low skill level required
- Easy to automate
- Low heat input and no weld bead: distortion and grain growth are minimized



Resistance Spot Welding

- Surfaces should be clean
- Accurate control of and timing of electric current and of pressure are essential in resistance welding

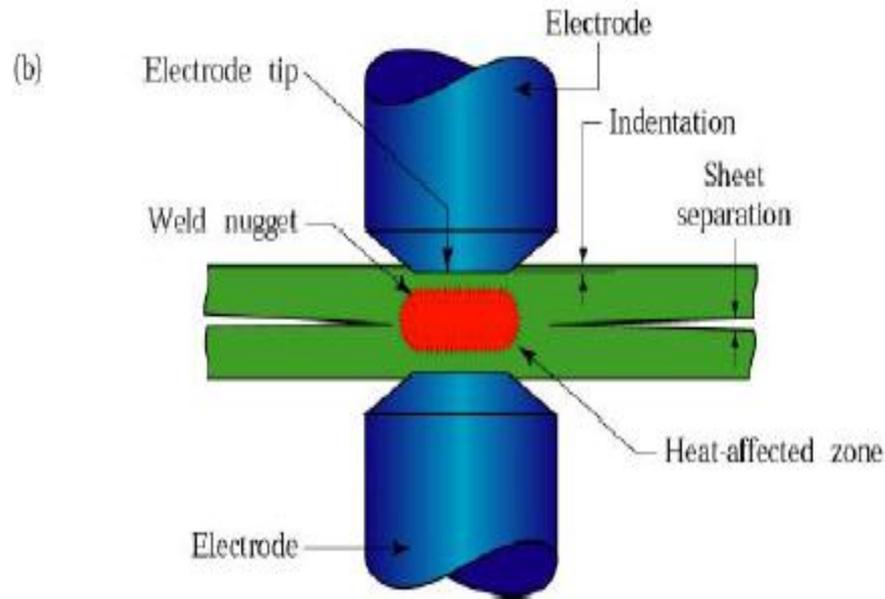


Fig: b) Cross-section of a spot weld, showing the weld nugget and the indentation of the electrode on the sheet surfaces. This is one of the most commonly used processes in sheet-metal fabrication and in automotive-body assembly.

Resistance Seam Welding

- RSEM is modification of spot welding wherein the electrodes are replaced by rotating wheels or rollers
- The electrically conducting rollers produce a spot weld
- RSEM can produce a continuous seam & joint that is liquid and gas tight

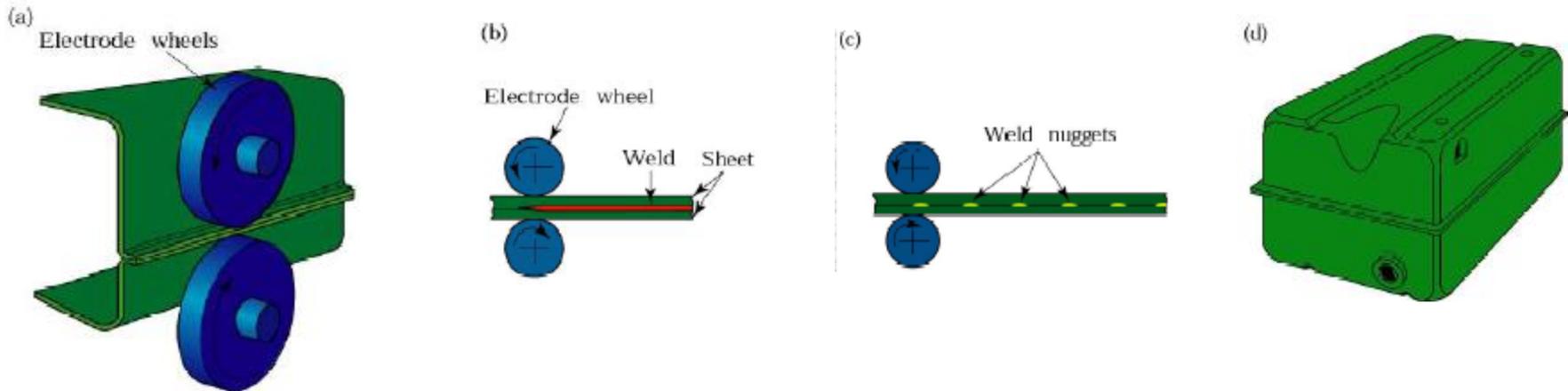


Fig : (a) Seam-Welding Process in which rotating rolls act as electrode (b) Overlapping spots in a seam weld. (c) Roll spot weld (d) Resistance-welded gasoline tank

Resistance Projection Welding

- RPW is developed by introducing high electrical resistance at a joint by embossing one or more projections on the surface to be welded
- Weld nuggets are similar to spot welding

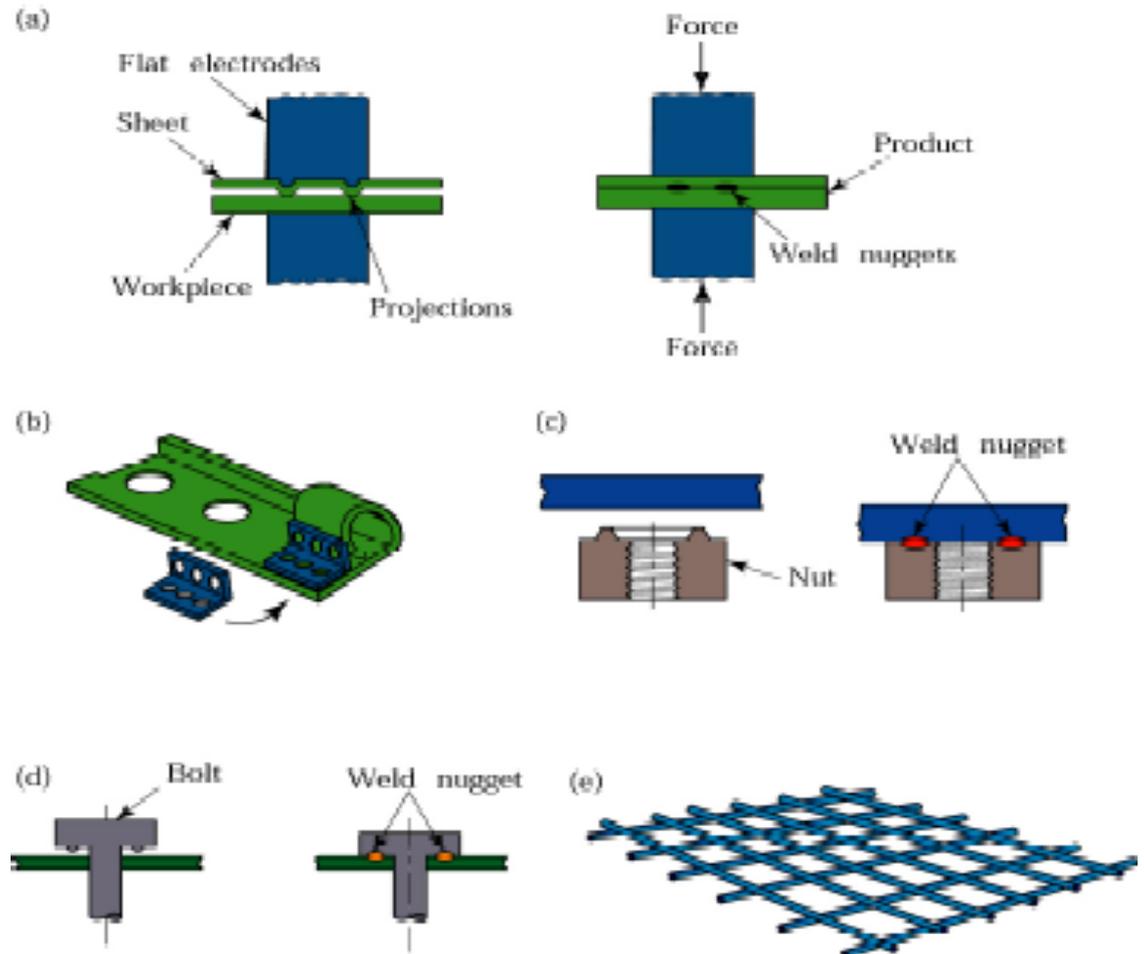


Fig: a) Resistance projection Welding b) A welded bracket c) & d) Projection welding of nuts r threaded hoses and stack

Resistance Projection Welding

- The electrodes exert pressure to compress the projections
- Nuts and bolts can be welded to sheet and plate by this process
- Metal baskets, oven grills, and shopping carts can be made by RPW

Flash Welding

- Heat is generated from the arc as the ends of the two members contact
- An axial force is applied at a controlled rate
- Weld is formed in plastic deformation

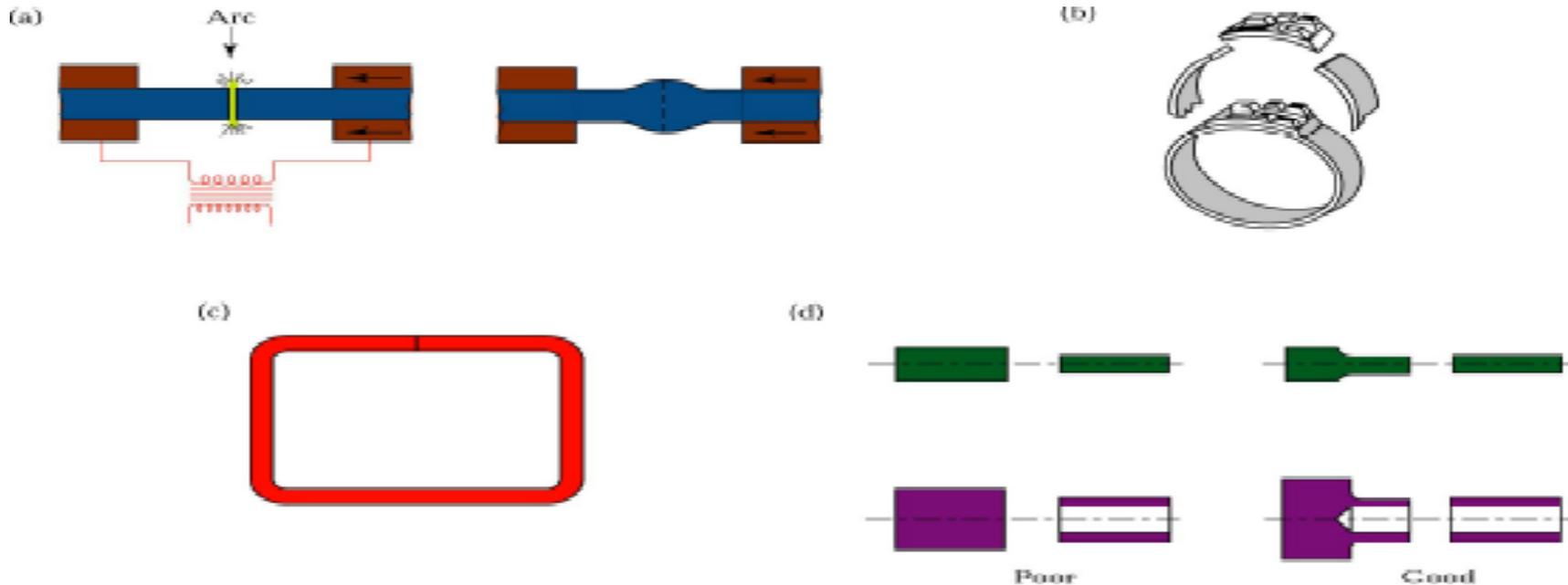


Fig : (a)Flash-welding process for end-to –end welding of solid rods or tubular parts
(b) & (c) Typical parts made by flash welding (d)Design Guidelines for flash welding

Stud Welding

- Small part or a threaded rod or hanger serves as an electrode
- Also called as Stud arc welding
- Prevent oxidation to concentrate the heat generation
- Portable stud-welding is also available

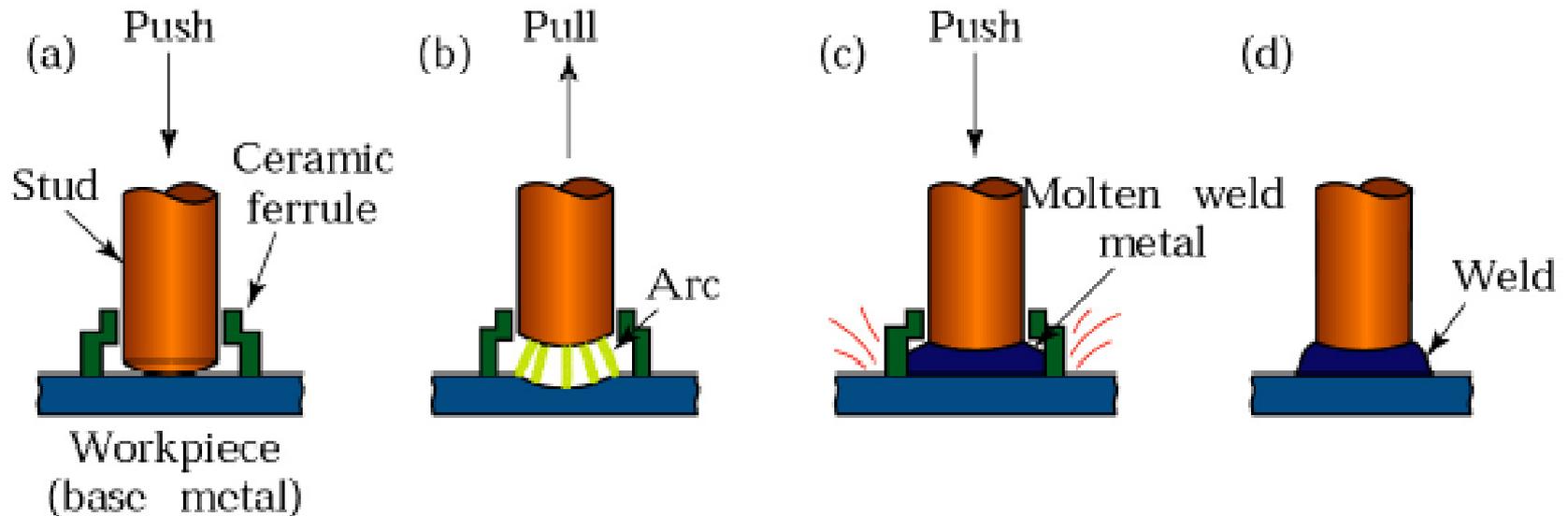
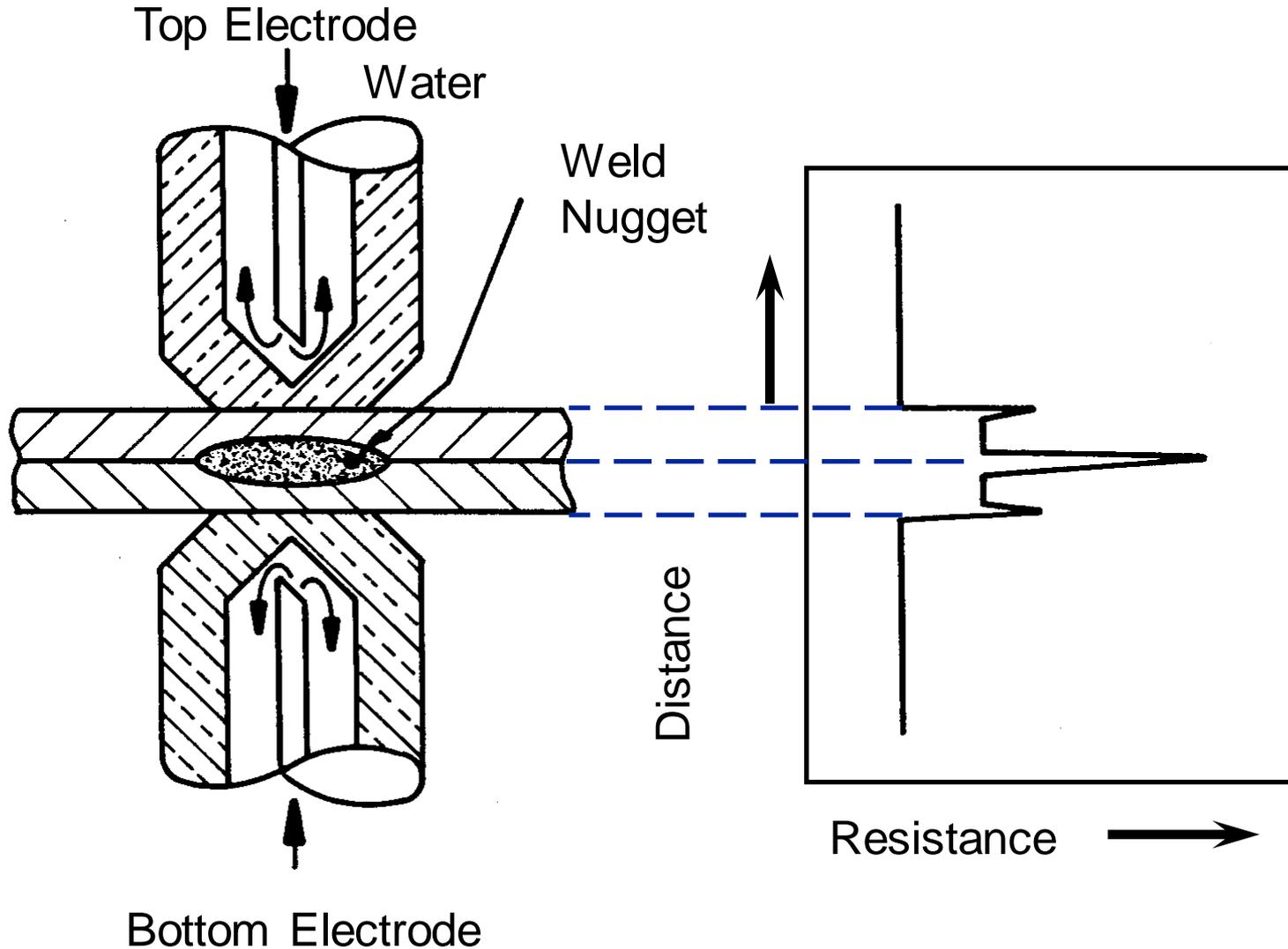


Fig: The sequence of operation in stud welding, which is used for welding bars, threaded rods, and various fasteners onto metal plates.

Introduction to Resistance Spot Welding



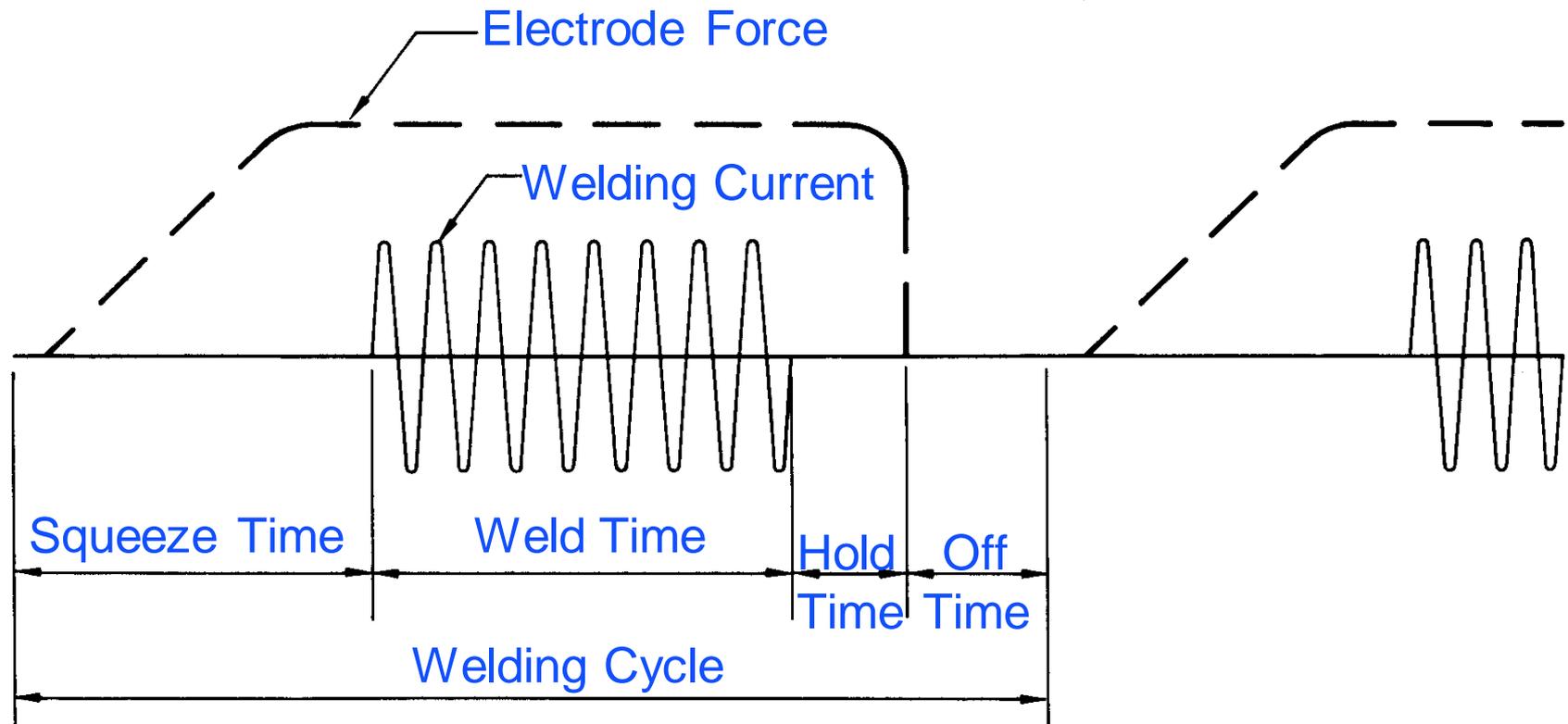
Advantages of Resistance Spot Welding

- | Adaptability for Automation in High-Rate Production of Sheet Metal Assemblies
- | High Speed
- | Economical
- | Dimensional Accuracy

Limitations of Resistance Spot Welding

- | Difficulty for maintenance or repair
- | Adds weight and material cost to the product, compared with a butt joint
- | Generally have higher cost than most arc welding equipments
- | Produces unfavorable line power demands
- | Low tensile and fatigue strength
- | The full strength of the sheet cannot prevail across a spot welded joint
- | Eccentric loading condition

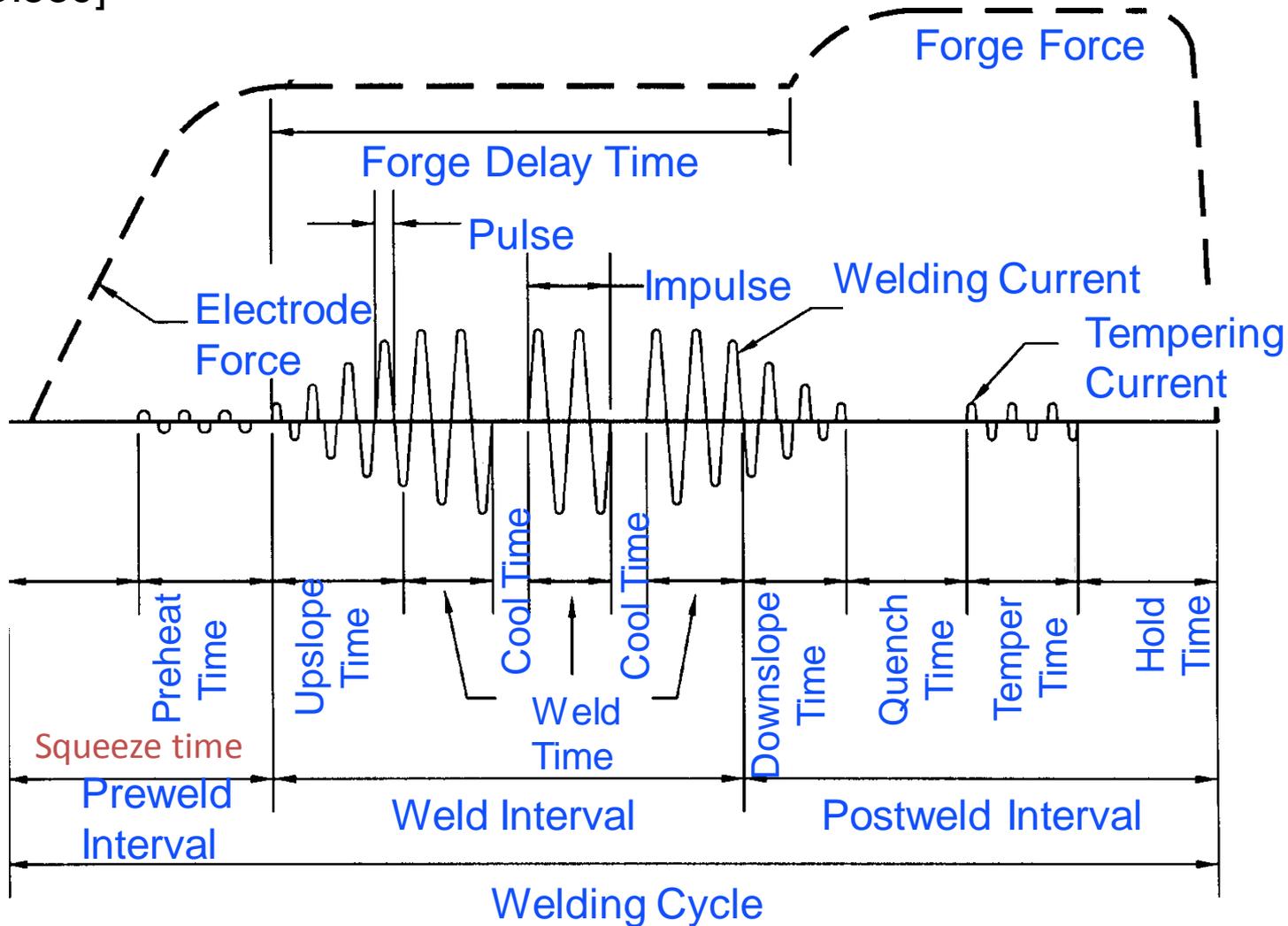
Basic Single Impulse Welding Cycle



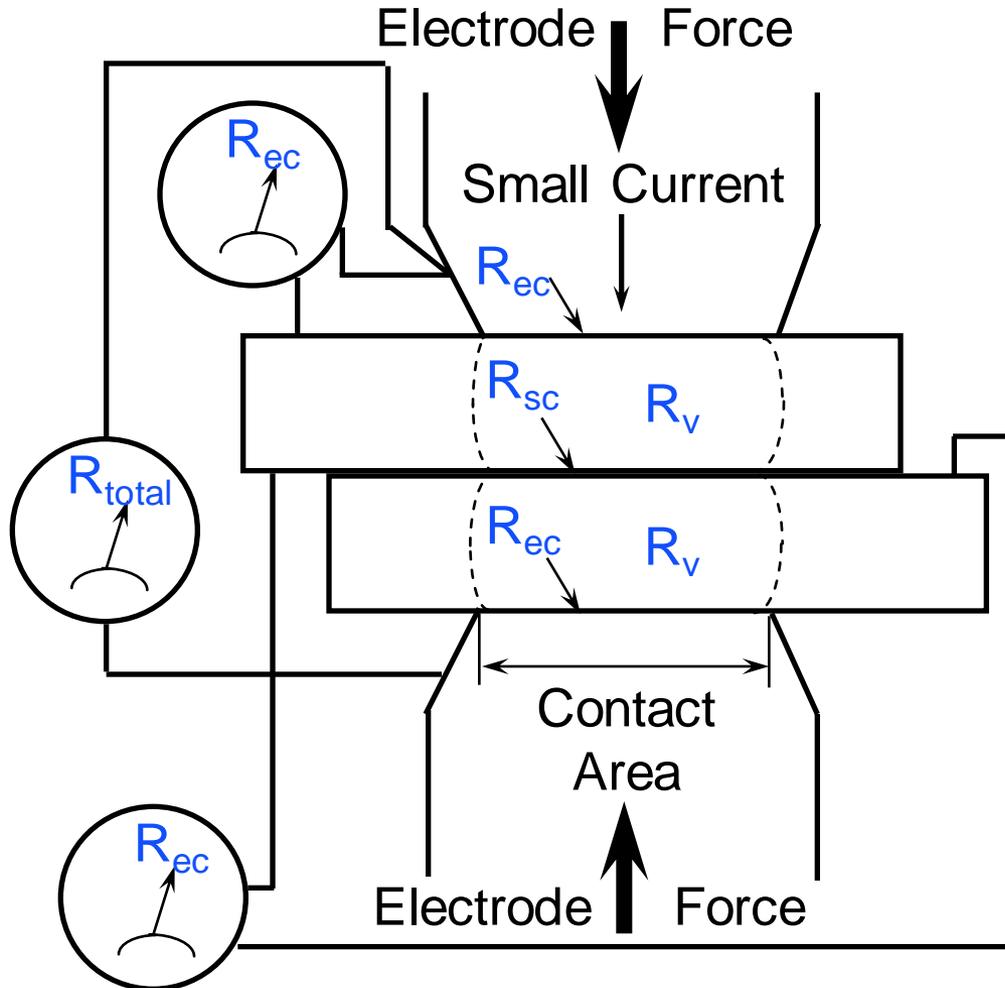
[Reference: Welding Handbook, Volume 2, AWS, p.538]

Enhanced Welding Cycle

[Reference: Welding Handbook, Volume 2,
AWS, p.539]



Contact-Resistance Measurement

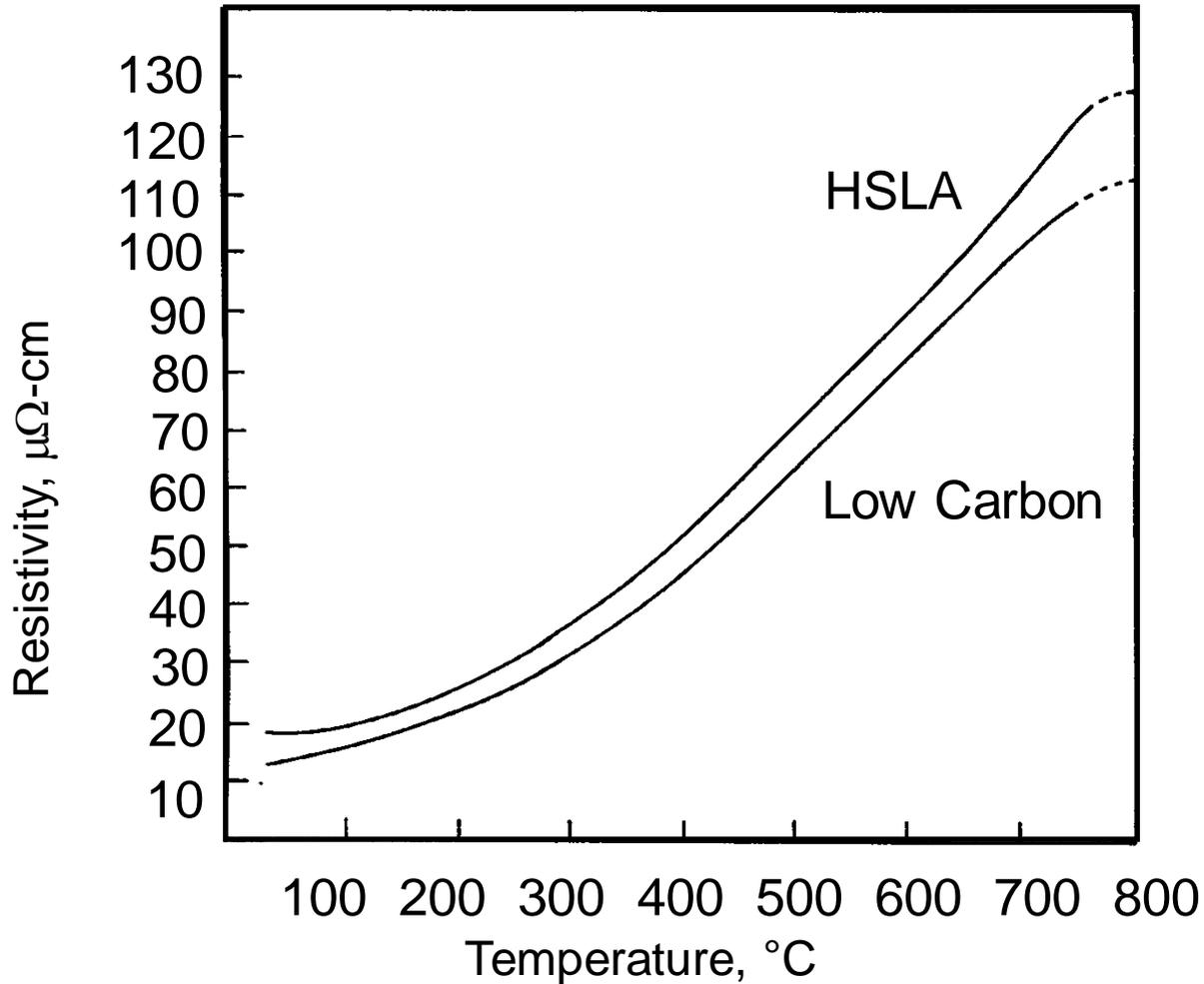


R_{ec} = contact resistance between electrode and sheet surface

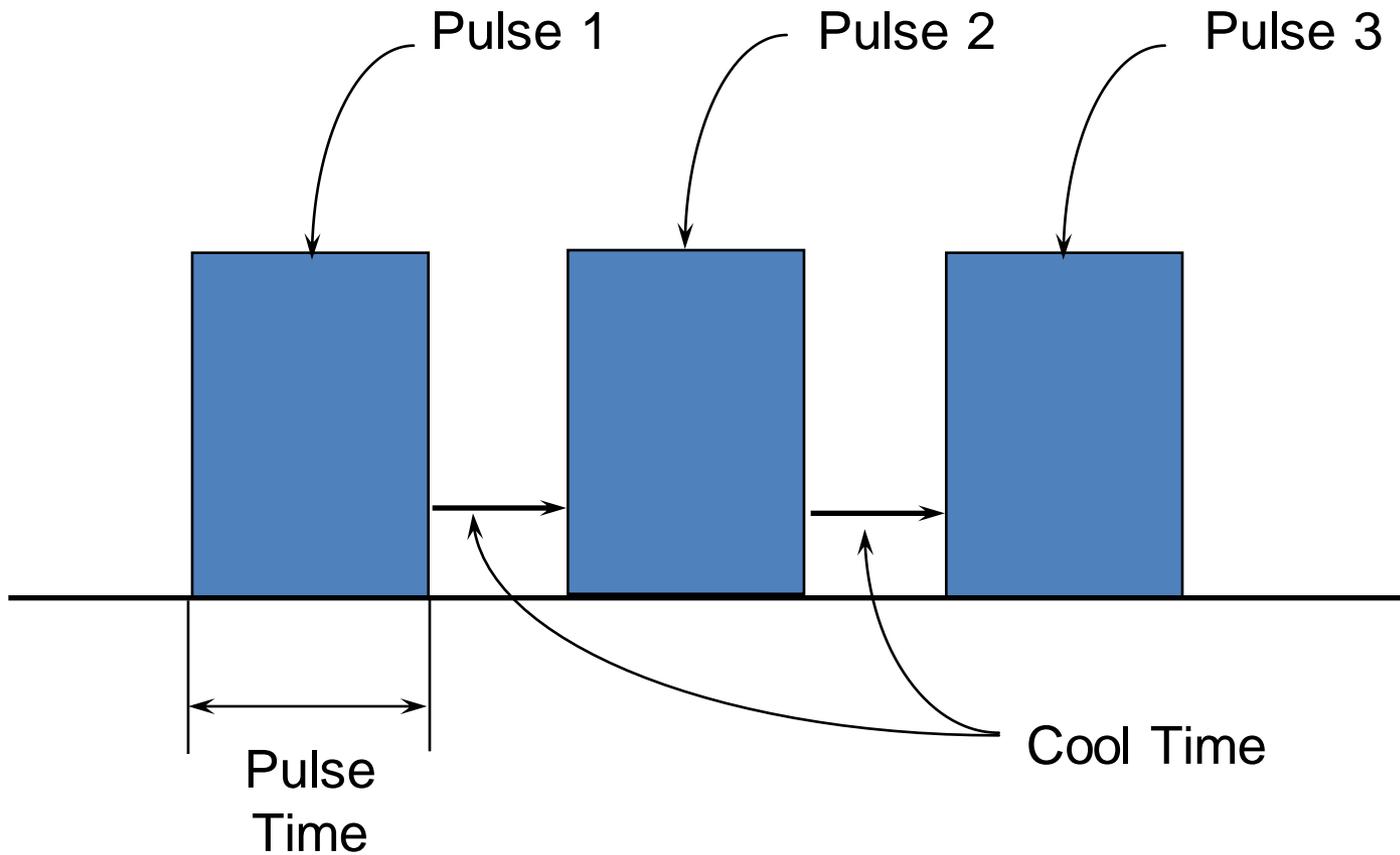
R_{sc} = contact resistance at the faying surface

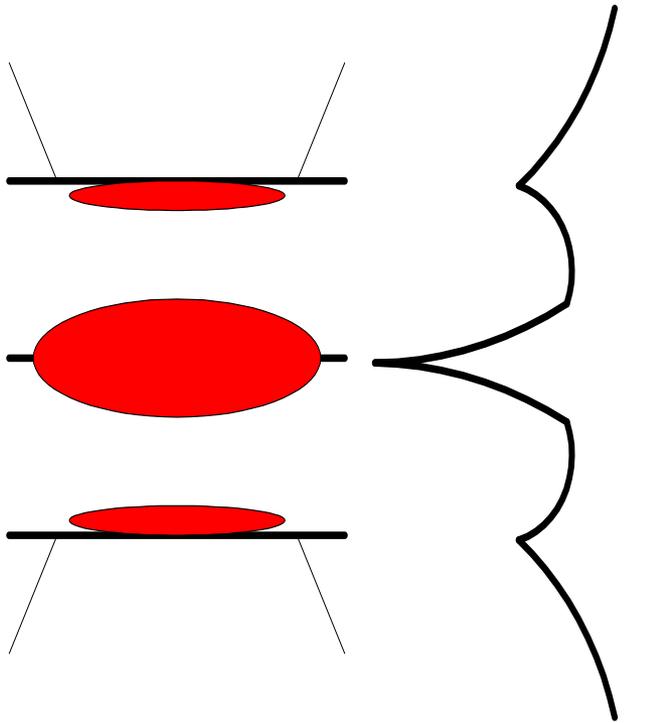
R_v = volume resistance of the sheets

Resistivity as A Function of Temperature

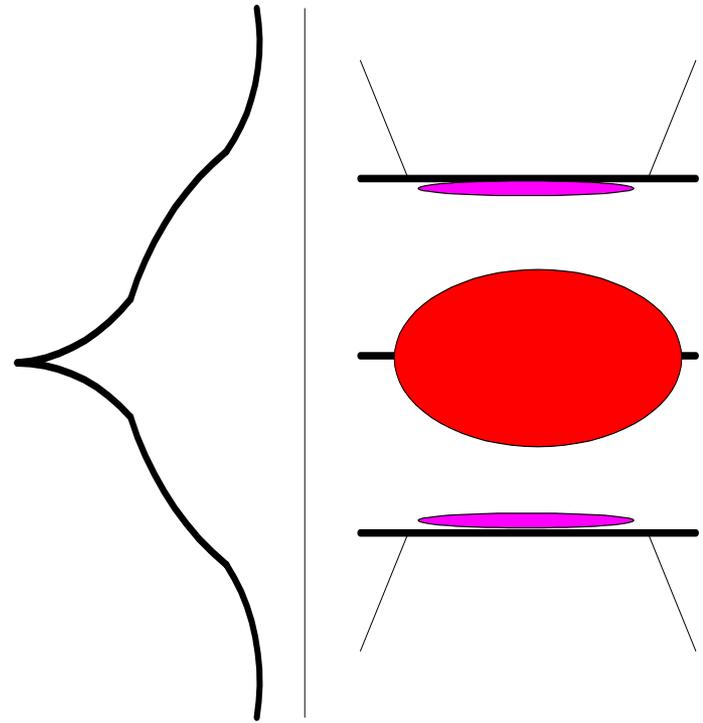


Pulsing





Without Pulsing



With Pulsing

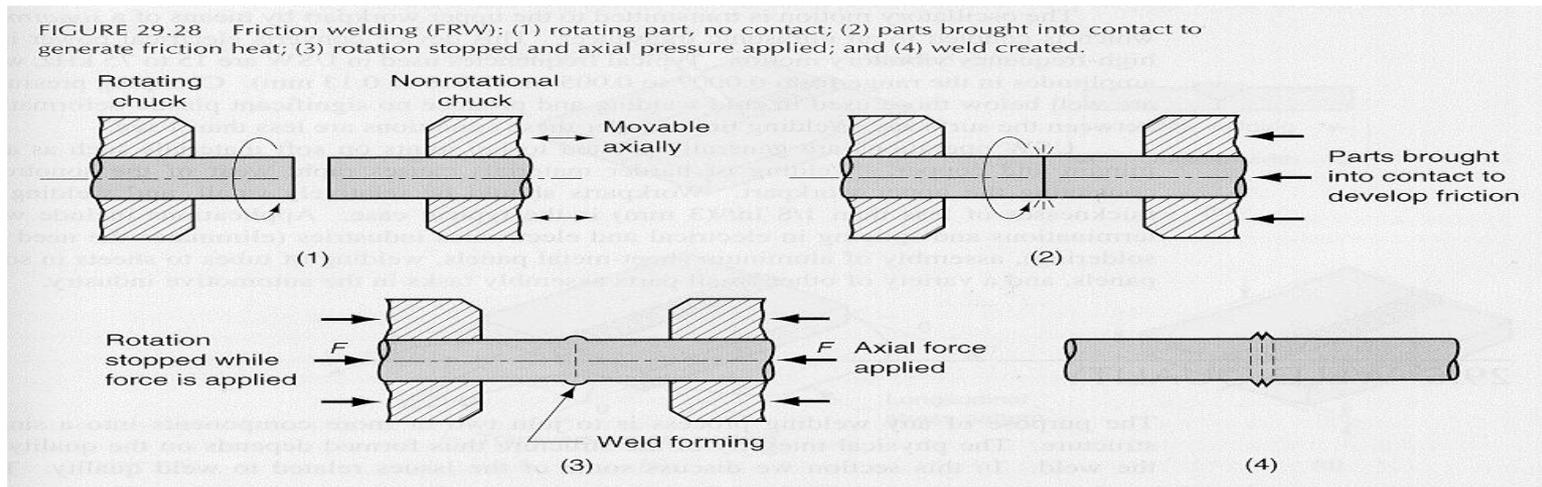
Laser Welding

Uses a laser beam to melt the metals; can be used for deep, narrow welds



Friction Welding

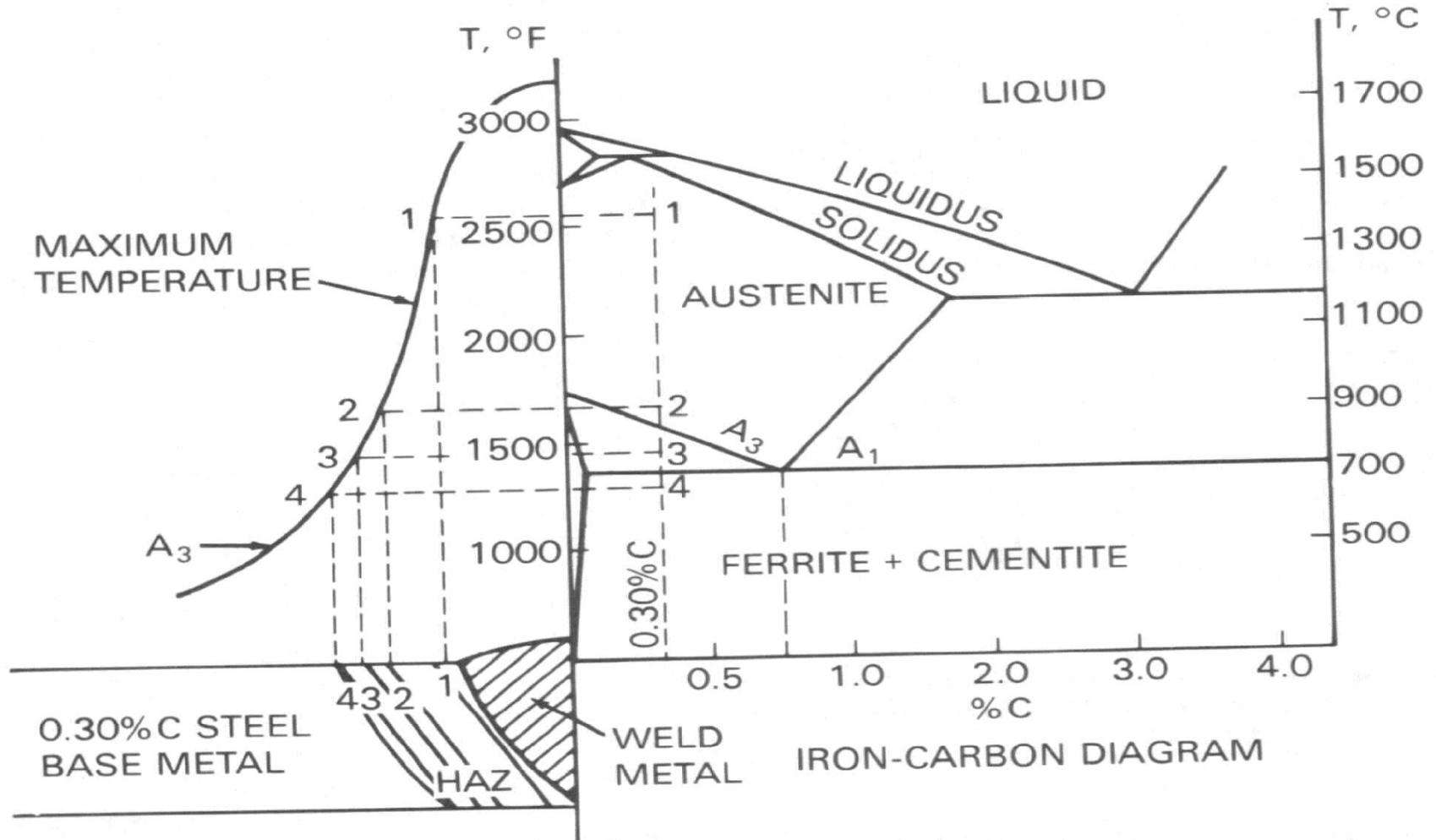
Uses pressure and frictional heat caused by mechanical rubbing, usually by rotation



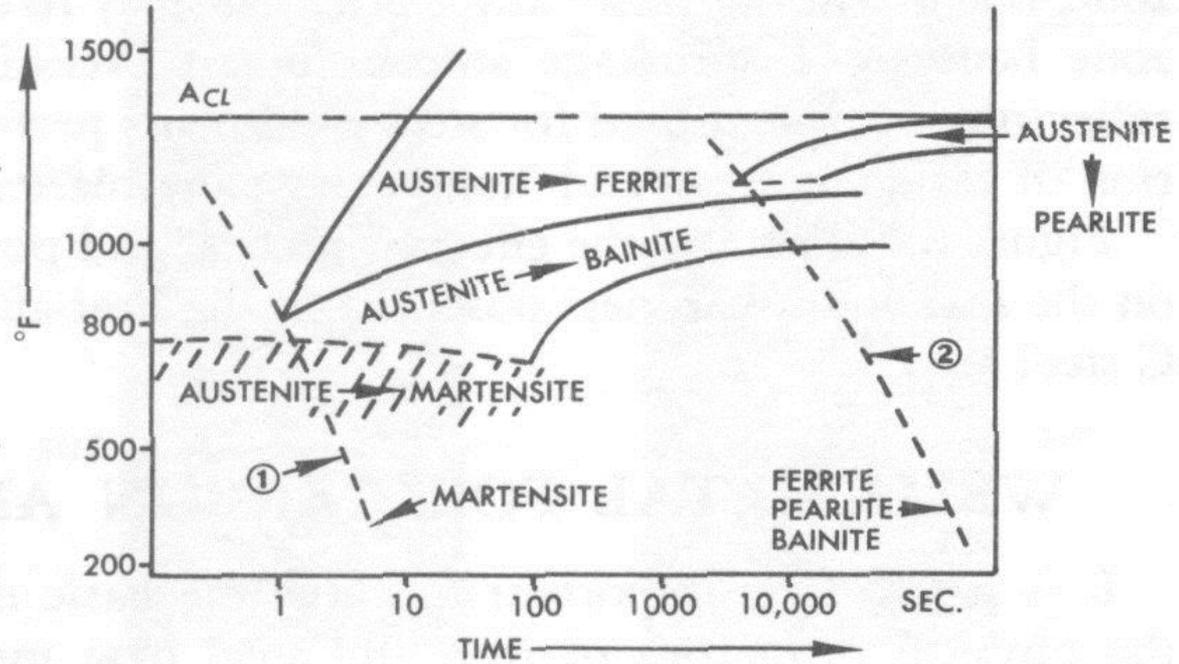
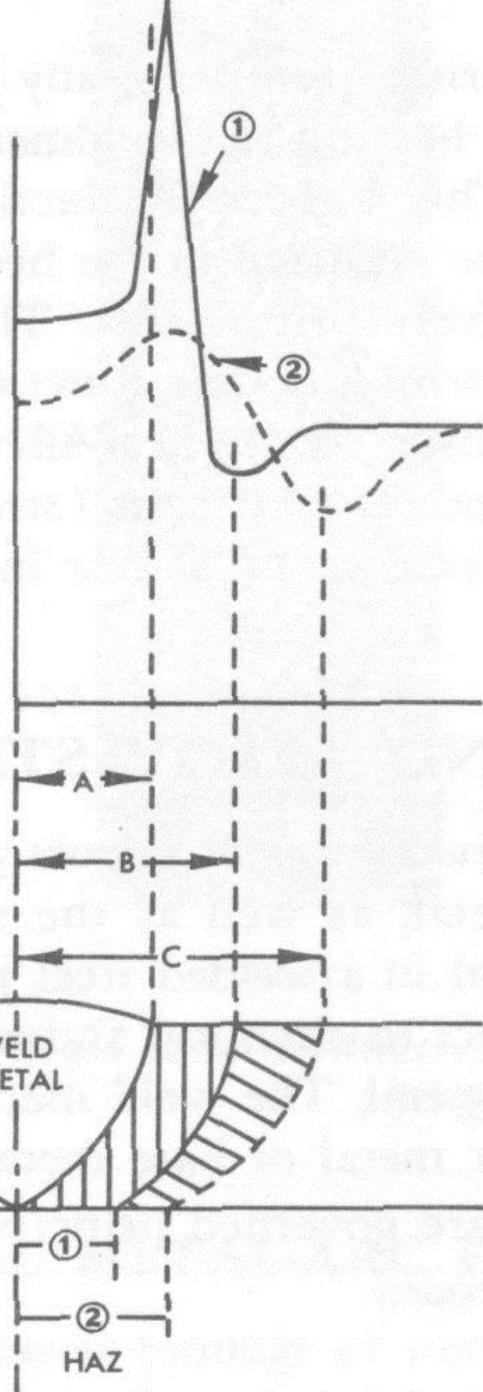
Friction Welding



Steel Alloys With Allotropic Transformation



HARDNESS



- ① ————— NO PREHEAT
- ② - - - - - PREHEAT

Fusion Weld Zone

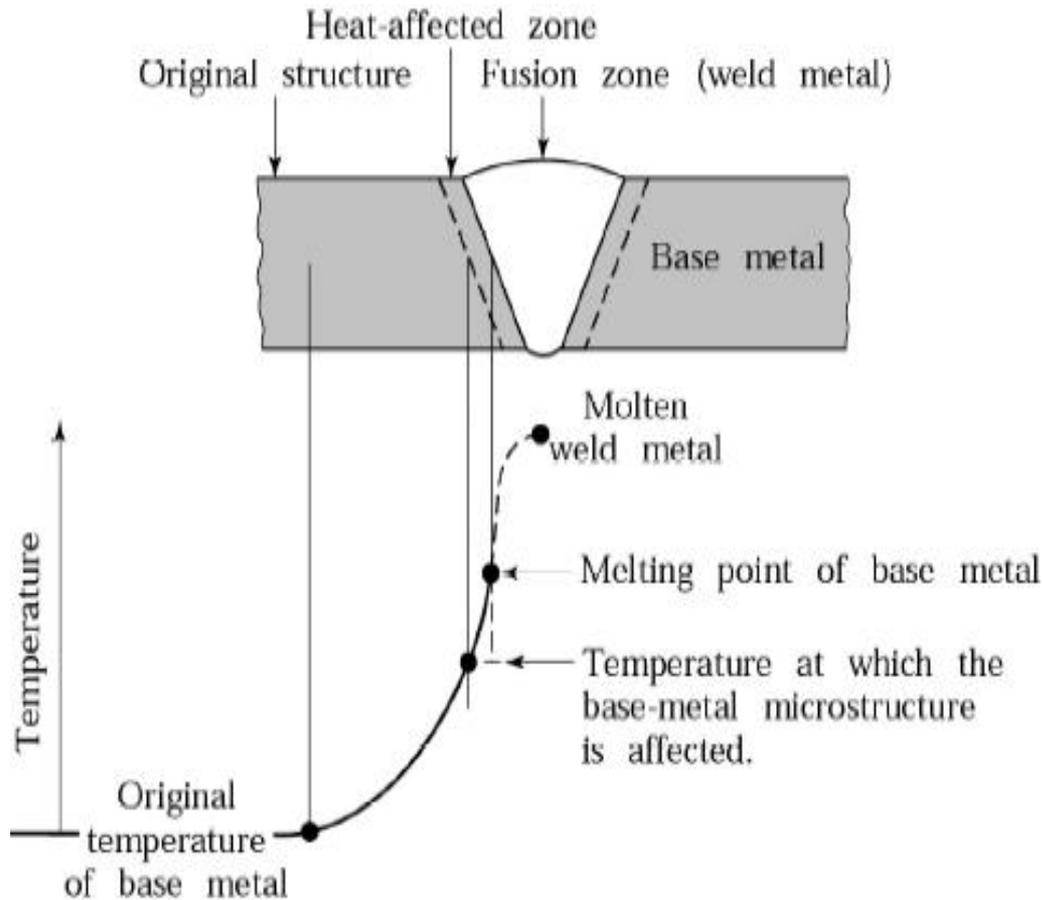


Fig : Characteristics of a typical fusion weld zone in oxyfuel gas and arc welding.

Heat Affected Zone

Weld is basically a rapidly formed casting surrounded by a heat affected zone (HAZ)

A temperature gradient is set up in the material during welding
Temperature gradient ranges from the melting point at the point of fusion to ambient temperature at some distance from the weld

High temperature followed by fairly rapid cooling causes changes in the metallurgy of the metal and the joint quality can be affected by:

- a.) Structure & quality of the weld metal
- b.) Structure & properties of the part of the metal in the heat affected zone

The slower the rate of cooling, the closer the structure to equilibrium
Cooling occurs mainly by conduction in the parent metal, depending upon the thermal mass (thickness & size of parent material)
The greater the thermal mass, the faster the rate of cooling

Welded Joint

Fusion zone

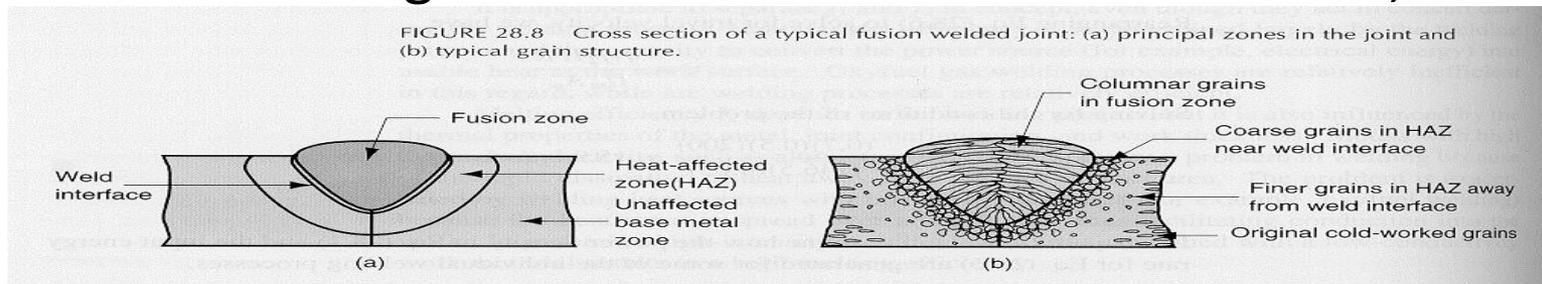
The area of base metal and filler metal that has been completely melted

Weld interface

A thin area of base metal that was melted or partially melted but did not mix with the filler metal

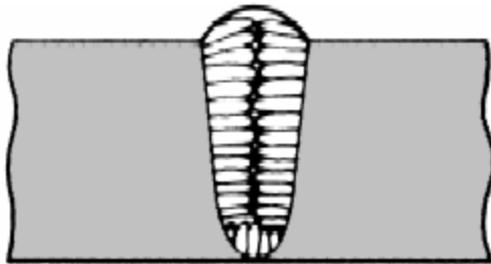
Heat affected zone

The surrounding area of base metal that did not melt, but was



Grain Structure

(a)

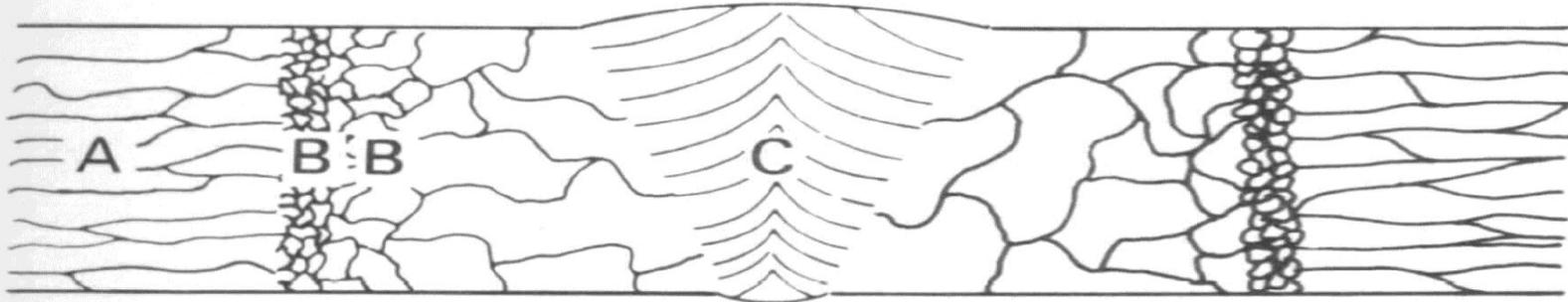


(b)

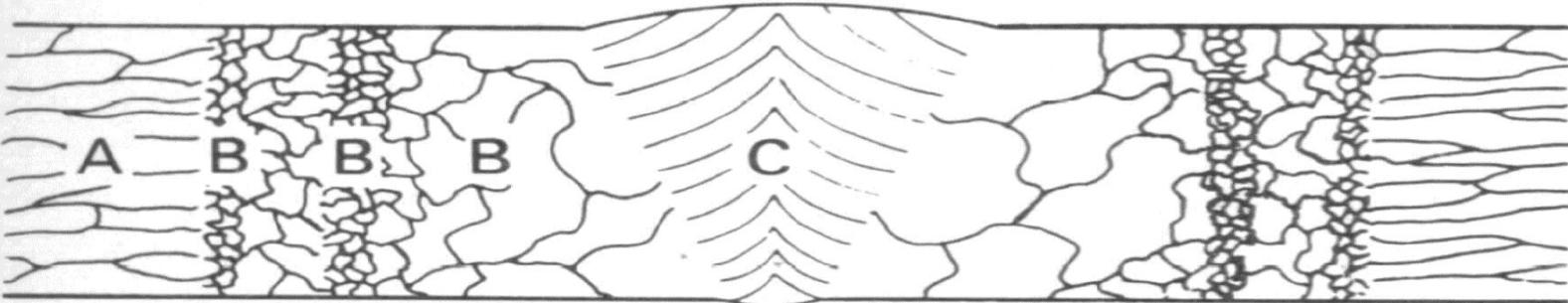


Fig : Grain structure in (a) a deep weld (b) a shallow weld. Note that the grains in the solidified weld metal are perpendicular to the surface of the base metal. In a good weld, the solidification line at the center in the deep weld shown in (a) has grain migration, which develops uniform strength in the weld bead.

Look At Two Types of Alloy Systems



(A) No phase change when heated



(B) Allotropic transformation when heated

Questions

Friction welding..[..\Lec notes\American Friction Welding - What is Friction Welding - YouTube.mp4](#)

Dissimilar Metals

Power source

Welding Dissimilar Metals

- A successful weld between dissimilar metals is one that is as strong as the weaker of the two metals being joined
- solubility
- coefficient of thermal expansion of both materials.
- The difference in melting temperatures of the two metals that are to be joined must also be considered.
- The difference of the metals on the electrochemical scale is an indication of their susceptibility to corrosion at the intermetallic zone. If they are far apart on the scale, corrosion can be a serious problem.

- use a piece of nickel, or
- deposit several layers of nickel alloy on the steel, i.e., buttering or surfacing the steel with a nickel weld metal deposit.
- Another method of joining dissimilar metals is the use of a composite insert between the two metals at the weld joint.

Cold welding used to join aluminum to copper.

Ultrasonic welding , **Percussion welding** , laser beam welding process very thin materials or small parts.

Friction welding steel to copper base alloys, steel to aluminum, stainless to nickel base alloys, etc.

The high-frequency resistance process joining copper to steel

Diffusion welding for aerospace applications of dissimilar metals weld

The electron beam welding process has had wide use.

The **flash butt welding process** will make high-quality welds between copper and aluminum.

Arc Welding. the shielded metal arc welding process, the gas tungsten arc welding process, and the gas metal arc welding process.

Weld design & Process Selection

Considerations:

- Configuration of the components or structure to be welded, and their thickness and size
- Methods used to manufacture the components
- Service requirements, Type of loading and stresses generated
- Location, accessibility and ease of welding
- Effects of distortion and discoloration
- Appearance
- Costs involved

Type of Weld Joints:

A – Butt Joints:

Requires full penetration “groove welding”, but it eliminates eccentricity and more pleasant to view. Suitable for shop welding.

B – Lap Joints:

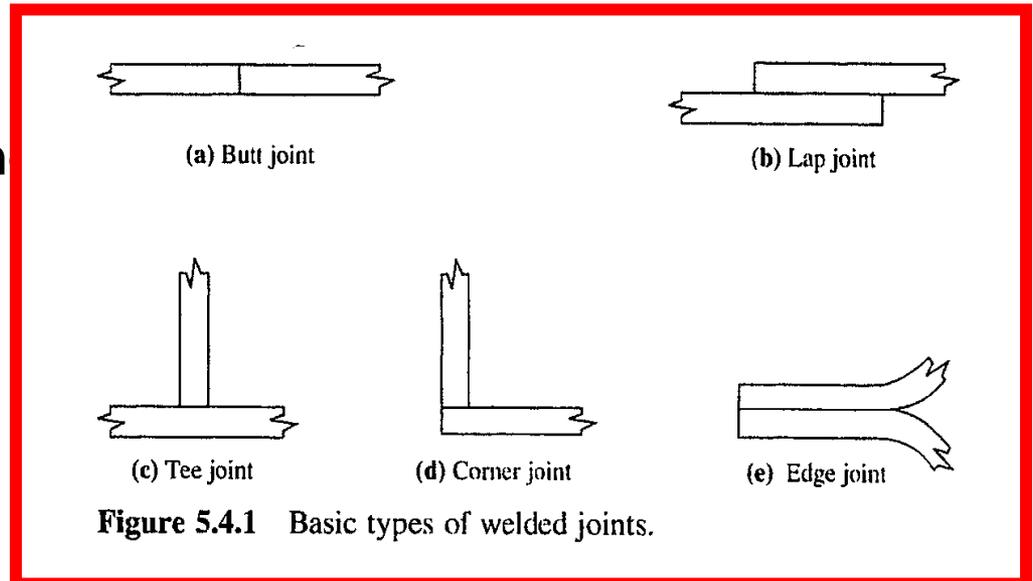
Is the most common, due to ease of fitting, requires “fillet weld”, and can be double-sided.

C – Tee Joints:

Useful for fabricating
“Built-up” sections

D – Corner Joints:-

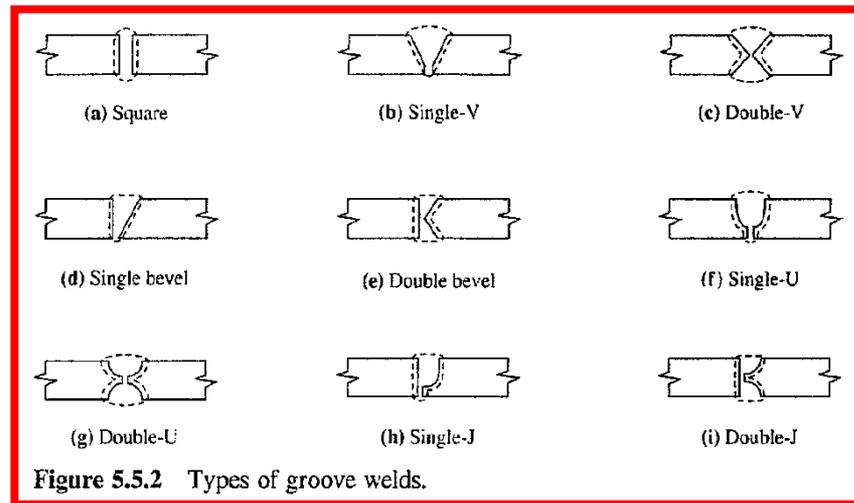
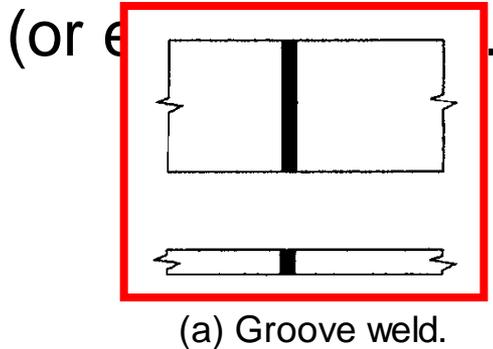
E – Edge joints:-



Type of Welds:

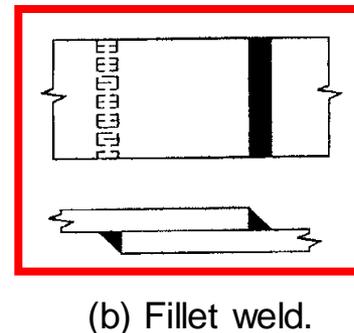
A) Groove Welds :

Is used to weld members aligned in the same plane. The weld should have the same strength of the base material



B) Fillet Welds :

More popular as they require no special alignment of pieces, nor edge preparation.

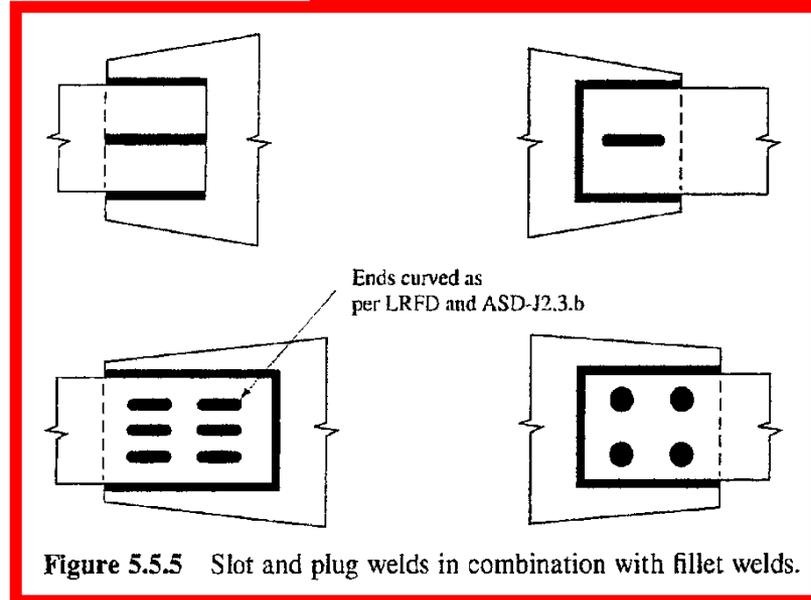
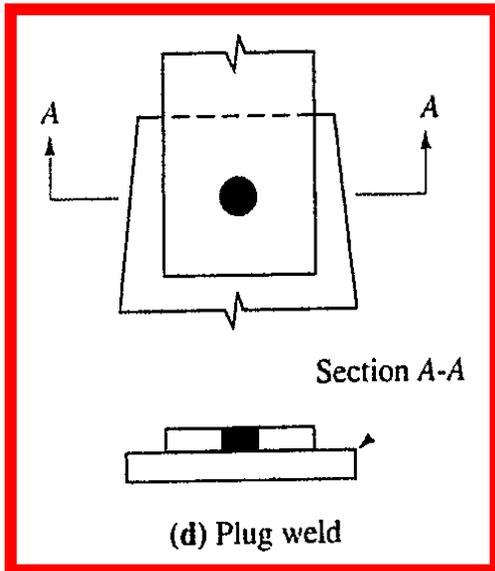
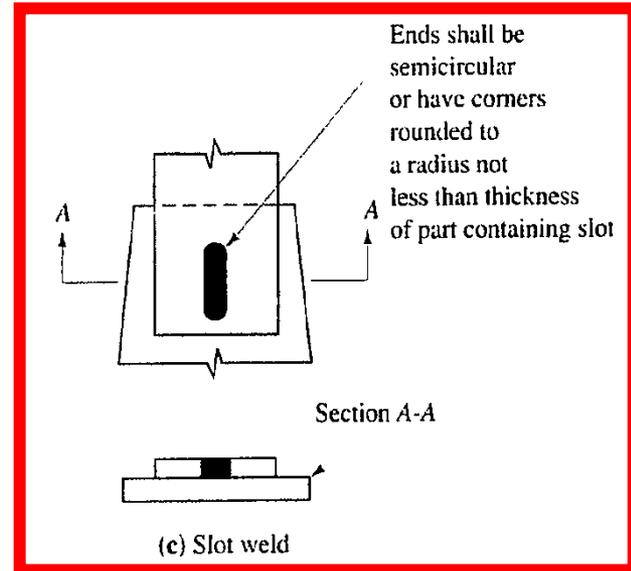


C) Slot Weld :

They can be used in addition to fillet welds when more areas of weld are required.

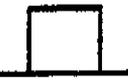
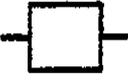
D) Plug Weld :

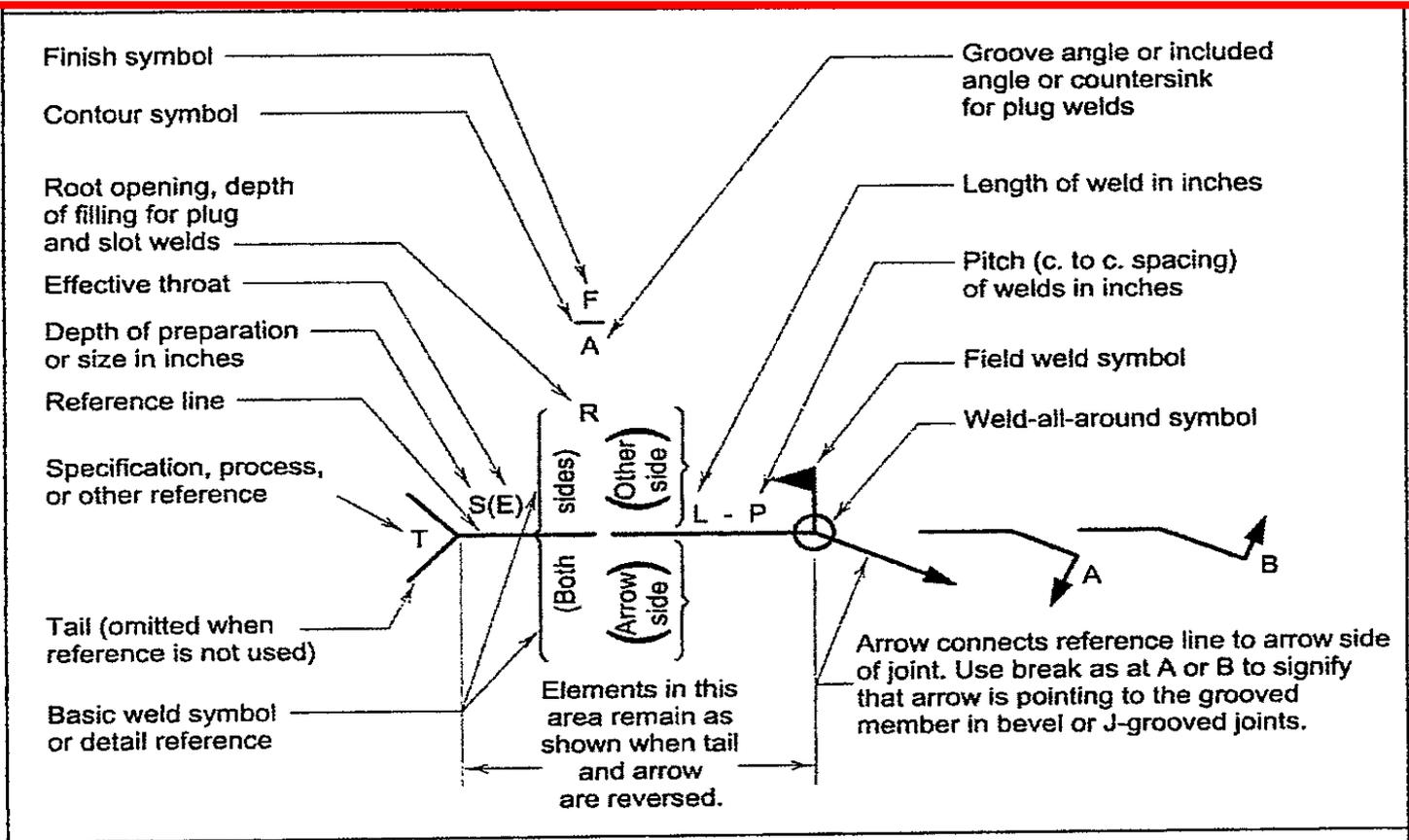
Same as above



Welding Symbols :-

Table 8-2 (continued)
Prequalified Welded Joints

Basic Weld Symbols									
Back	Fillet	Plug or Slot	Groove or Butt						
			Square	V	Bevel	U	J	Flare V	Flare Bevel
									
Supplementary Weld Symbols									
Backing	Spacer	Weld All Around	Field Weld	Contour		For other basic and supplementary weld symbols, see AWS A2.4			
				Flush	Convex				
									
Standard Location of Elements of a Welding Symbol									



Note:

Size, weld symbol, length of weld, and spacing must read in that order, from left to right, along the reference line. Neither orientation of reference nor location of the arrow alters this rule.

The perpendicular leg of Δ , V , P , U , weld symbols must be at left.

Arrow and other side welds are of the same size unless otherwise shown. Dimensions of fillet welds must be shown on both the arrow side and the other side symbol.

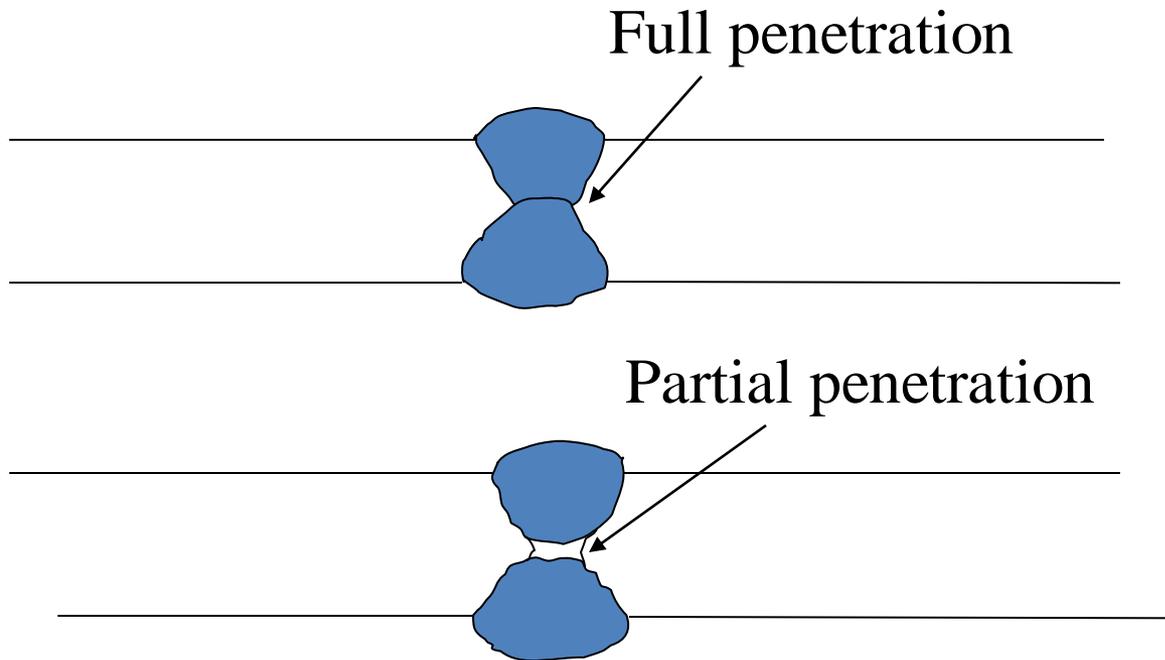
The point of the field weld symbol must point toward the tail.

Symbols apply between abrupt changes in direction of welding unless governed by the "all around" symbol or otherwise dimensioned.

These symbols do not explicitly provide for the case that frequently occurs in structural work, where duplicate material (such as stiffeners) occurs on the far side of a web or gusset plate. The fabricating industry has adopted this convention: that when the billing of the detail material discloses the existence of a member on the far side as well as on the near side, the welding shown for the near side shall be duplicated on the far side.

Typical Welds

Butt Weld



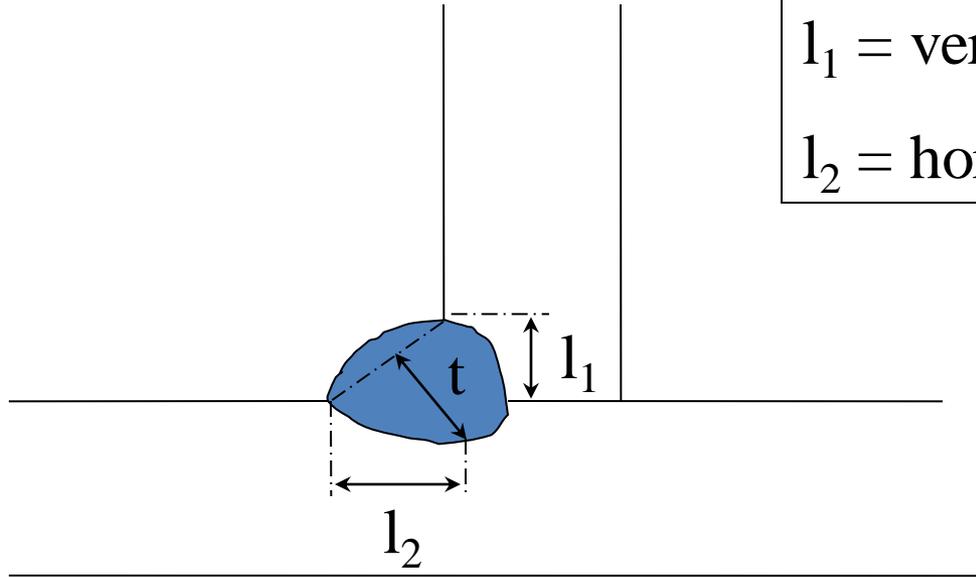
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Fillet Weld

t = throat

l_1 = vertical leg

l_2 = horizontal leg



Welding Design Guidelines

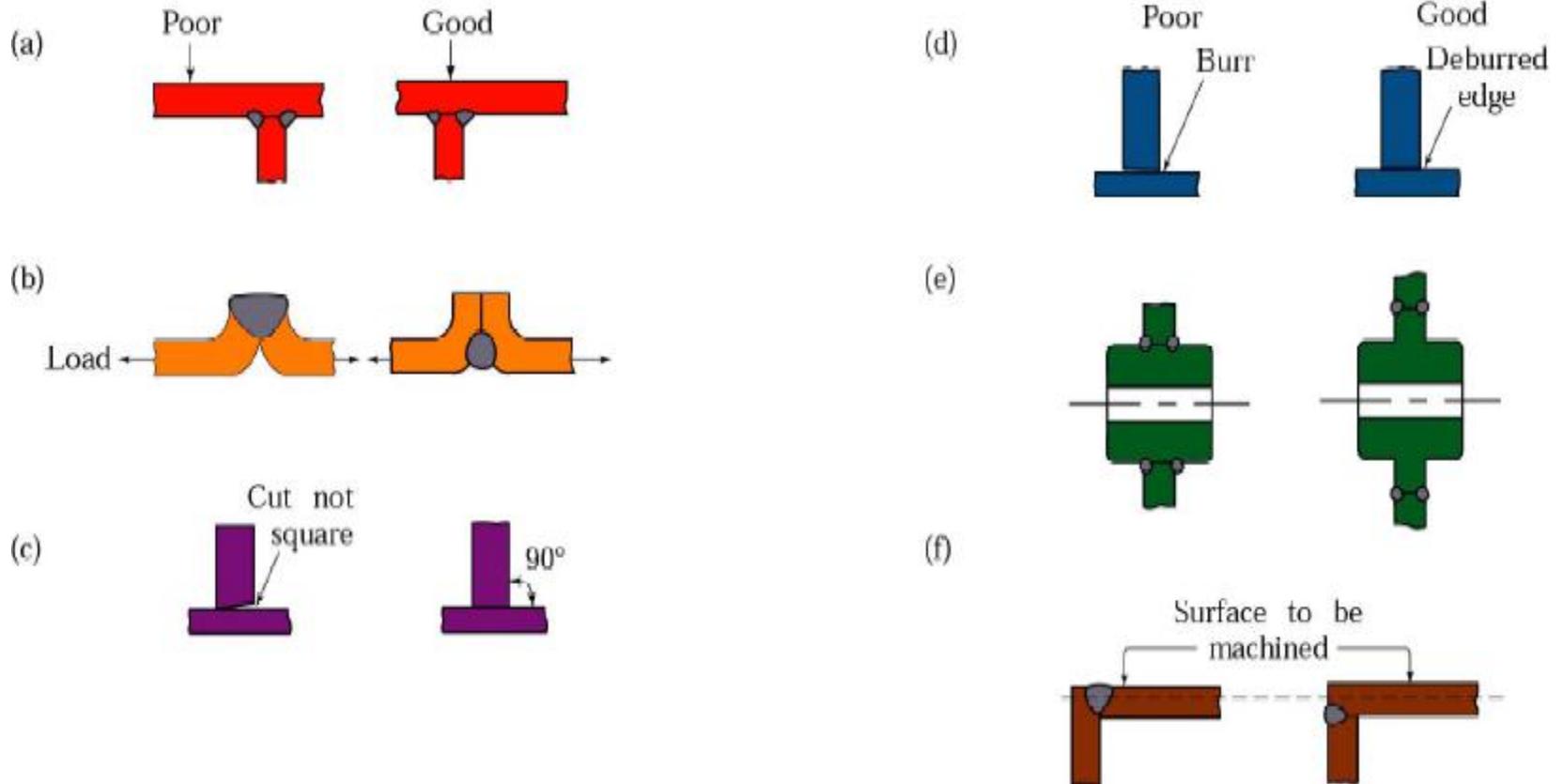
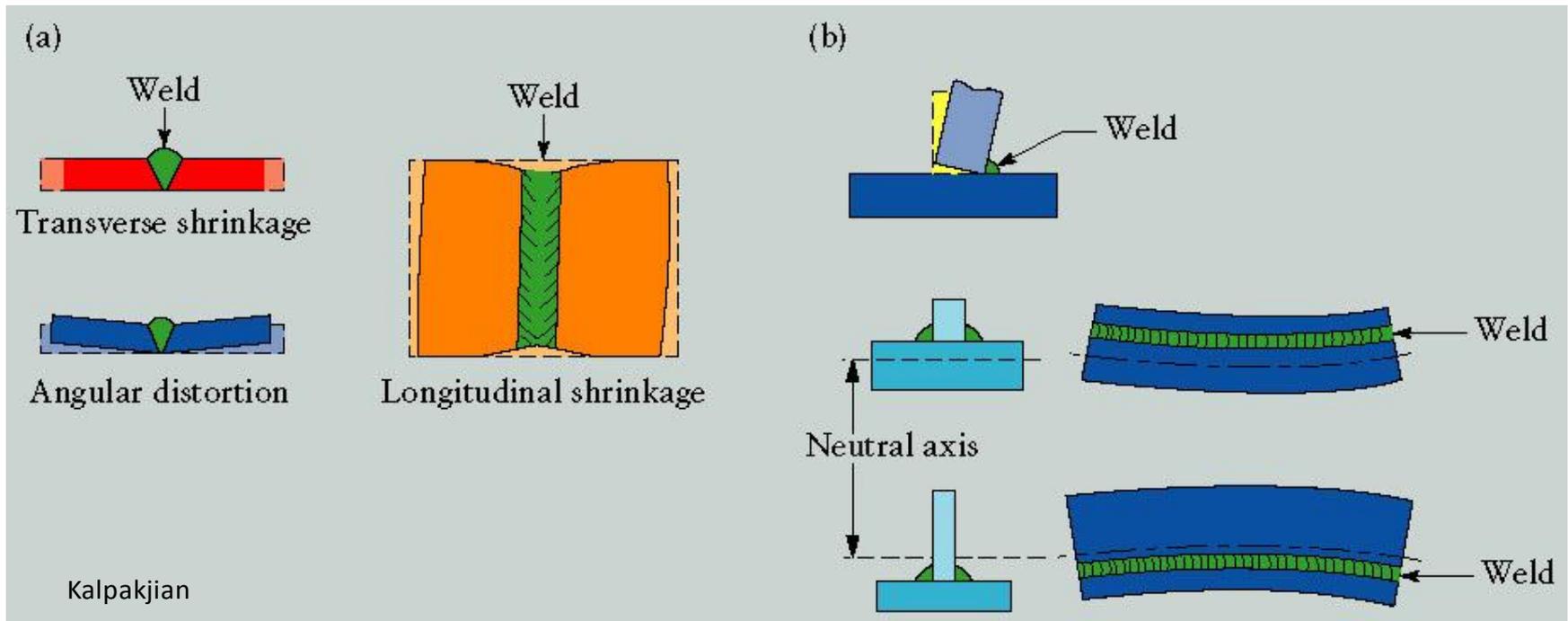


Fig : Design guidelines for welding

	Defects
	<ul style="list-style-type: none"> • Residual stresses • Distortions • Undercut • Incomplete penetration • Porosity • Slag inclusion
Weld metal solidification cracking	Weld metal solidification cracking – hot cracking – longitudinal in a fillet weld – blue appearance (oxidised surface) – due to material composition and/or weld restraint & bead shape
Heat Affected Zone (HAZ) Cracking	<p>Heat Affected Zone (HAZ) Cracking – heat affected zone due to weld – adjacent to bead – affected by heat input & cooling cycle – depends on composition but cooling rate can affect microstructure – hardening – more brittle – carbide formation</p> <p>Susceptibility also affected by hydrogen in the weld metal – introduced from the weld rod which is consumable</p>

Distortion from Welding Processes

- Non-uniform shrinkage of weld bead
- Difficult to maintain alignments
- Solution: Rigid fixtures, pre-compensate for warping, loose tolerances



Weld bead profile: Convex or Concave?

- Solidification of molten bead leads to shrinkage
- Shrinkage of a *concave* bead leads to tension on surface → tends to crack
- Shrinkage of a *convex* bead leads to compression on surface → does not crack
- Generally, slightly convex beads are preferred.

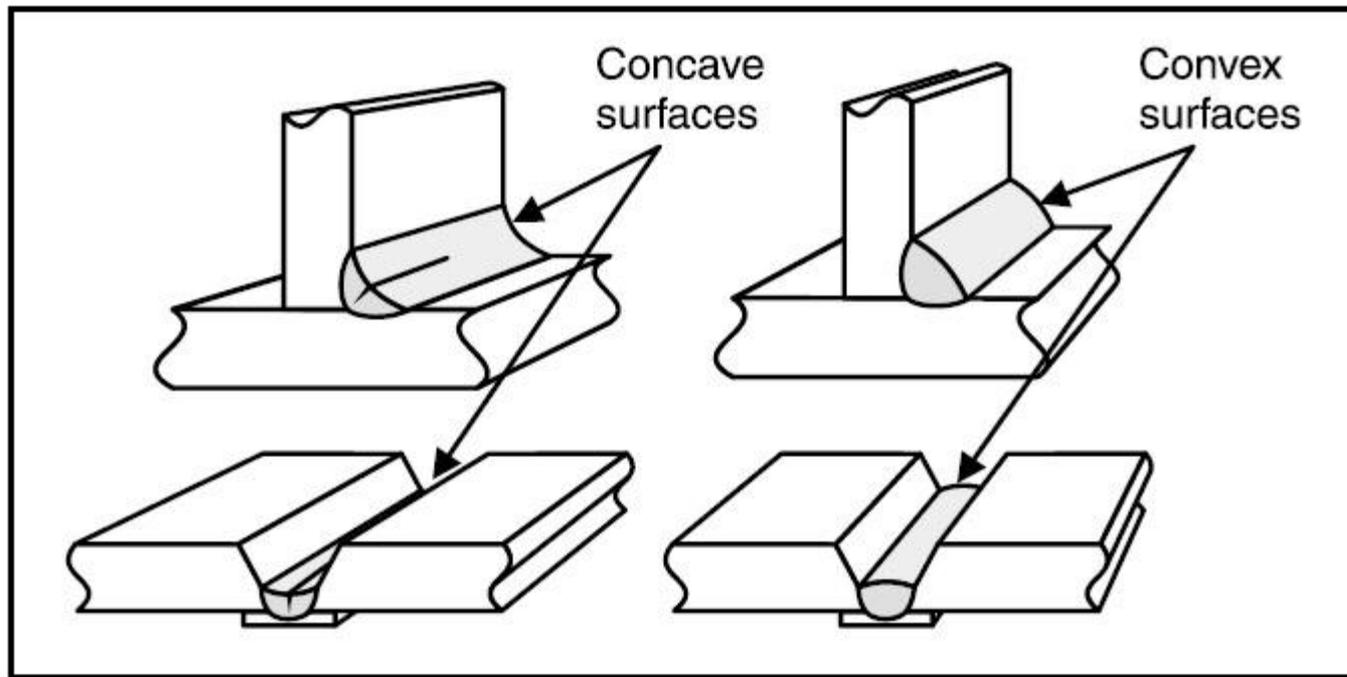
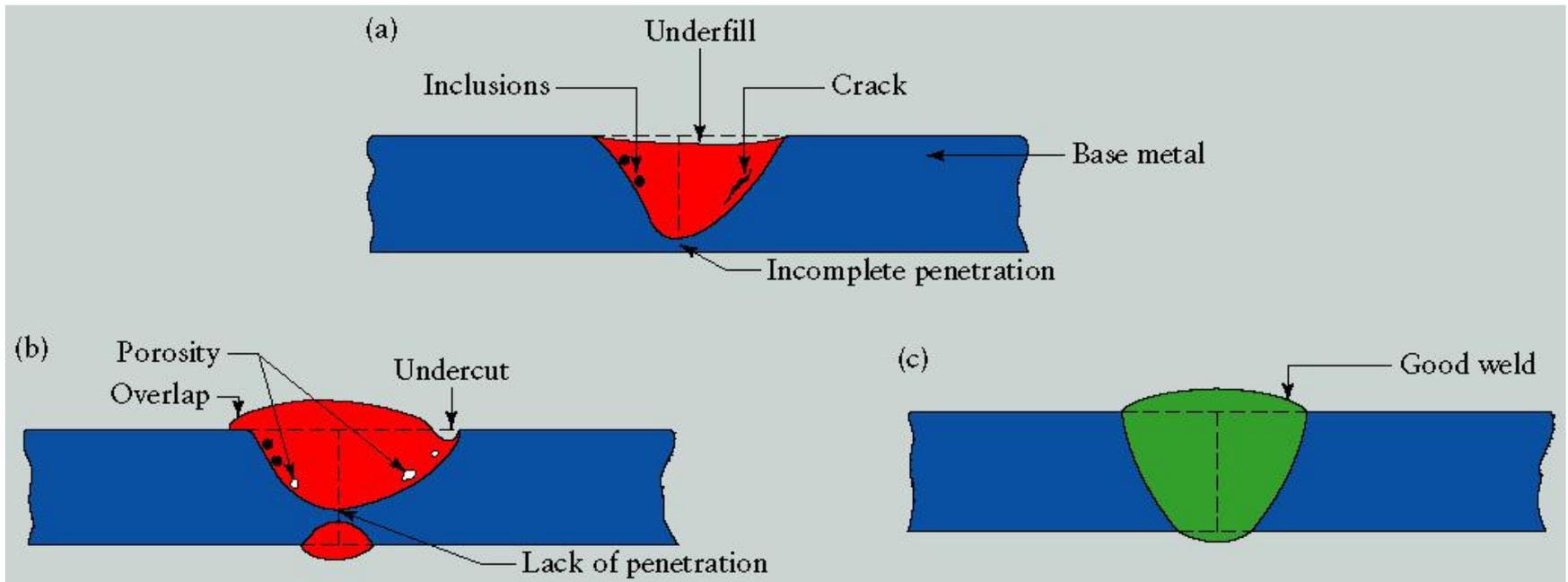


Figure 4 Surface profile induced cracking

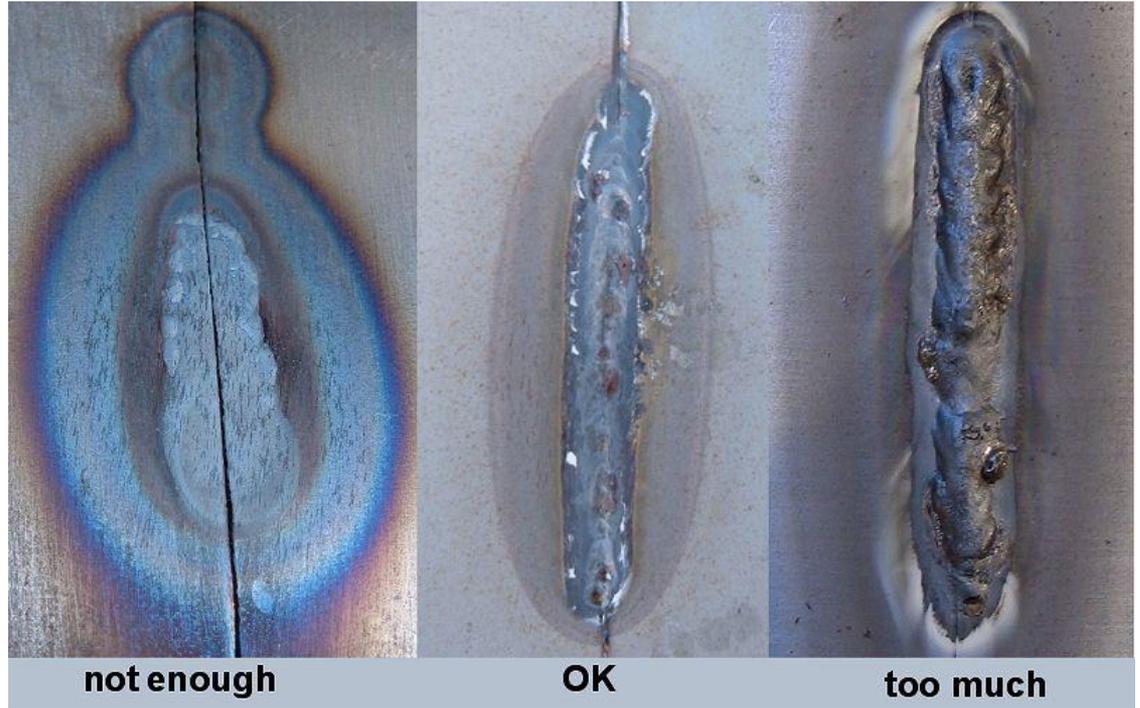
Welding Defects



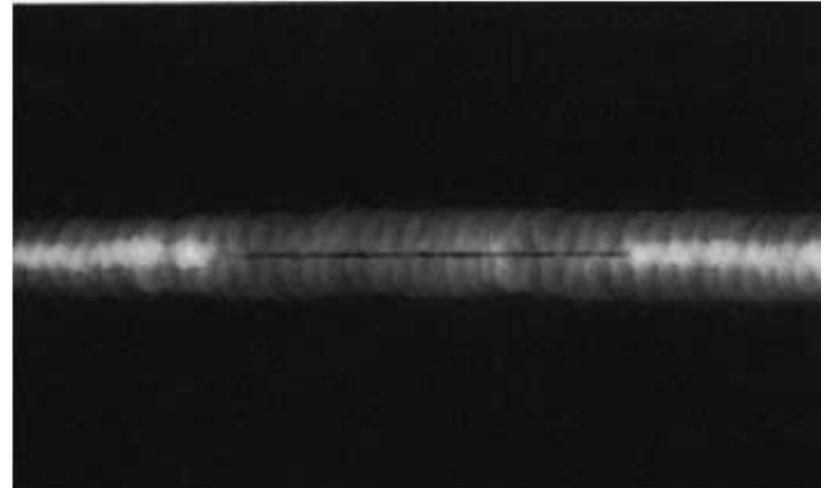
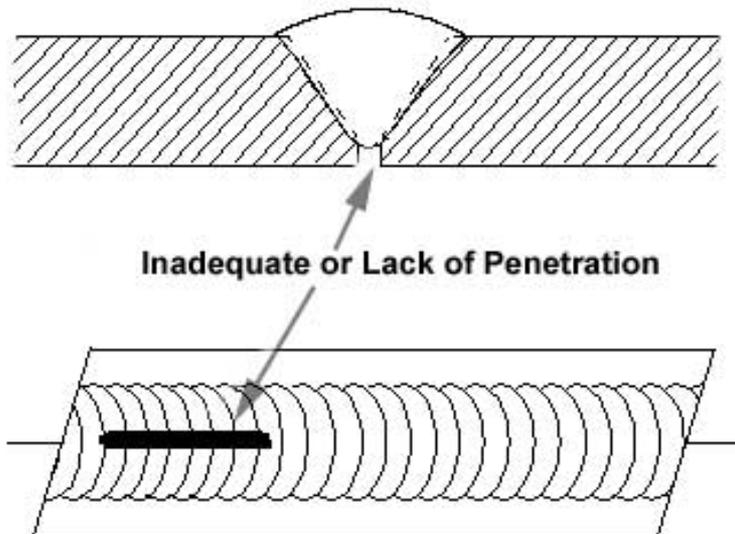
Kalpakjian

Welding Defects

Incomplete Penetration
(not enough heat input)



www.mig-welding.co.uk



www.ndt-ed.org/EducationResources

Weld Quality

- Welding discontinuities can be caused by inadequate or careless application
- The major discontinuities that affect weld quality are
 - Porosity
 - Slag Inclusions
 - Incomplete fusion and penetration
 - Weld profile
 - Cracks
 - Lamellar tears
 - Surface damage
 - Residual stresses

Porosity

- Caused by gases released during melting of the weld area but trapped during solidification, chemical reactions, Contaminants
- They are in form of spheres or elongated pockets
- Porosity can be reduced by
 - Proper selection of electrodes
 - Improved welding techniques
 - Proper cleaning and prevention of contaminants
 - Reduced welding speeds

Slag Inclusions

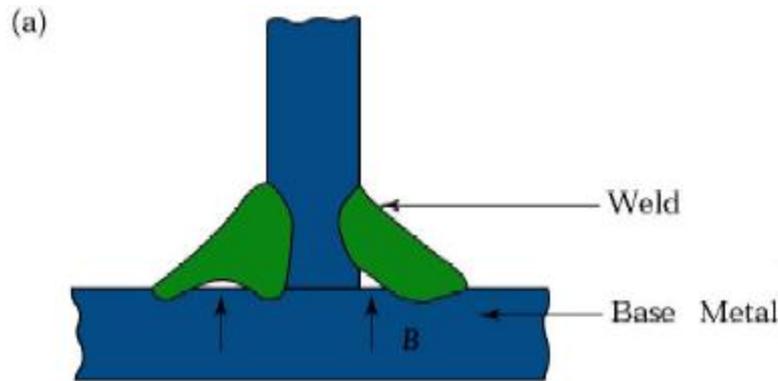
- Compounds such as oxides ,fluxes, and electrode-coating materials that are trapped in the weld Zone
- Prevention can be done by following practices :
 - Cleaning the weld bed surface before the next layer is deposited
 - Providing enough shielding gas
 - Redesigning the joint

Incomplete Fusion and Penetration

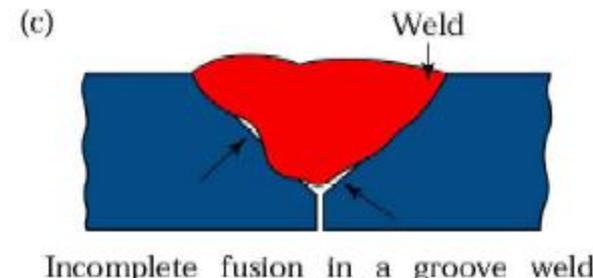
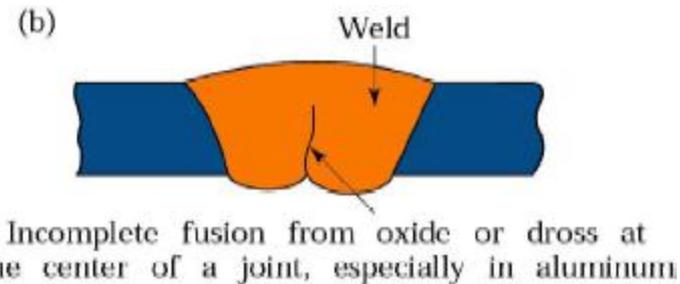
- Produces lack of weld beads
- Practices for better weld :
 - Raising the temperature of the base metal
 - Cleaning the weld area, prior to the welding
 - Changing the joint design and type of electrode
 - Providing enough shielding gas

Penetration:

- Incomplete penetration occurs when the depth of the welded joint is insufficient
- Penetration can be improved by the following practices :
 - Increasing the heat Input
 - Reducing the travel speed during the welding
 - Changing the joint design
 - Ensuring the surfaces to be joined fit properly



Incomplete fusion in fillet welds. B is often termed 'bridging'



Weld Profile:

- Under filling results when the joint is not filled with the proper amount of weld metal.
- Undercutting results from the melting away of the base metal and consequent generation of a groove in the shape of a sharp recess or notch.
- Overlap is a surface discontinuity usually caused by poor welding practice and by the selection of improper material.

Discontinuities in Fusion Welds

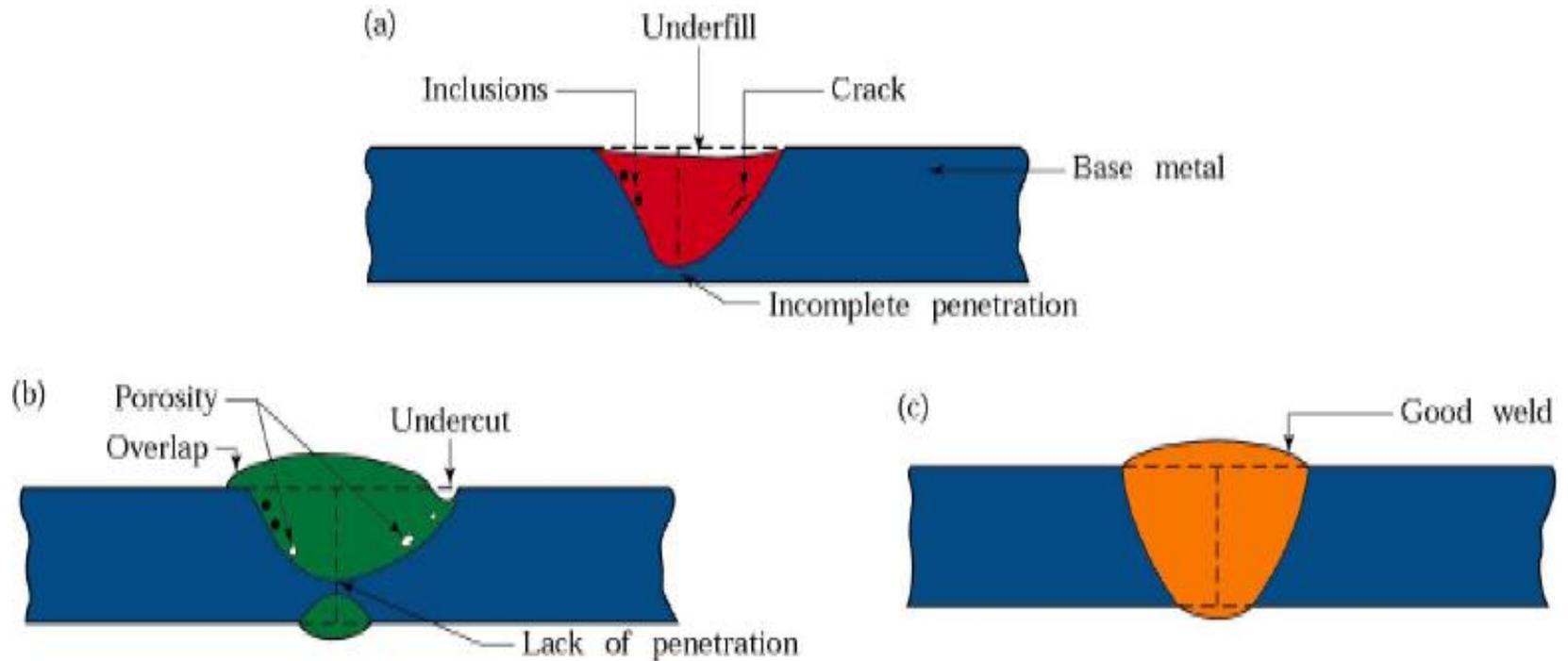


Fig : Schematic illustration of various discontinuities in fusion welds.

Cracks

- Cracks occur in various directions and various locations

Factors causing cracks:

- Temperature gradients that cause thermal stresses in the weld zone
- Variations in the composition of the weld zone.
- Embrittlement of grain boundaries
- Inability of the weld metal to contract during cooling

Cracks

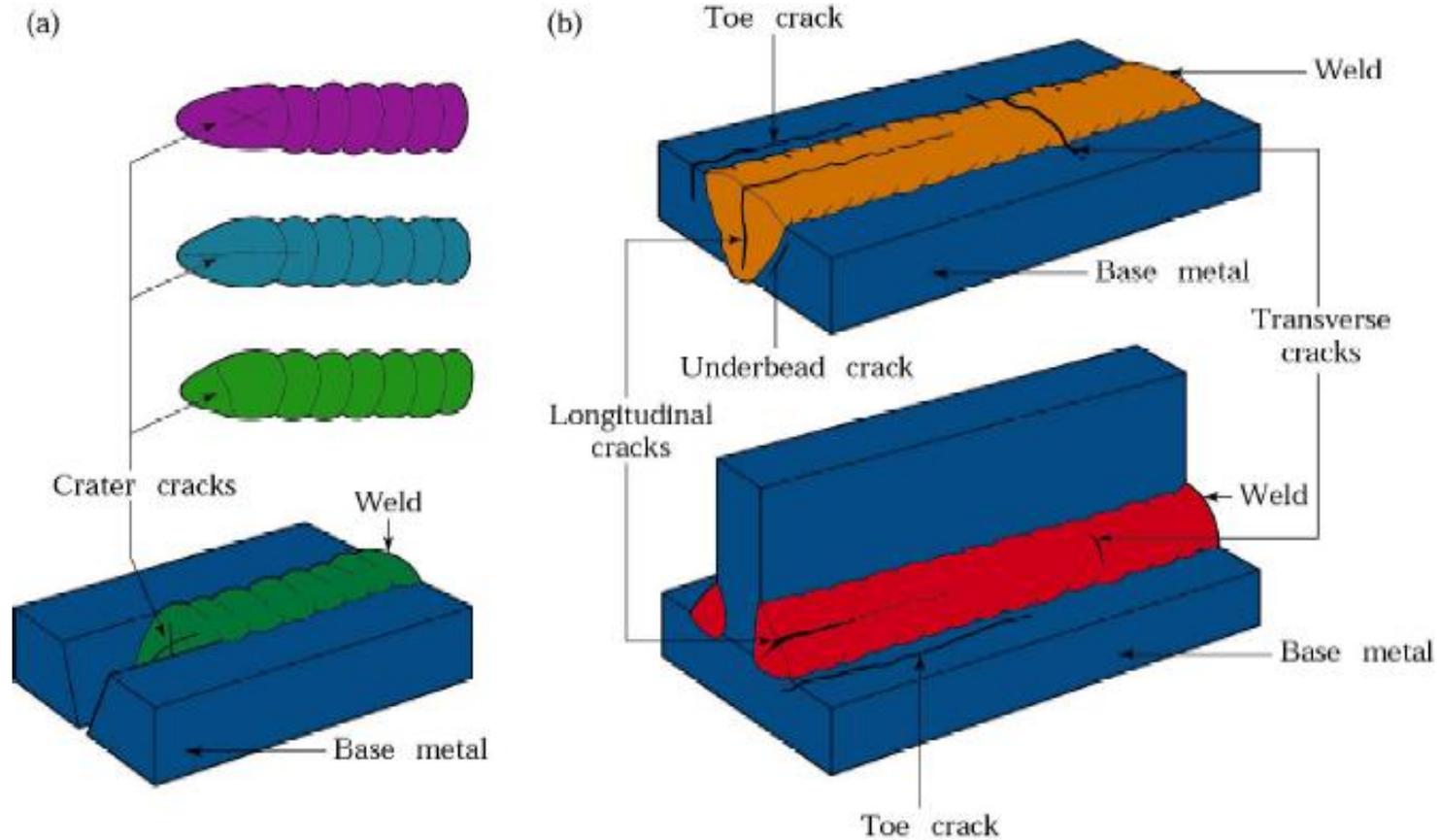


Fig : Types of cracks (in welded joints) caused by thermal stresses that develop during solidification and contraction of the weld bead and the surrounding structure. (a) Crater cracks (b) Various types of cracks in butt and T joints.

Cracks

- Cracks are classified as Hot or Cold.
- *Hot cracks* – Occur at elevated temperatures
- *Cold cracks* – Occur after solidification
- Basic crack prevention measures :
 - Change the joint design ,to minimize stresses from the shrinkage during cooling
 - Change the parameters, procedures, the sequence of welding process
 - Preheat the components to be welded
 - Avoid rapid cooling of the welded components

Cracks in Weld Beads

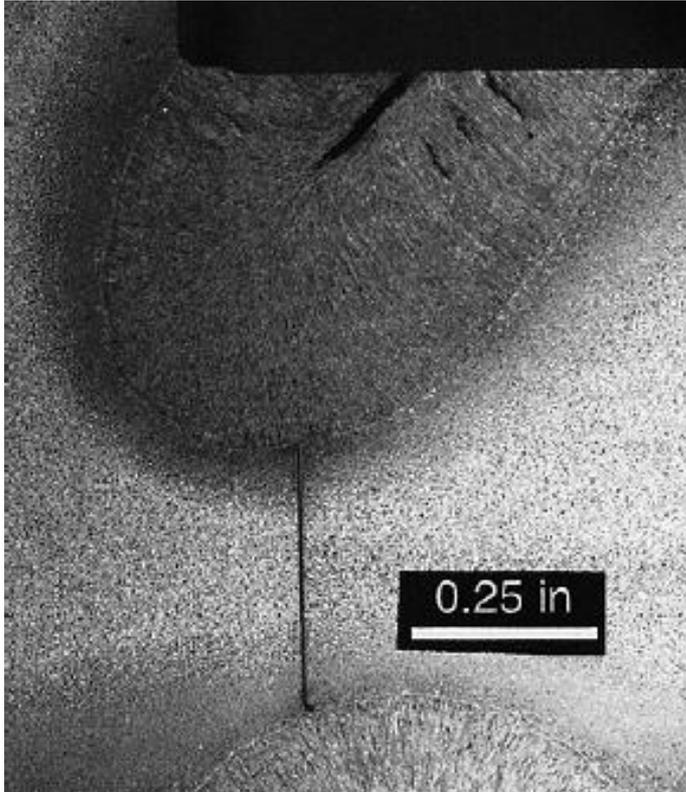
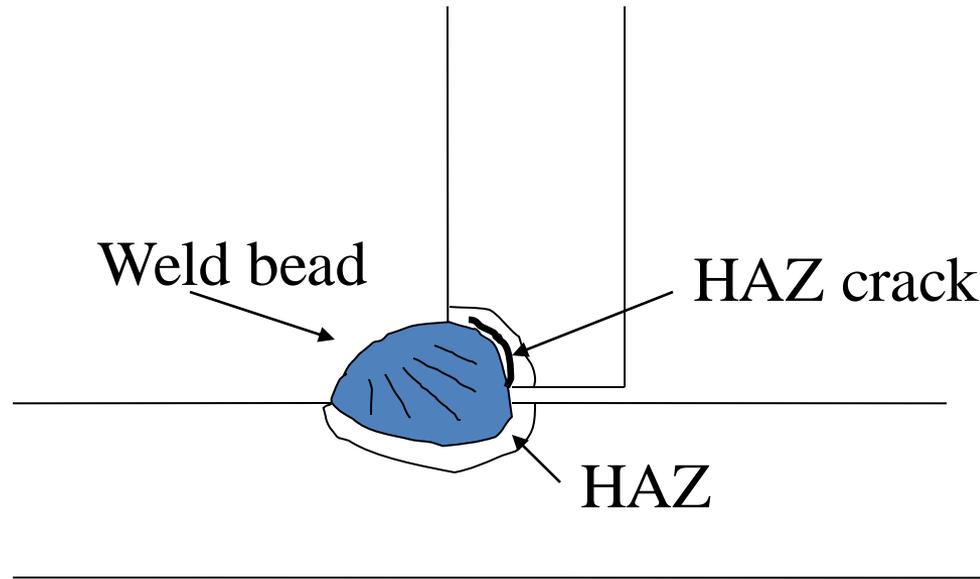


Fig : Crack in a weld bead, due to the fact that the two components were not allowed to contract after the weld was completed.

HAZ Cracking



Hydrogen Cracking

Causes

Hydrogen cracking, also called cold cracking, requires all three of these factors

- Hydrogen
- Stress
- Susceptible microstructure (high hardness)

Occurs below 300°C

Prevention

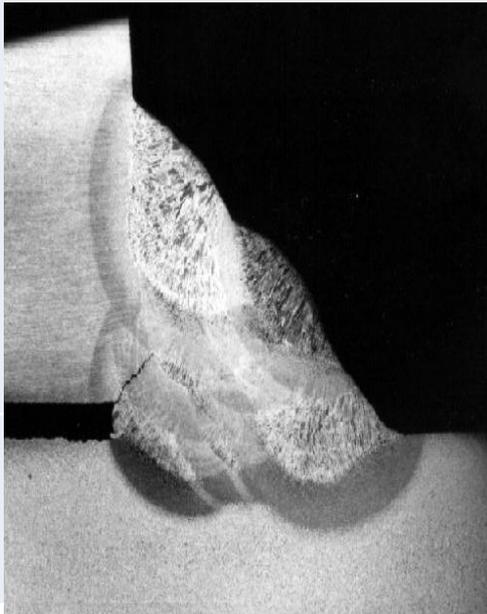
- Preheat slows down the cooling rate; this can help avoid martensite formation and supplies heat to diffuse hydrogen out of the material
- Low-hydrogen welding procedure

Postweld heat treatment (~ 1200°F) tempers any martensite that may have formed

- Increase in ductility and toughness
- Reduction in strength and hardness

Residual stress is decreased by postweld heat treatment

Rule of thumb: hold at temperature for 1 hour per inch of plate thickness; minimum hold of 30 minutes



Preheat and Postweld Heat Treatment

Preheat

Preheat reduces the temperature differential between the weld region and the base metal

- Reduces the cooling rate, which reduces the chance of forming martensite in steels
- Reduces distortion and shrinkage stress
- Reduces the danger of weld cracking
- Allows hydrogen to escape

Postweld Heat treatment

The fast cooling rates associated with welding often produce martensite

- During postweld heat treatment, martensite is tempered (transforms to ferrite and carbides)
- Reduces hardness
- Reduces strength
- Increases ductility
- Increases toughness
- Residual stress is also reduced by the postweld heat treatment

Carbon Equivalent

Metal arc welding of carbon & carbon manganese steels need to be checked by reference to BS EN 1011 – 2: 2001 – guidance on carbon equivalents – suggests suitable preheat levels to reduce cooling rate for various thicknesses & limits on hydrogen levels – sometimes need post heat (heat treatment)

Empirical Formula

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

C & Mn have a significant effect

Cr, Mo, Ni, Cu have little effect

Limited usually to CE value <0.5%

- Few problems are encountered at values <0.25%
- Higher values from 0.30% up to 0.70% may be tolerated if cooling is controlled & precautions taken to keep down the hydrogen content of the weld & the HAZ – hydrogen can be introduced by moisture in fluxes – tends to result in cold cracking unless dispersed by heat treatment

If, of the elements in this formula, only carbon and manganese are stated on the mill sheet for carbon and carbon manganese steels, then 0,03 should be added to the calculated value to allow for residual elements.

Where steels of different carbon equivalent or grade are being joined, the higher carbon equivalent value should be used

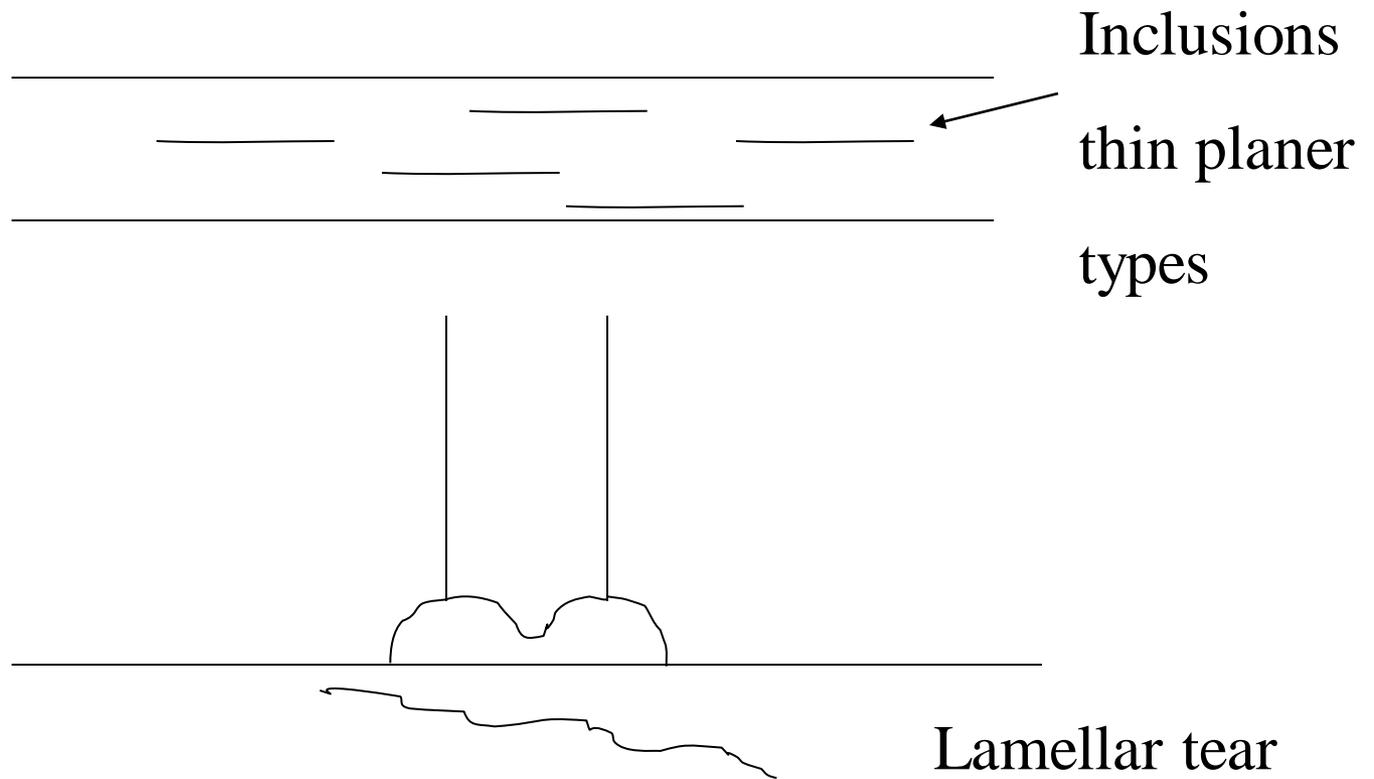
Carbon Equivalent and Pre /Postweld Heating recommendations

Carbon Equivalent CE	$CE = \%C + \%Mn/6 + \%(Cr+Mo+V)/5 + \%(Si+Ni+Cu)/15$ Carbon equivalent (CE) measures ability to form martensite, which is necessary cracking and hydrogen cracking
CE < 0.35	no preheat or postweld heat treatment
0.35 < CE < 0.55	preheat
CE > 0.55	preheat and postweld heat treatment
	Preheat temp. as CE and plate thickness increase

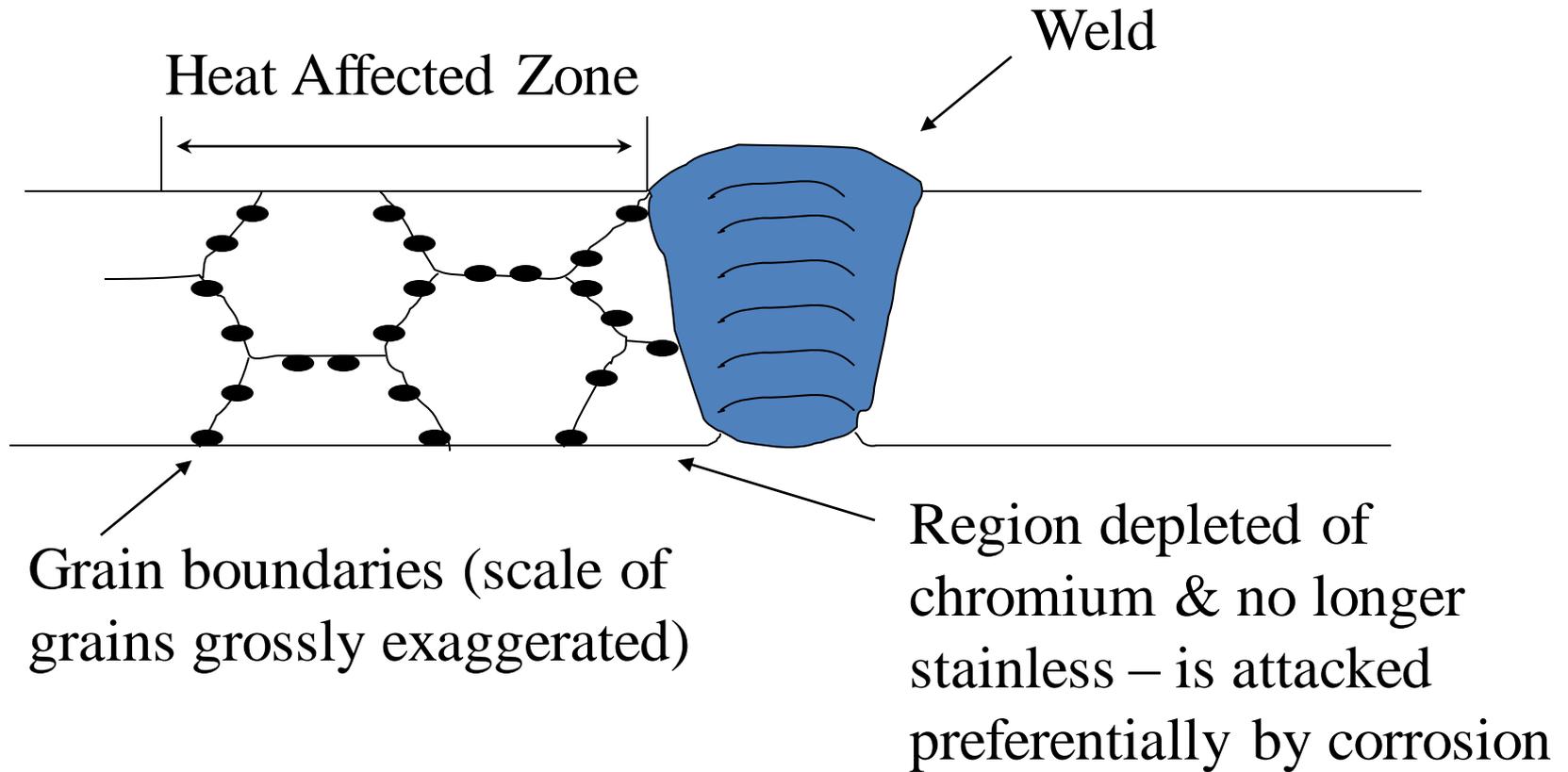
Lamellar Tearing

- Associated with non-metallic manganese – sulphides & silicates when rolled material is extended as planer type inclusions (like wrought iron)
- Welds run parallel to inclusions & cracks are induced through contractile stressing across thickness of the plate

Lamellar Tear Diagram



Weld Decay in Stainless Steel



Corrosion



Fig : Intergranular corrosion of a 310-stainless-steel welded tube after exposure to a caustic solution. The weld line is at the center of the photograph. Scanning electron micrographs at 20X.

Slag Inclusion



Residual Stresses:

- Caused because of localized heating and cooling during welding, expansion and contraction of the weld area causes residual stresses in the work piece.
- Distortion, Warping and buckling of welded parts
- Stress corrosion cracking
- Further distortion if a portion of the welded structure is subsequently removed
- Reduced fatigue life

Residual Stresses developed during welding

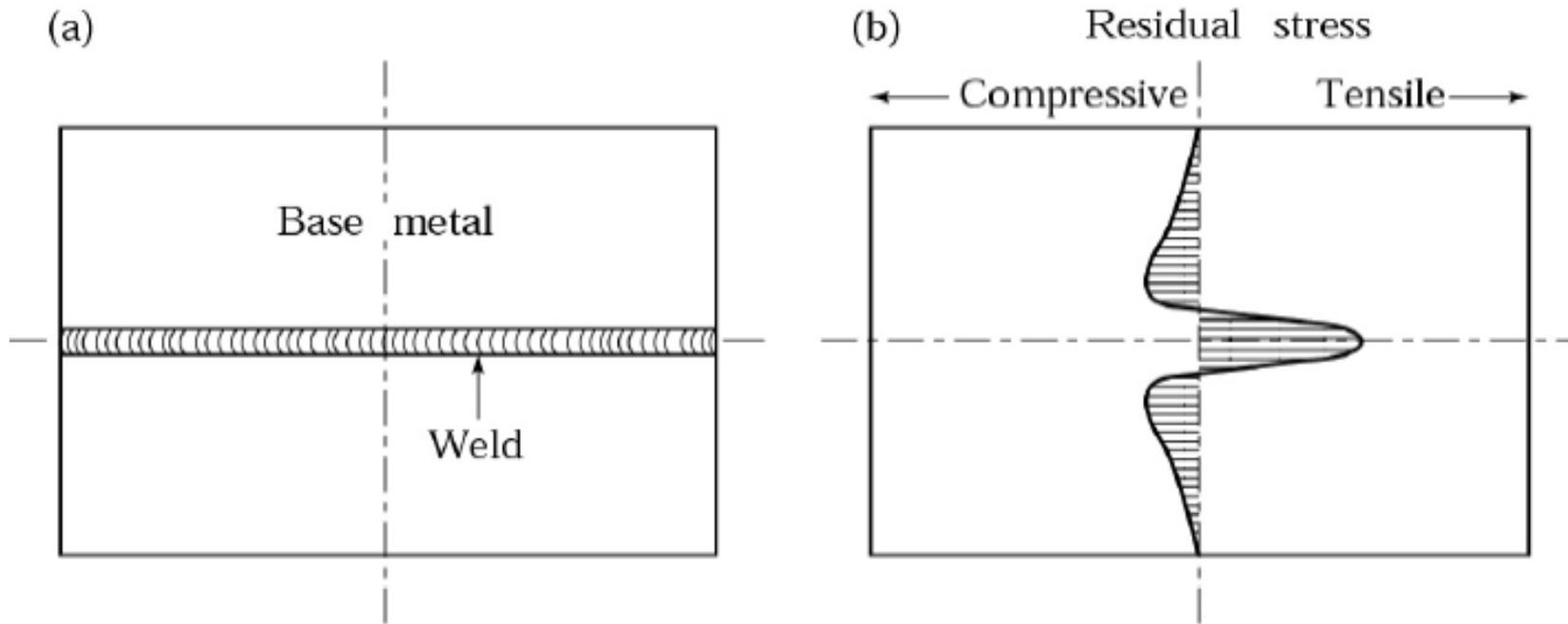


Fig : Residual stresses developed during welding of a butt joint.

Stress relieving of welds :

- Preheating reduces reduces problems caused by preheating the base metal or the parts to be welded
- Heating can be done electrically, in furnace, for thin surfaces radiant lamp or hot air blast
- Some other methods of stress relieving : Peening, hammering or surface rolling

Destructive Techniques

Tension Test :

- Longitudinal and transverse tension tests are performed
- Stress strain curves are obtained

Tension-Shear Test

- Specifically prepared to simulate actual welded joints and procedures.
- Specimen subjected to tension and shear strength of the weld metal

Bend test :

- Determines ductility and strength of welded joints.
- The welded specimen is bend around a fixture
- The specimens are tested in three-point transverse bending
- These tests help to determine the relative ductility and strength of the welded joints

Destructive Techniques

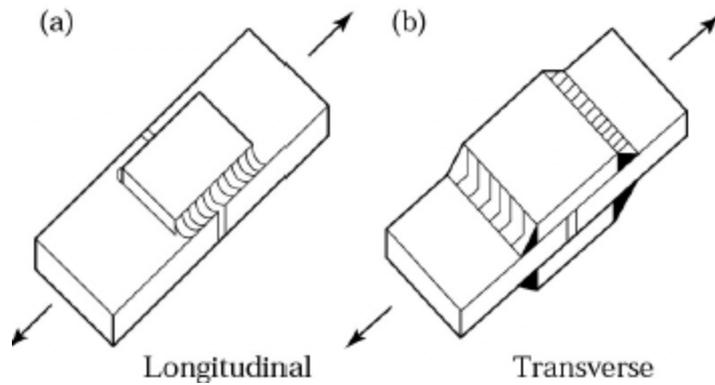


Fig : Two types of specimens for tension-shear testing of welded joints.

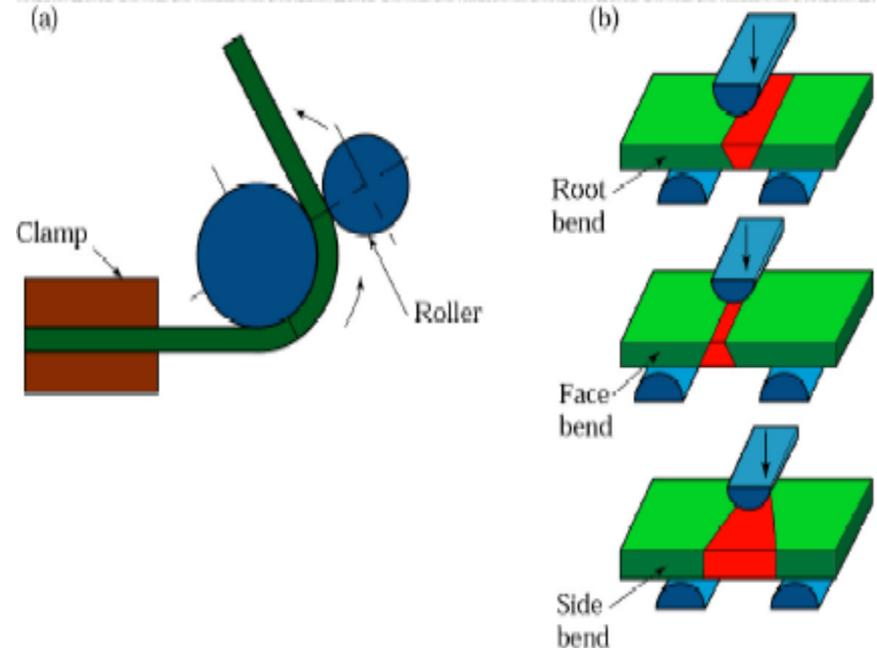


Fig : (a) Wrap-around bend test method. (b) Three-point bending of welded specimens.

Other destructive testing

- Fracture Toughness Test:
- Corrosion and creep tests
- Testing of spot welds
- Tension-Hear
- Cross-tension
- Twist
- Peel

Non-Destructive testing :

- Often weld structures need to be tested Non-Destructively
- Non-Destructive testing are :
- Visual
- Radiographic
- Magnetic-particle
- Liquid-penetrant
- Ultrasonic

Testing of Spot Welds

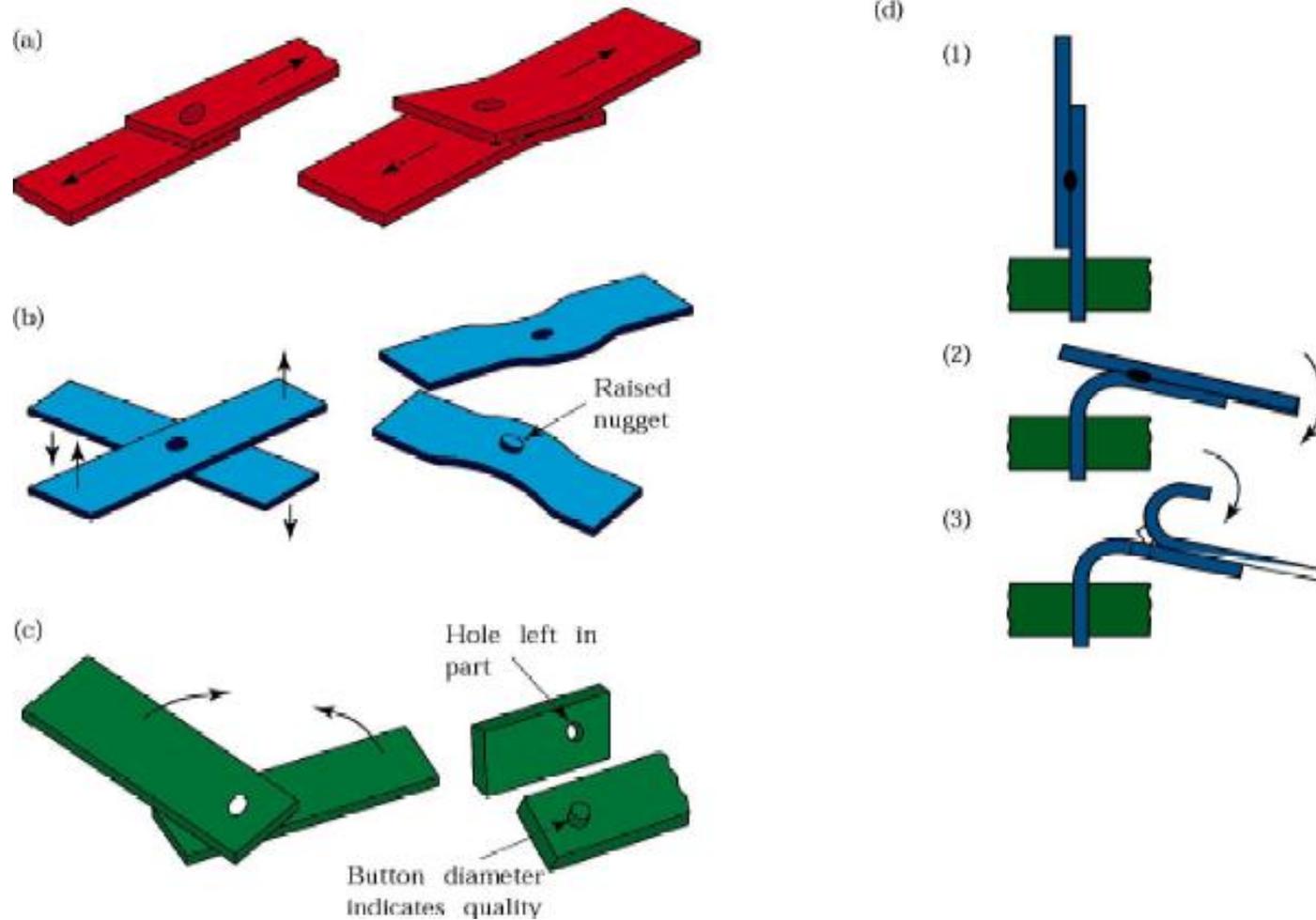


Fig : (a) Tension-shear test for spot welds. (b) Cross-Tension test. (c) Twist test. (d) Peel test