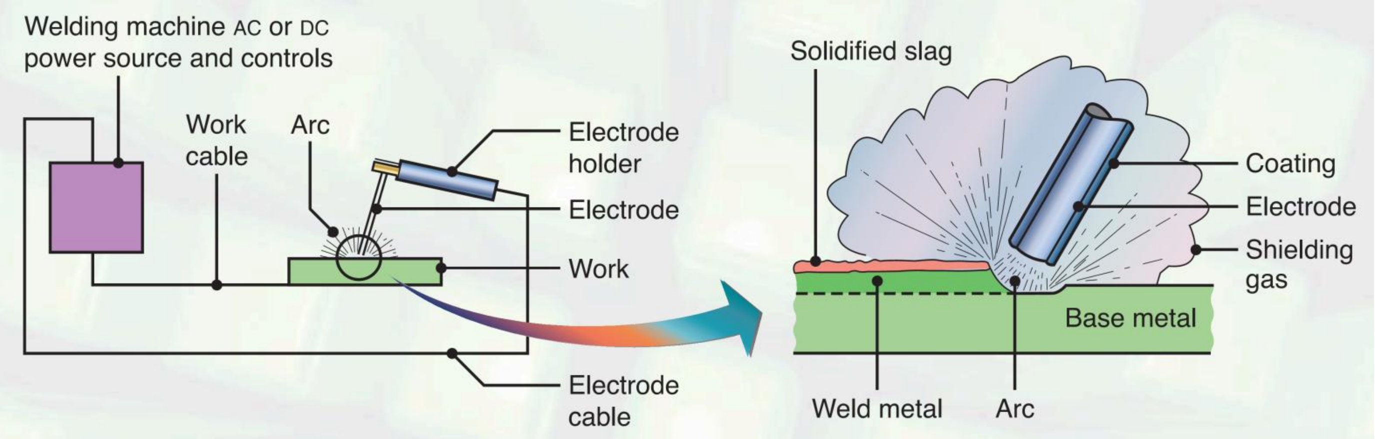
Machine Parts

Welded Joints

Łukasz Jedliński, Ph.D., Eng.

Introduction

Welding – is a technique for permanently joining metal components by using a molten material that can be either a layer of the components (base material) or a filler metal



Advantages:

- joint is not heavy and has high strength,
- leakproof,
- economical – material, labour and production time.

Disadvantages (depends on the method of welding):

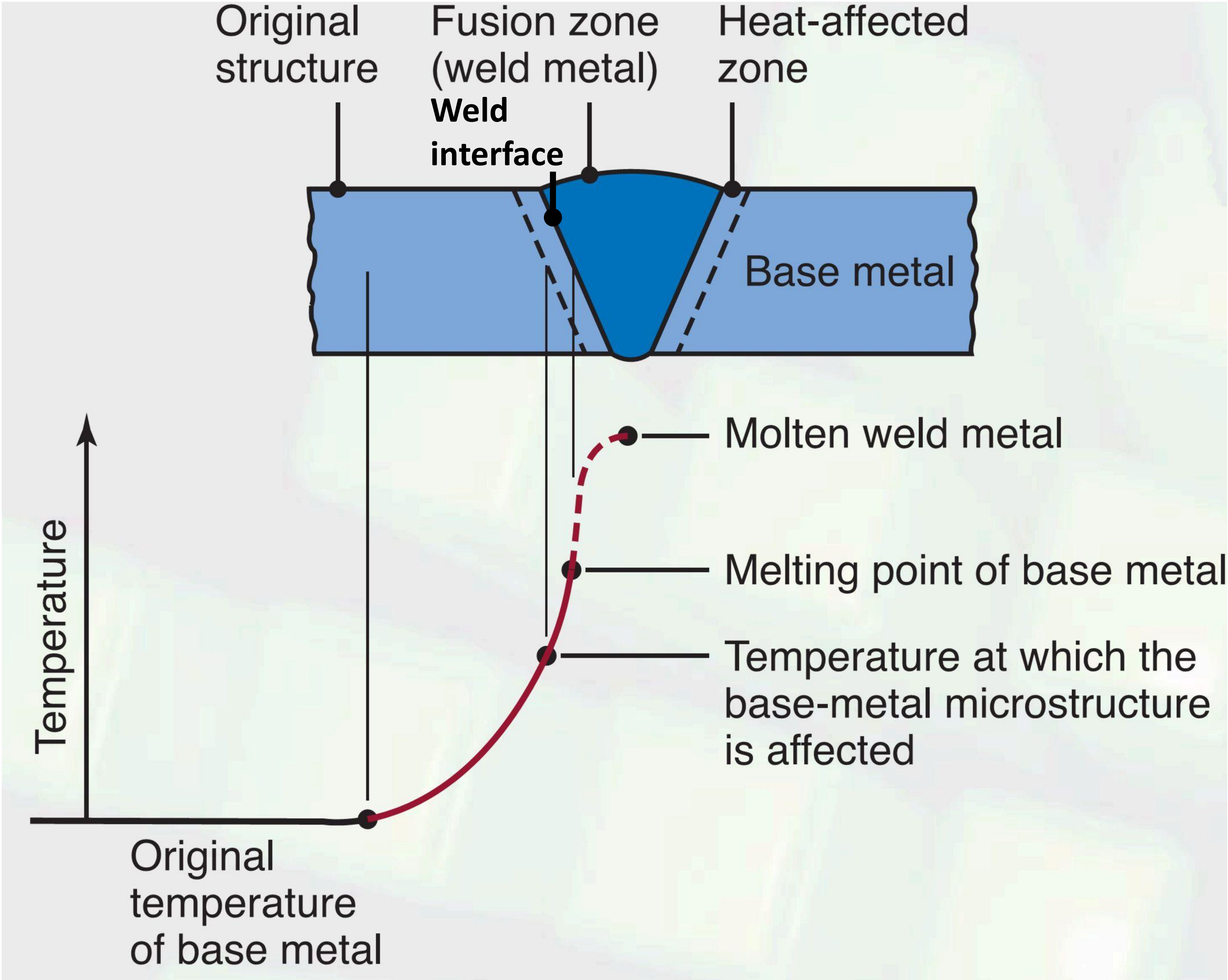
- thermal distortion of the parts, therbay including residual stress (therefore it could be needed stress relieving heat treatment),
- the quality and strengh of welded joints depend upon the skill of the labour (welding defects),
- it has poor vibration damping characteristics.

Introduction

General applications:

- welding can be used as a fabrication medium to join parts permanently and to form built-up parts,
- welding can be used as a substitute for a riveted joint,
- welding can be used to substitute casting and forging manufacturing methods.

Introduction



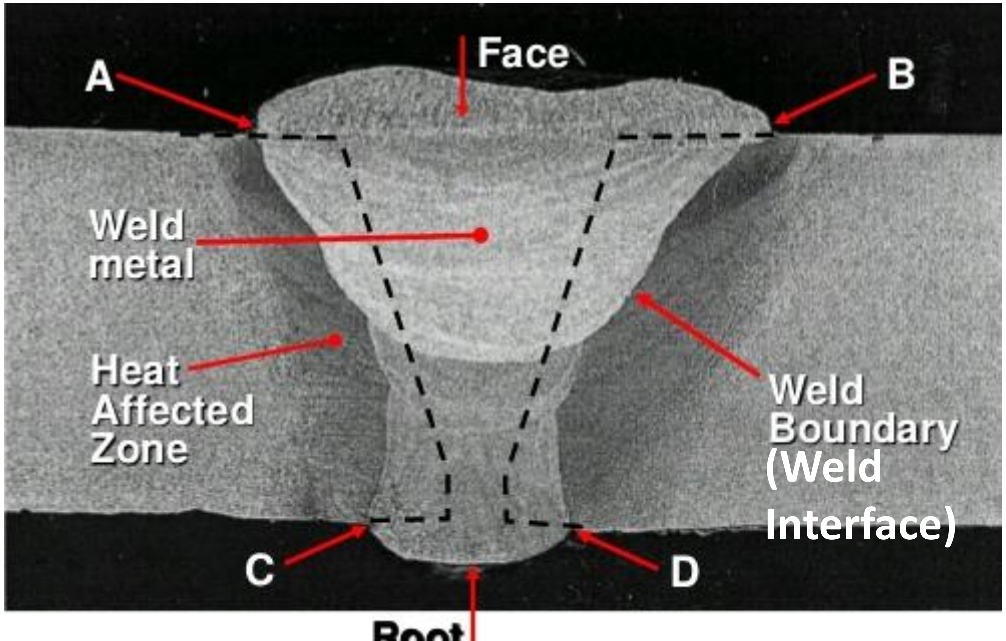
Introduction

The **fusion zone** can be characterized as a mixture of completely molten base metal (and filler metal if consumable electrodes are in use) with high degree of homogeneity where the mixing is primarly motivated by convection in the molten weld pool.

The **weld interface** is a narrow zone consisting of partially melted base material which has not got an opportunity for mixing. This zone separates the fusion zone and heat affected zone.

The **heat affected zone (HAZ)** is the region that experiences a peak temperature that is well below the solidus temperature while high enough that can change the microstructure of the material. The amount of change in microstructure in HAZ depends on the amount of heat input, peak temp reached, time at the elevated temp, and the rate of cooling. As a result of the marked change in the microstructure, the mechanical properties also change in HAZ and, ***usually, this zone remains as the weakest section in a weldment***.

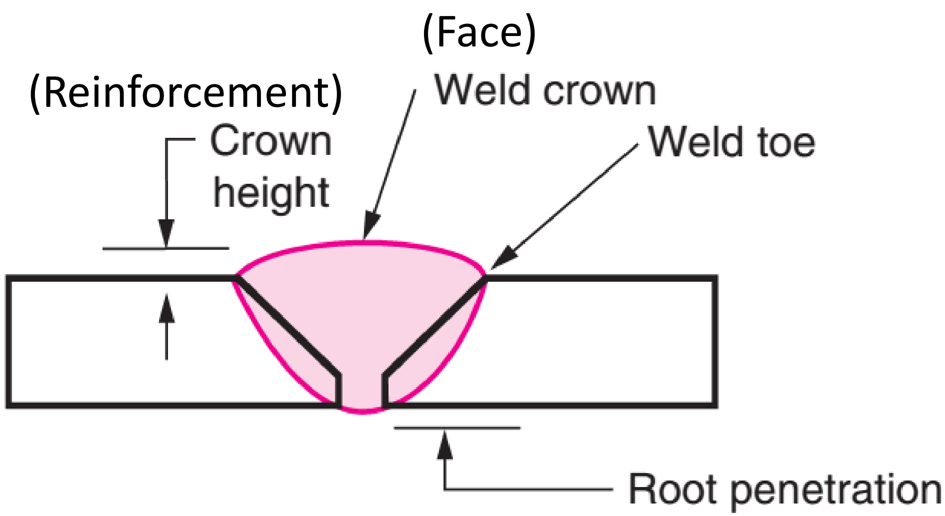
The **unaffected base metal zone** surrounding the HAZ is likely to be in a state of high residual stress,m due to the shrinkage in the fusion zone. However, this zone does not undergo any change in the microstructure.



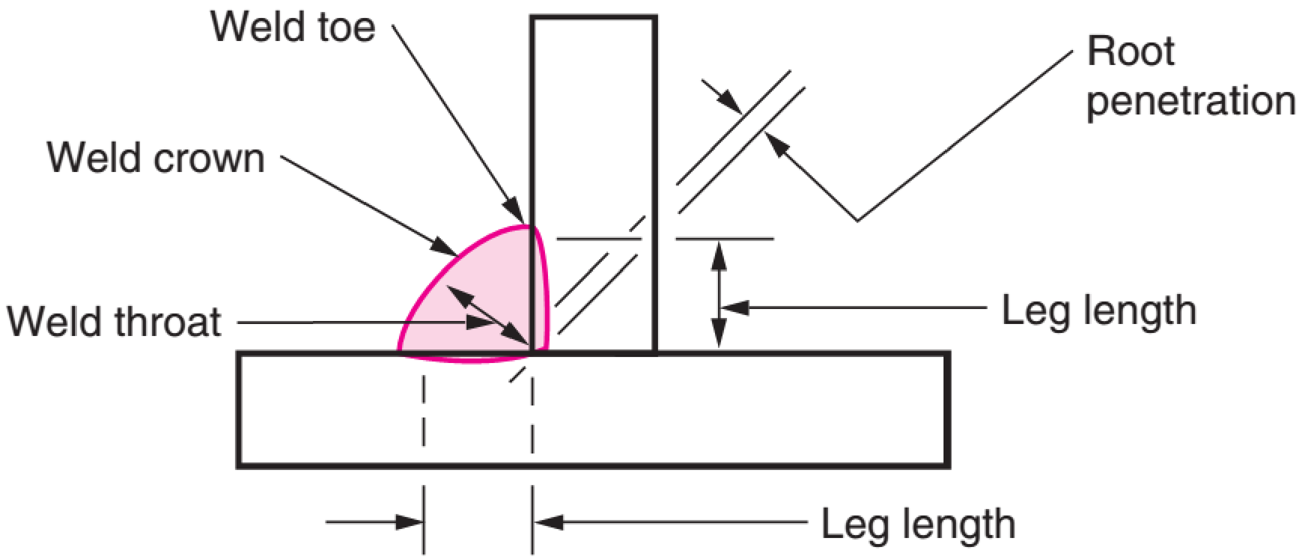
A, B, C & D = Weld Toes

Nomenclature of Welds

Groove weld



Fillet weld



Basic types of welded joints

According to the relative position of the two components

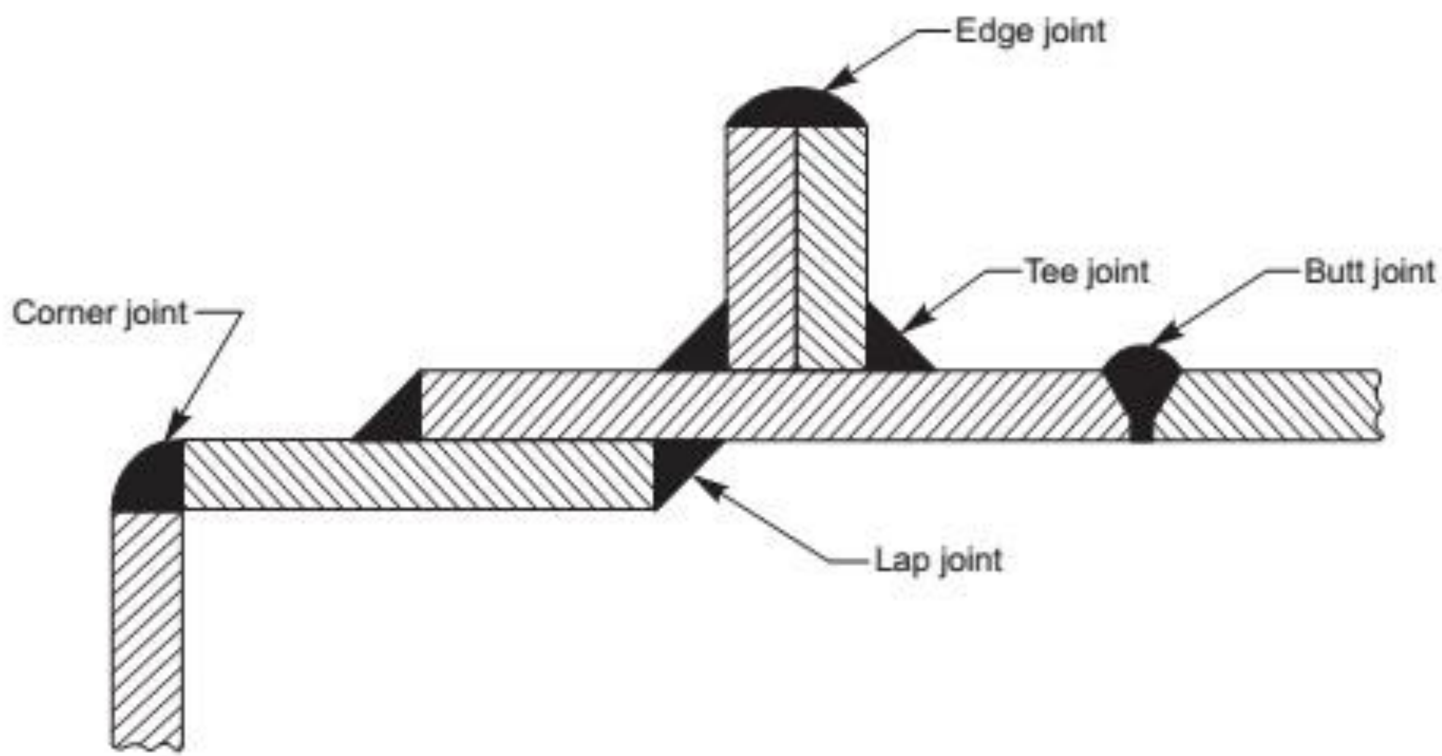


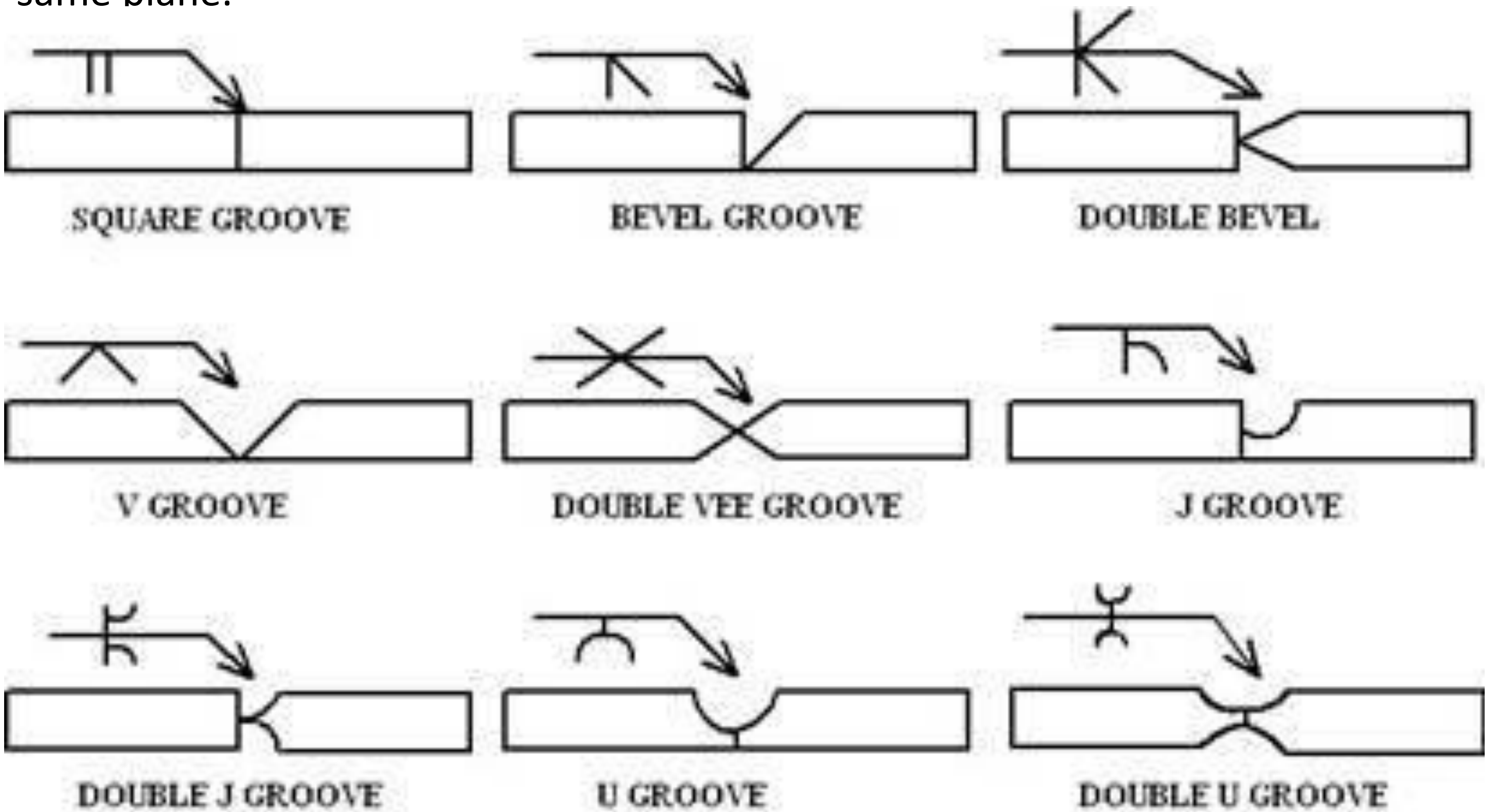
Fig. The five basic types of joints used in welding

Basic types of welded joints

According to the relative position of the two components:

1. Butt joint

It is used to join ends or edges of two plates. Surfaces of plates are located in the same plane.

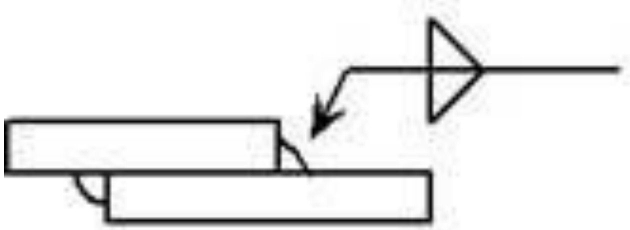


Basic types of welded joints

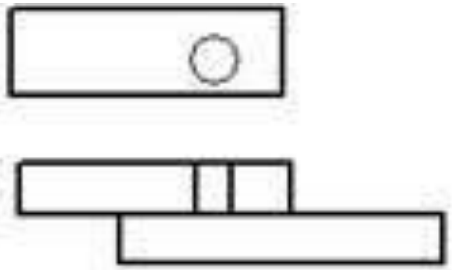
According to the relative position of the two components:

2. Lap joint

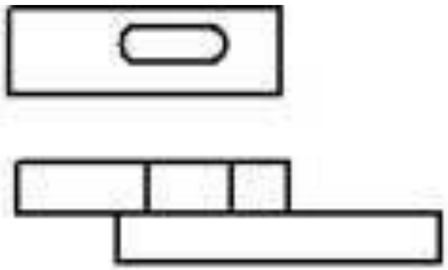
Two plates are overlapped each other for a certain distance.



LAP JOINT WITH FILLETS



LAP JOINT WITH PLUG

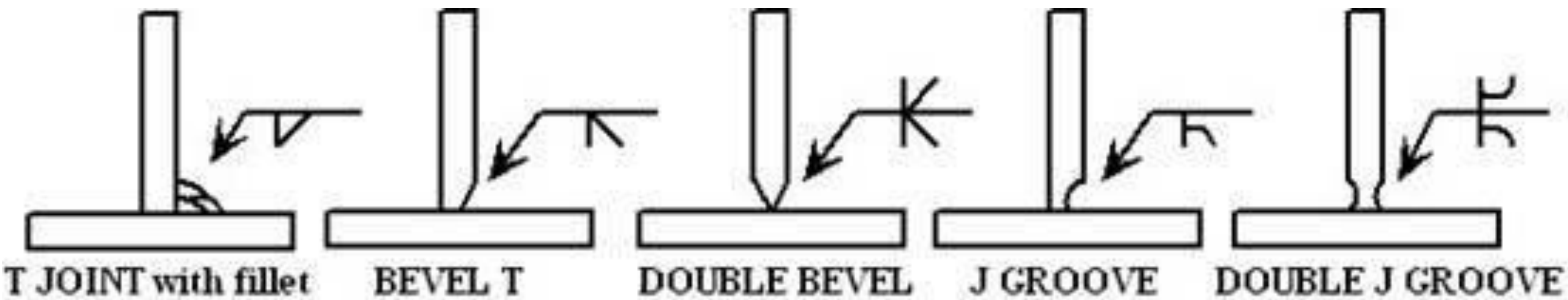


LAP JOINT WITH SLOT

Basic types of welded joints

According to the relative position of the two components:

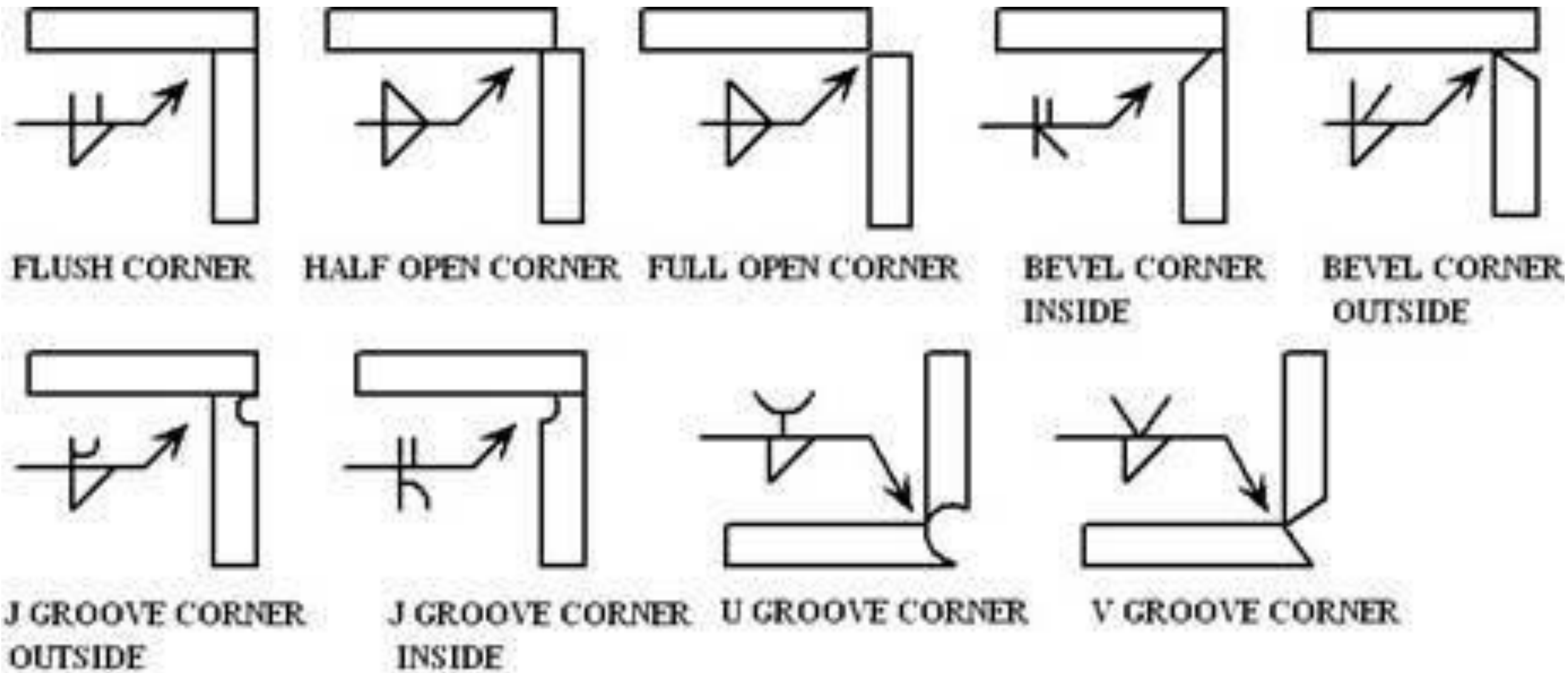
3. Tee joint
The two plates are arranged in T shape i.e. located at right angle to each other



Basic types of welded joints

According to the relative position of the two components:

4. Corner joint
Two plates are arranged at right angle such that it forms an L shape

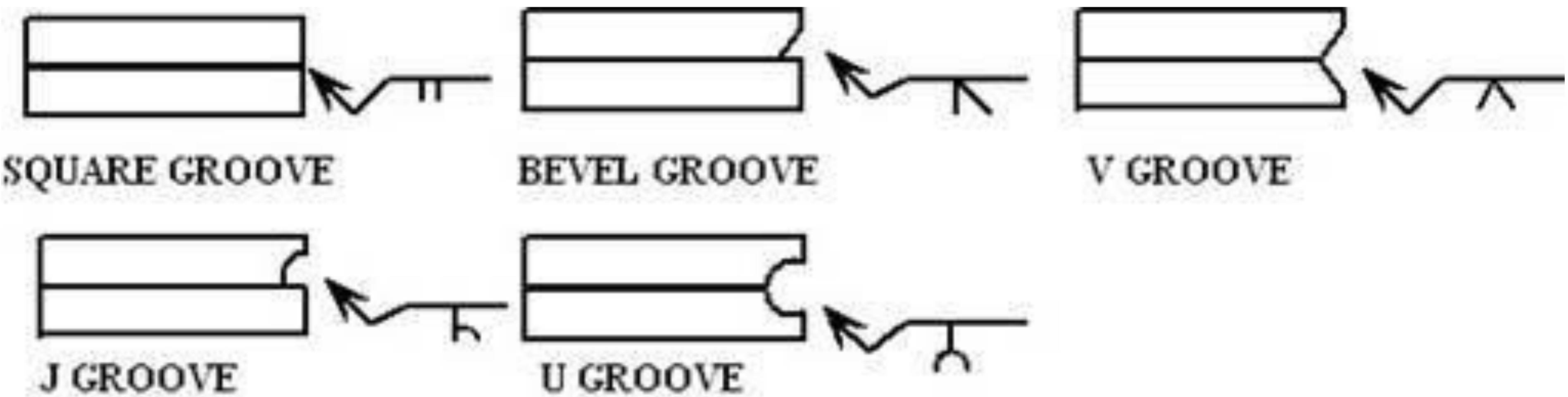


Basic types of welded joints

According to the relative position of the two components:

5. Edge joint

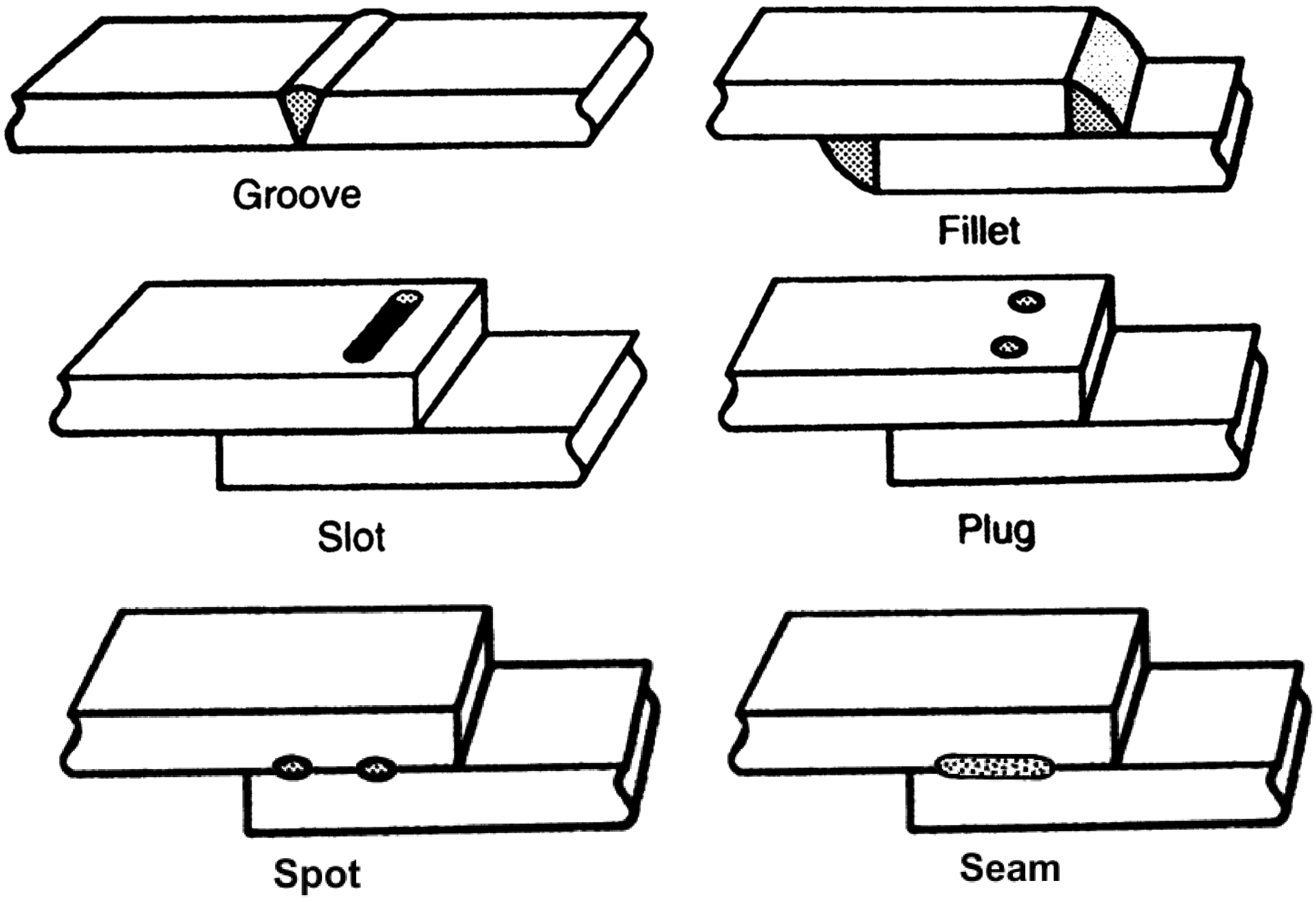
Two plates are overlapping, welded ends of elements are laying in the same plane.



Basic types of welds

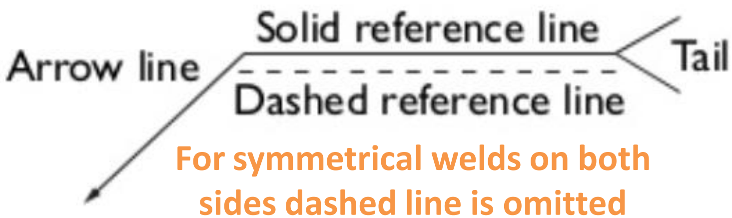
According to the relative position of welds to the joined surfaces :

● Fillet , ● Groove, ● Slot /Plug, ● Spot/Seam



Welding symbols on drawings - ISO

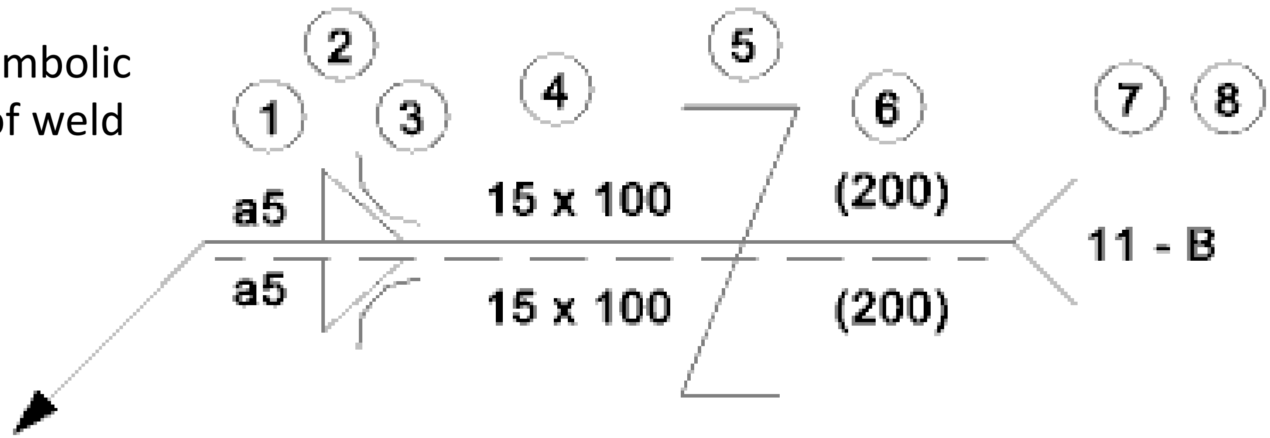
Basic weld symbol



Tail is use to give additional information (not obligatory)

For symmetrical welds on both sides dashed line is omitted

More detailed symbolic representation of weld

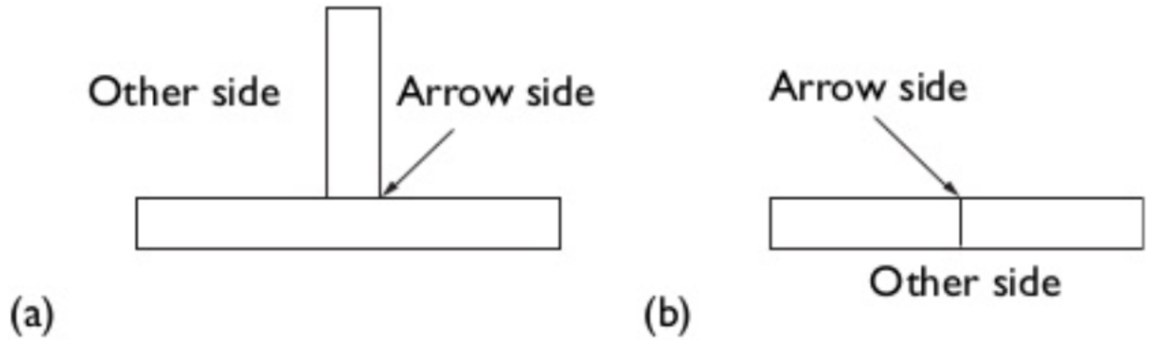


Information above reference line identifies weld on same side as symbolic representation
Information below reference line identifies weld on opposite side to symbolic representation.

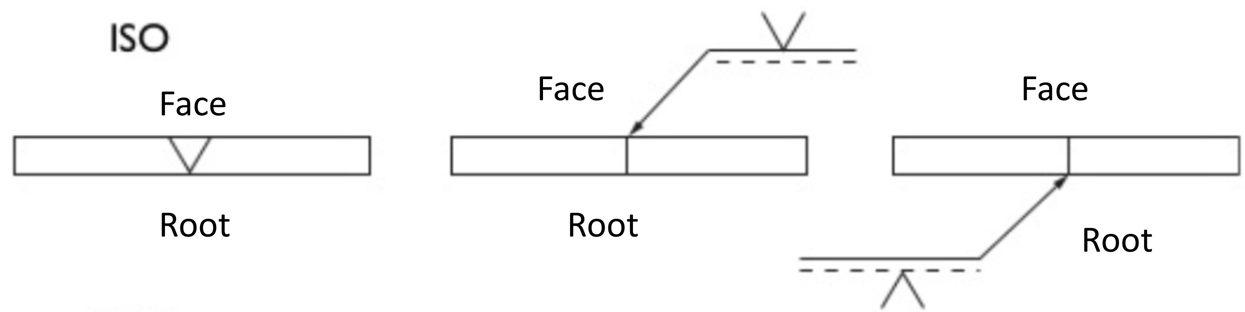
1) Dimension referring to cross section of weld
2) Weld Symbol
3) Supplementary symbol
4) Number of weld elements x length of weld element
5) Symbol for staggered intermittent weld
6) Distance between weld elements
7) Welding process reference
8) Welding class

Welding symbols on drawings - ISO

It is conventional practice to refer to the opposite sides of a welded joints as the arrow side and the other side



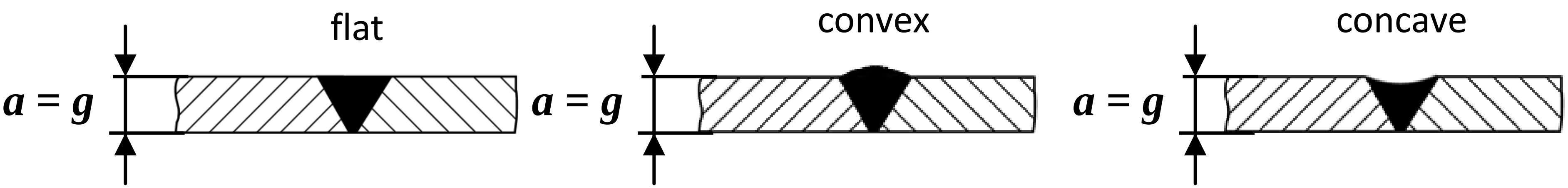
Weld on the arrow side is indicated by placing the weld symbol on the solid reference line and a weld on the other side has the symbol on the dashed line



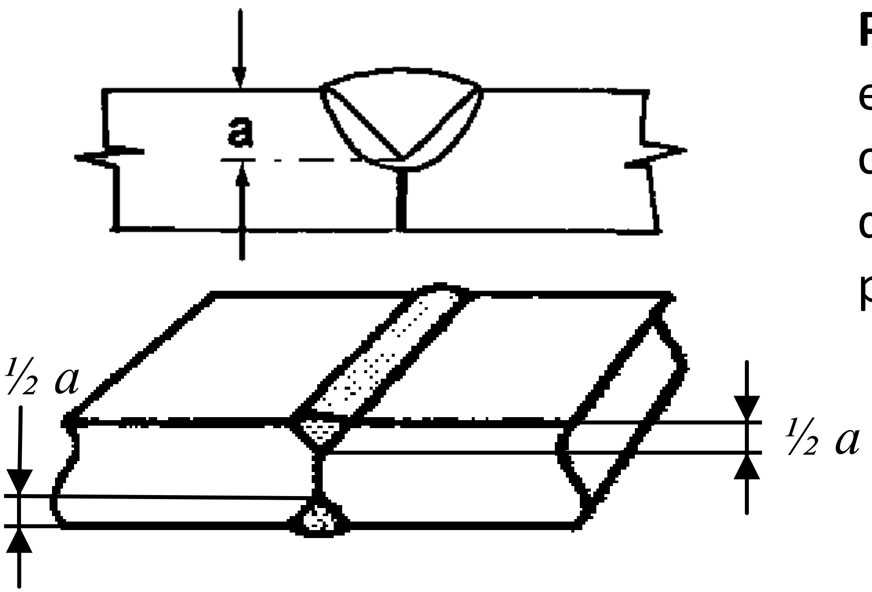
① Dimension referring to cross section of weld

Groove welds – effective throat *a*

For **full penetration** groove welds effective area is the thickness of the thinner part joined. It is obligatory for flat, convex and concave face.



g - thickness of a thinner part of the joint



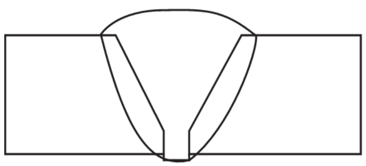
Partial penetration groove welds - the effective throat is normally the depth of the chamfer (If chamfer has small angle, throat depth is reduced because of the insufficient penetration)

① Dimension referring to cross section of weld

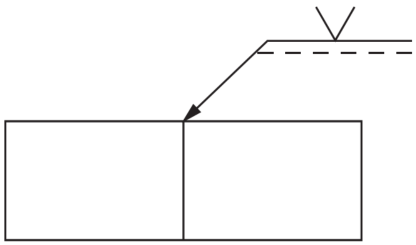
Groove welds – effective throat *a* - *EXAMPLES*

Full penetration groove welds – If the weld dimension from the welding symbol is omitted it means, that joint must have full (complete) penetration

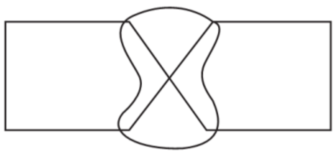
Illustration



ISO



Illustration



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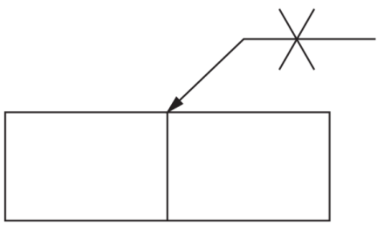
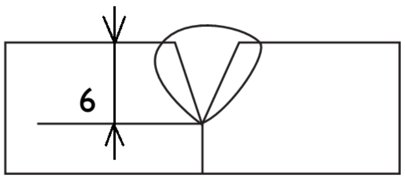
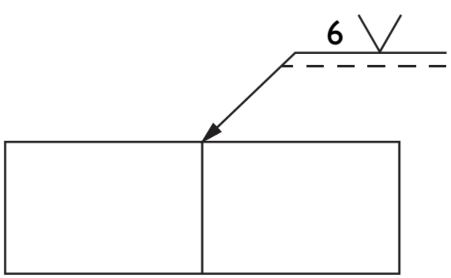


Partial penetration groove welds

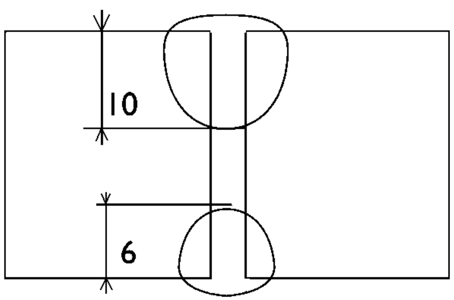
Illustration



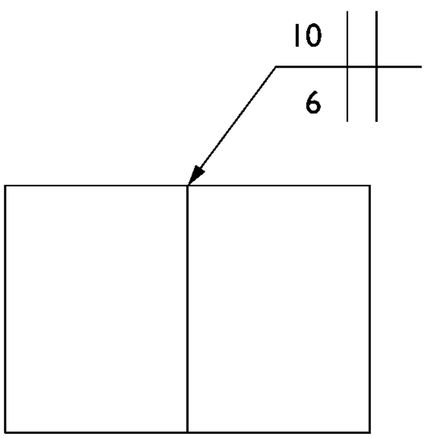
ISO



Illustration



ISO

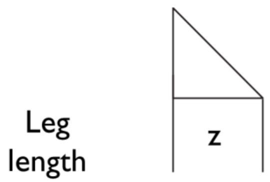


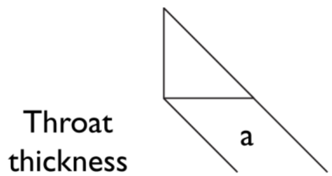
Welding symbols on drawings - ISO

① Dimension referring to cross section of weld

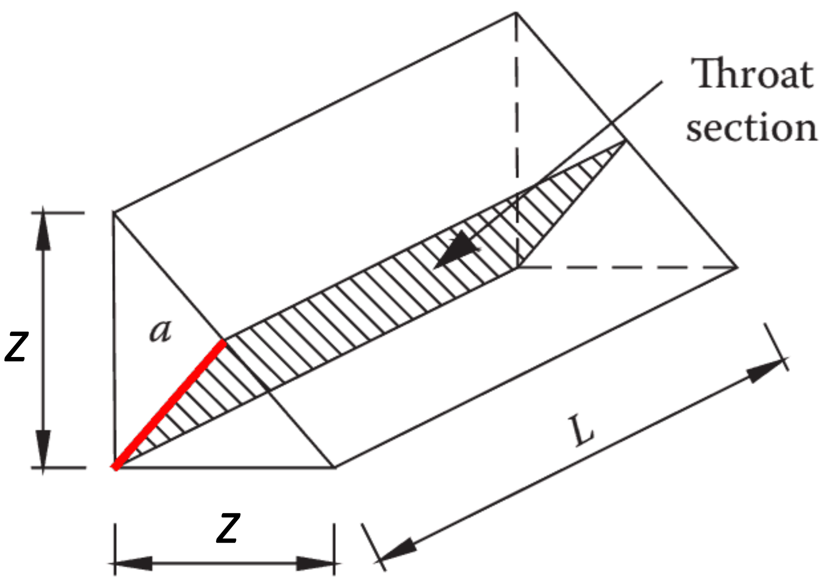
Fillet welds – effective throat *a*

The ISO standard includes two methods to indicate fillet weld sizes: leg length (z) and throat thickness (a)



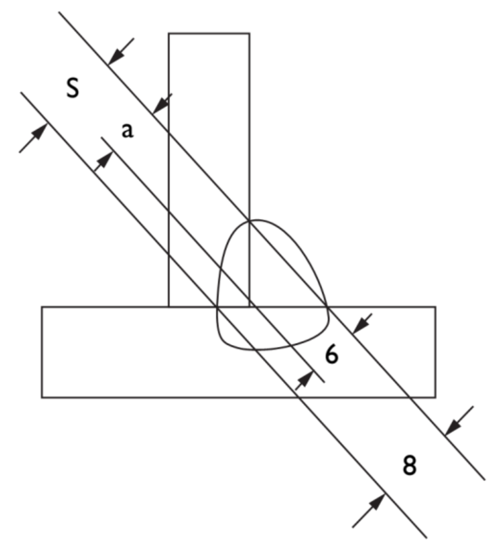


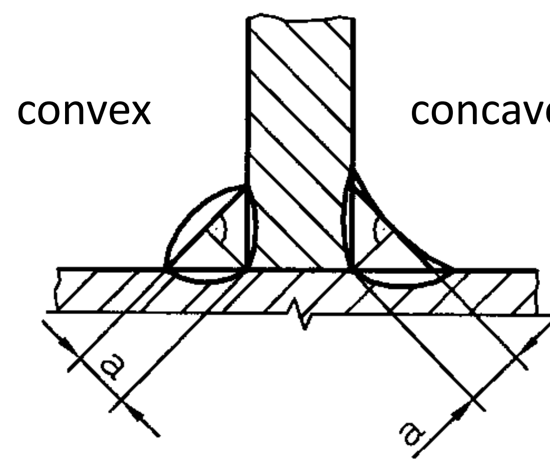
For equal legs $a = \frac{z}{\sqrt{2}} = 0.707z$



The effective weld throat being indicated by the letter ***s*** placed in front of the throat thickness dimension. This is followed by the nominal throat thickness preceded by the letter ***a***

Illustration

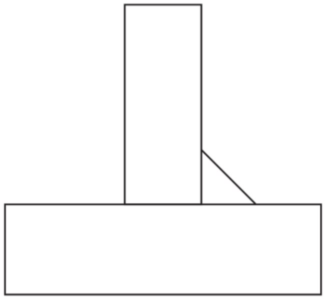




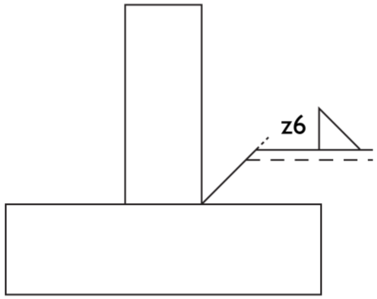
① Dimension referring to cross section of weld

Fillet welds – *EXAMPLES*

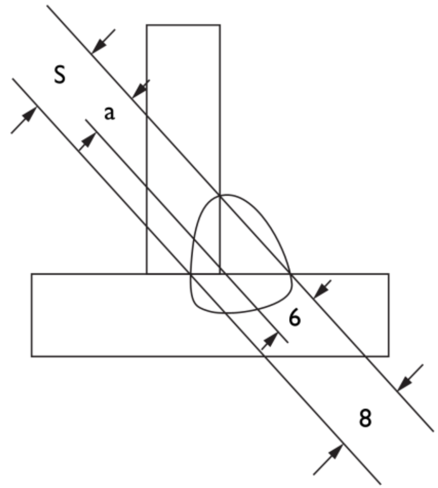
Illustration



ISO



Illustration



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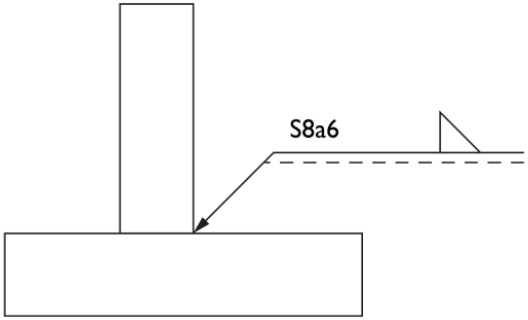
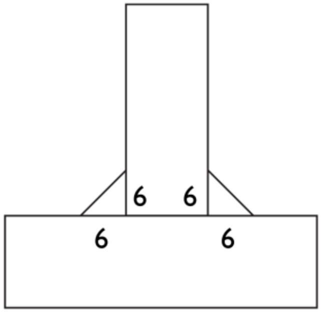


Illustration



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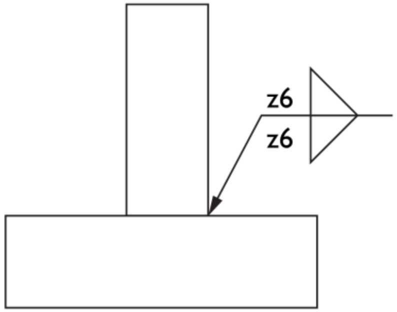


Welding symbols on drawings - ISO

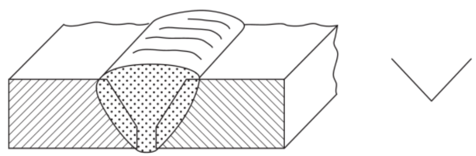
② Weld symbols

Factors which influence choice of edge preparation:
● thickness, ● material, ● welding process, ● extent of penetration required, ● welding distortion, ● cost.

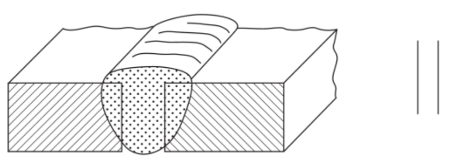
g – recommended thickness of joined materials, when welded joint is made by using shielded metal arc welding

Designation | Illustration | Symbol

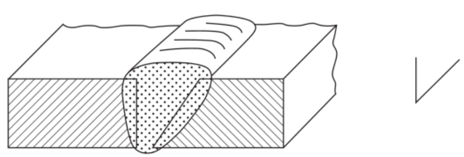
(a) Single-V butt/groove weld
g = 3 ÷ 20



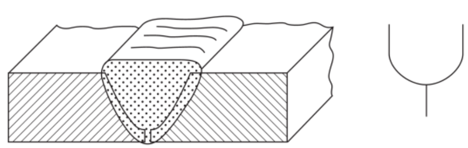
(b) Square butt/groove weld
g = 1 ÷ 3



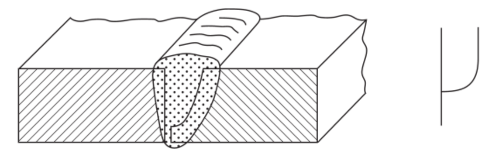
(c) Single bevel butt/groove weld
g = 3 ÷ 20



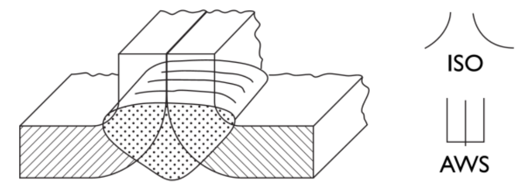
(d) Single-U butt/groove weld
g = 15 ÷ 40



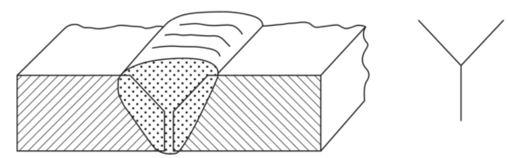
(e) Single-J butt/groove weld
g > 15



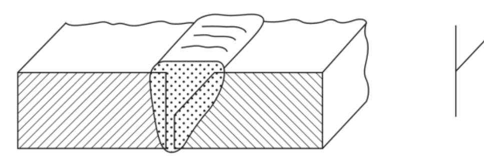
(f) Butt weld between plates with raised edges (ISO)
Edge weld on a flanged groove joint (AWS)
g < 4



(g) Single-V butt weld with broad root face
g = 3 ÷ 20

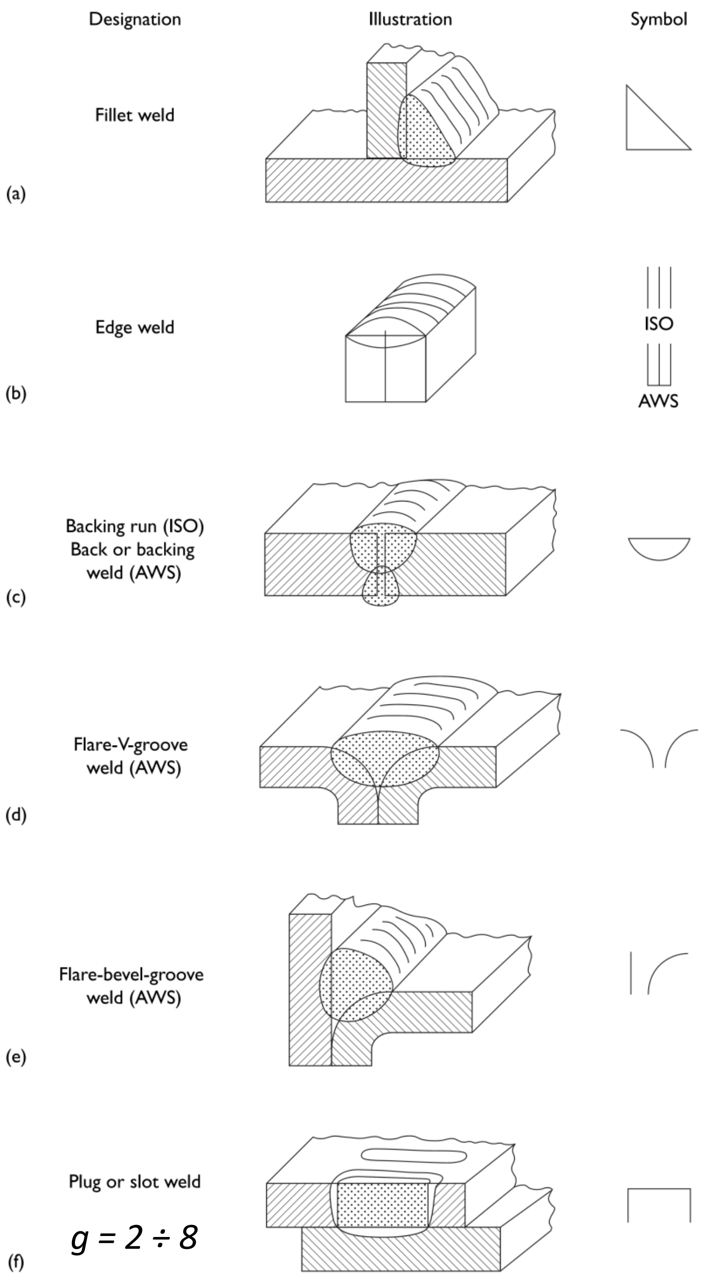


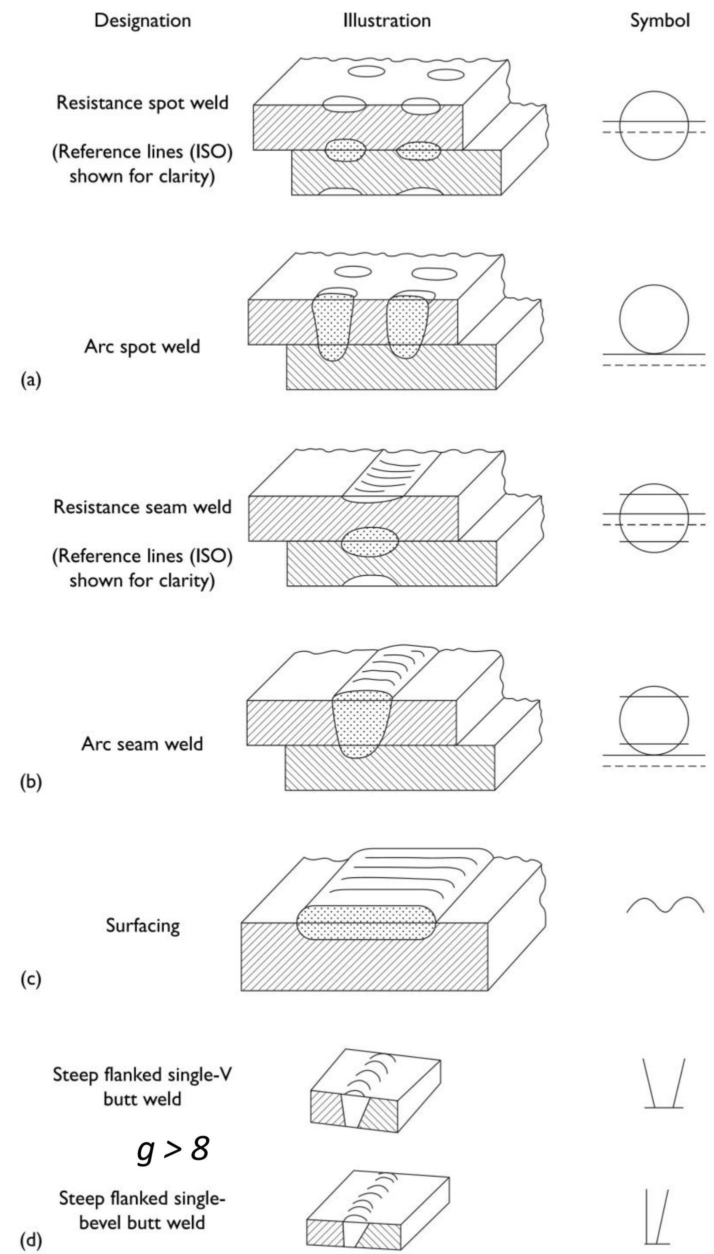
(h) Single bevel butt weld with broad root face
g = 3 ÷ 20



Welding symbols on drawings - ISO

② Weld symbols





Welding symbols on drawings - ISO

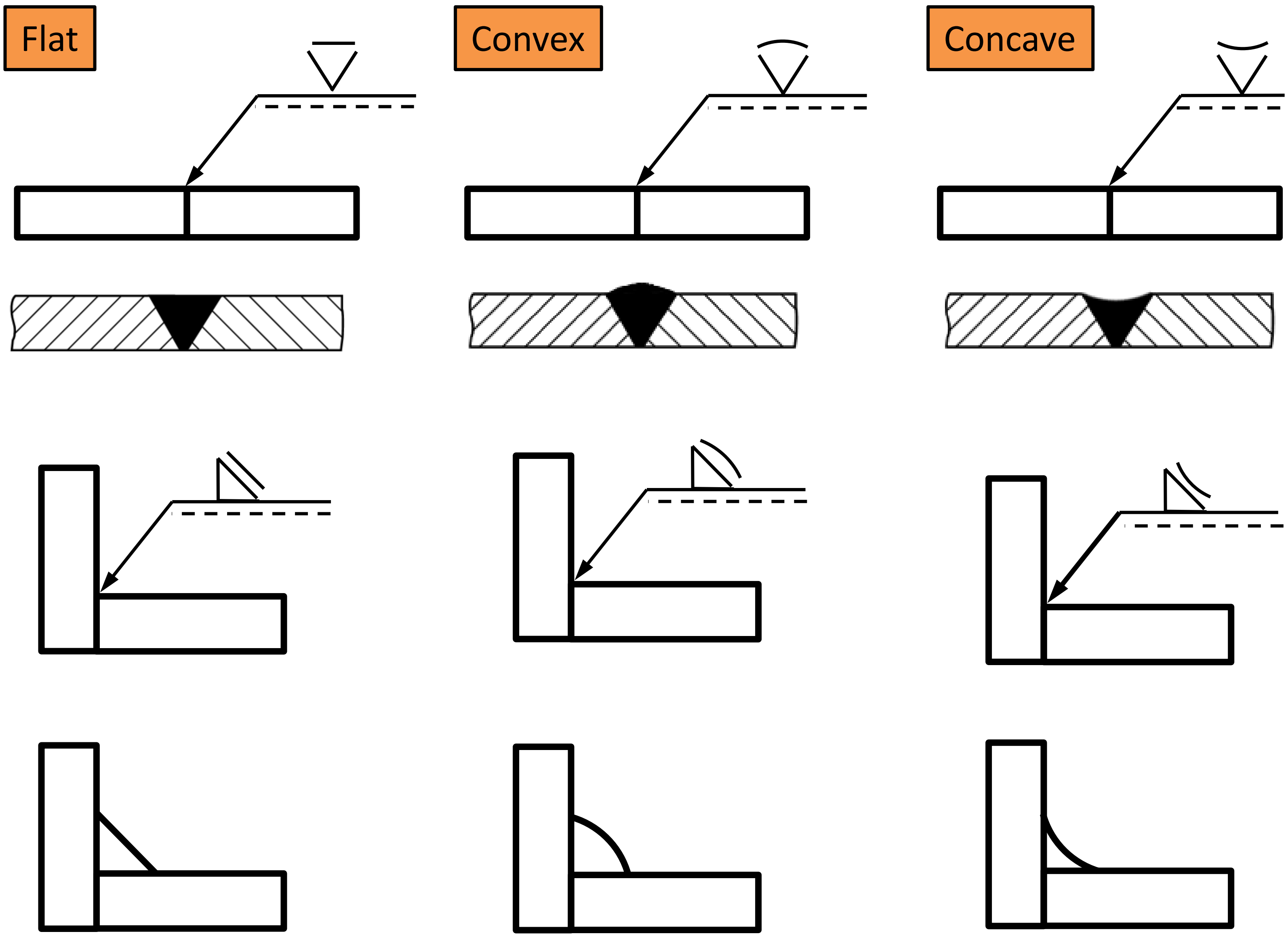
③ Supplementary symbols – weld profile

Symbolic representation

Graphic representation

Symbolic representation

Graphic representation

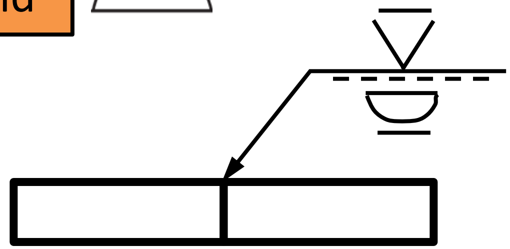


Welding symbols on drawings - ISO

③ Supplementary symbols

Back or backing weld

Symbolic representation

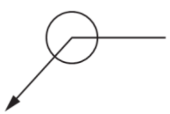


Graphic representation

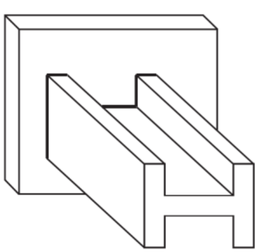
Flat (flush) single-V butt weld with flat (flush) backing run.

A **back weld** is made on the reverse side of a groove/butt weld after the main weld is completed. A **backing weld** is made before the main weld is made.

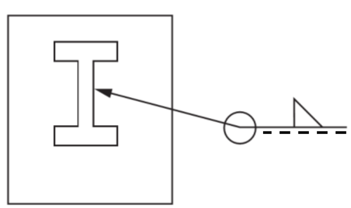
Weld all round



Illustration



ISO

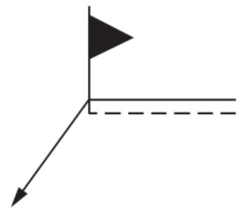


A continuous weld all round a joint is shown by a circle at the intersection of the arrow and the reference line

Welding symbols on drawings - ISO

③ Supplementary symbols

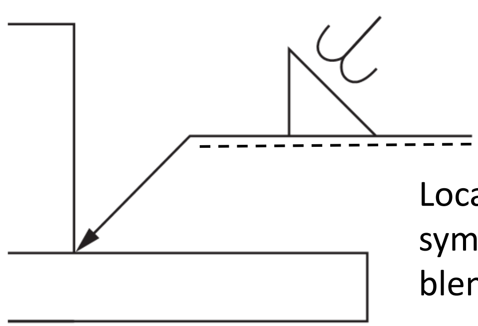
Field or site weld



Welding can be done in the factory or on site.
A site weld is indicated by a flag. There is no significance in the flag being placed either above or below the reference line or whether it points left or right.

Toes shall be blended smoothly

It can be used to inform the welder that the weld toes are to be ground in order to remove any small slag intrusions that exist at the toes of welds.
The purpose of weld toe grinding is to increase the fatigue strength of the welded joint. This is important because slag intrusions can act as initiation sites for fatigue cracks.



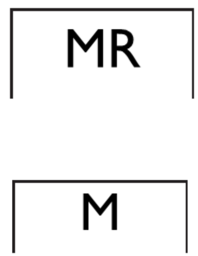
Location of the symbol for toes blended smoothly

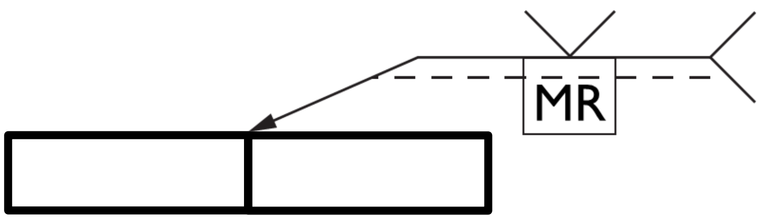
Welding symbols on drawings - ISO

③ Supplementary symbols

Removable backing strip used

Permanent backing strip used

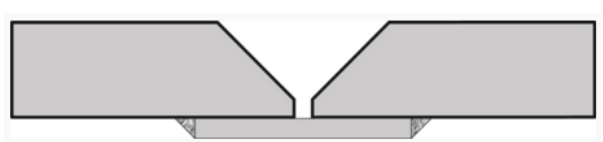




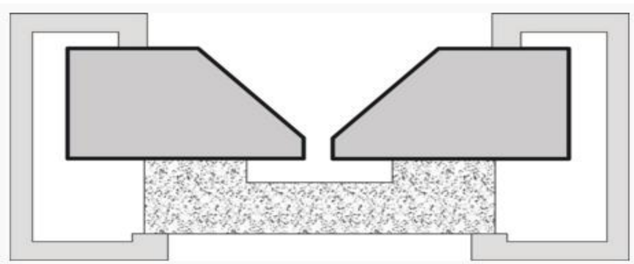
A joint with a backing strip is denoted by placing the symbol on the side of the reference line opposite the butt/groove weld symbol.

The letter R indicates that the backing is to be removed after welding.

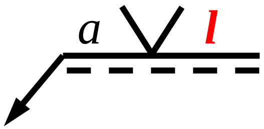
Permanent backing strip
Protecting and shaping the weld bead by providing a permanently attached strip of material similar to that being welded is popular. It is inexpensive, easily applied, and requires little special skill.
The backing bar becomes a permanent feature of the joint, which may be undesirable from an aesthetic point of view, depending on the part.



Temporary backing strip
To ensure the strip cannot be welded to the joint, this temporary support often is water-cooled and manufactured from copper.
The manufactured temporary backing bar is held in place by a suitable tool or fixture that allows it to be removed easily after welding.



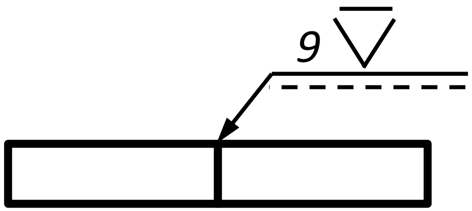
④⑥ Dimensions referring to longitudinal size of weld



Longitudinal dimensions are given on the right-hand side of the symbol.

Continuous groove and fillet weld

The absence of dimension means, that the weld is continuous along the whole length of the joint.



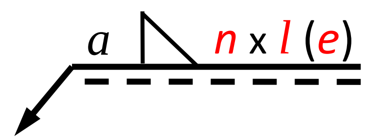
Not continuous fillet weld

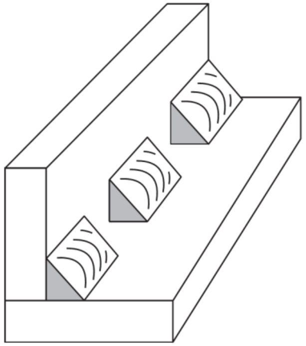
If the weld is not continuous and consists of intermittent fillet welds, the weld lengths and the gaps between them are indicated by dimensions *n* x *l* (*e*), where:

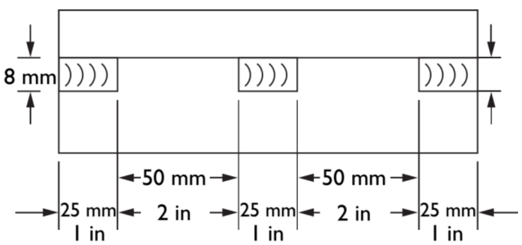
n - number of separate welds,

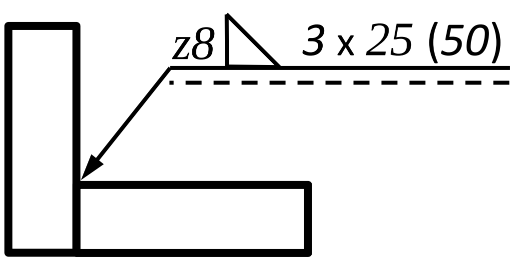
l - length of each weld (without end craters),

e - distance between the ends of adjacent welds.









Welding symbols on drawings - ISO

④⑥ Dimensions referring to longitudinal size of weld
⑤ Symbol for staggered intermittent weld

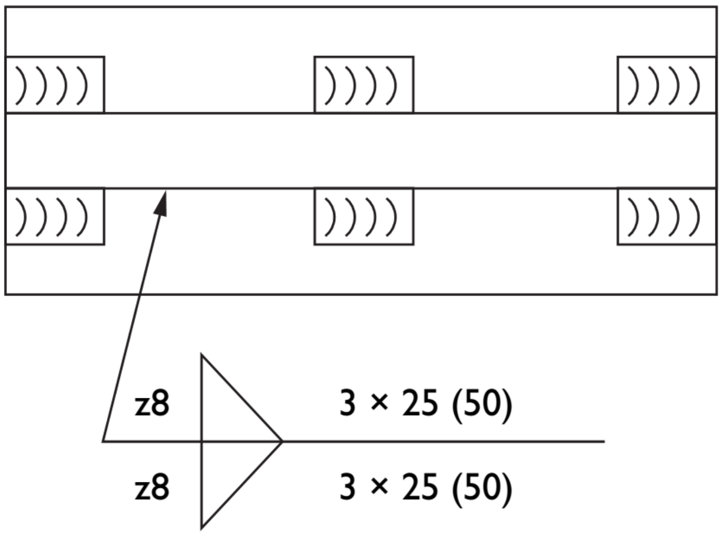
Not continuous fillet weld

There are two cases of not continuous **double** fillet weld:

1. intermittent fillet welds,
2. staggered intermittent fillet weld.

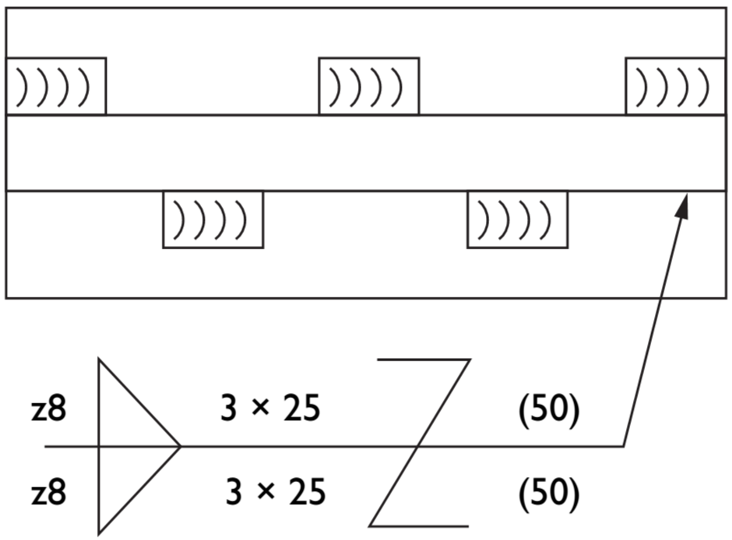
1. Intermittent fillet welds

Dashed reference line is omnited

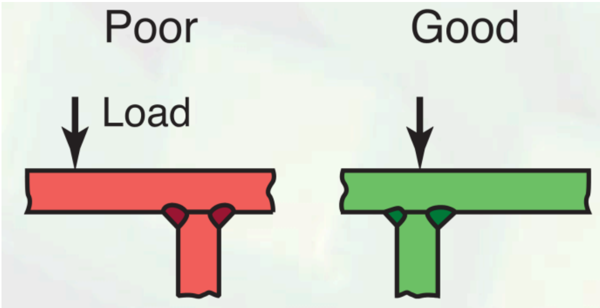


2. Staggered intermittent fillet weld

Staggered intermittent fillet welds are indicated by an elongated „Z"

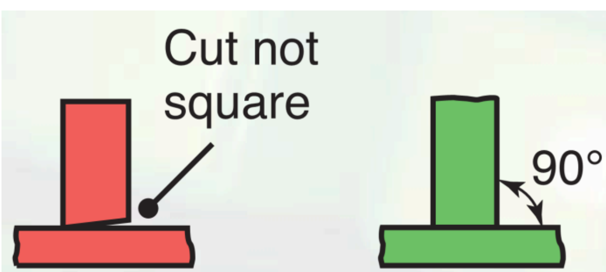


Good practice in design

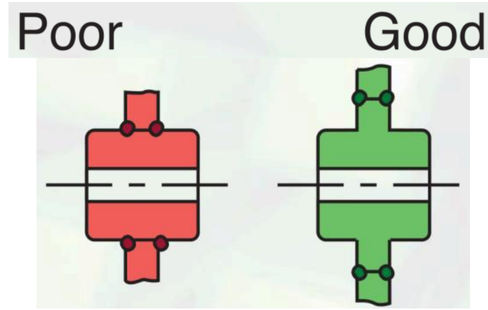


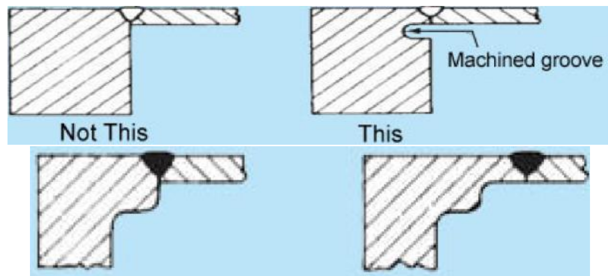
Design the weld joint in such a fashion that it stays away from the stressed area or the part itself bears the load instead of the weld joints

Positive effects (good design):
- natural groove /slot for weld,
- lower stress concetration.

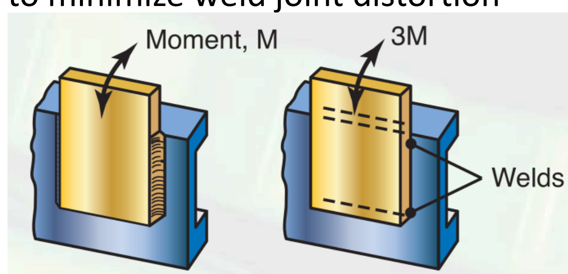


Negative effects (poor design):
- incorect position of elements,
- smaler throat.

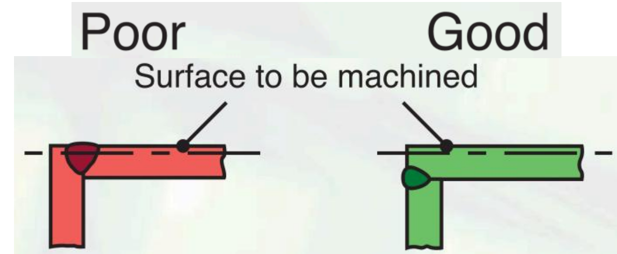


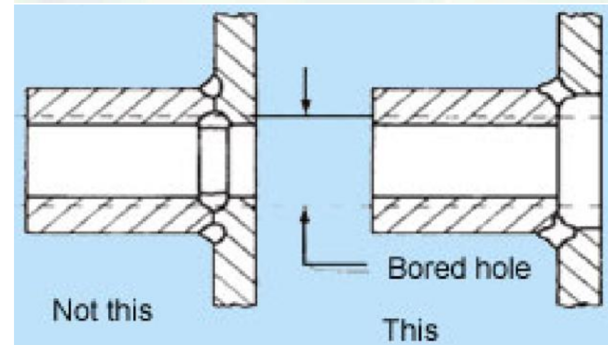


Cast and forged parts should be designed so that the wall thickness of both these parts to be joined is equal at the joint interface to minimize weld joint distortion

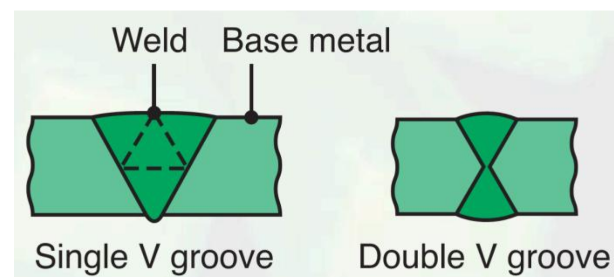


Proper arrangement of welds can increase carrying load





If machining after welding is required, welds should be placed away from the material to be machined to avoid machining near to the weld joints



Residual stress and distortion in welded joint

Causes of residual stress and distortions

The inherent local non-uniform heating and cooling cycles associated with the joining processes, in particular with the fusion welding processes, results in complex stresses and strains in and around the weld joint. These finally lead to the development of residual stress and distortion in welded structure.

Three main reasons for the development of residual stresses in welded structure are:

1. non-uniform heating and cooling of metal in and adjacent to the weld region,
2. volume shrinkage of metal in weld during solidification (freezing),
3. structural change of metal on solidification resulting in the change of its mechanical properties.

Definitions

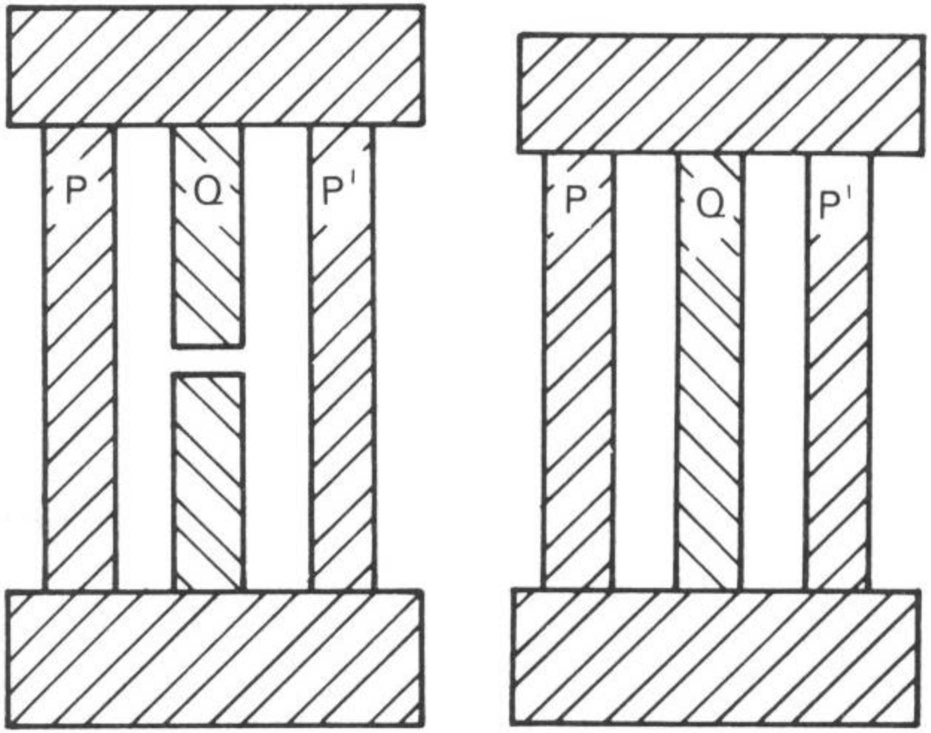
Residual stresses are referred to as internal stresses that would exist in a body after the removal of all external loads.

Distortion refers to the permanent (*plastic*) strain that would be exhibited in terms of dimensional change after the welding is over. **Distortion is caused by residual stress.**

Meaning

While the residual stresses can reduce the service life of a structure or even cause catastrophic failures, distortion usually results in misalignment with consequent difficulties in assembly and poor appearance of the final structure.

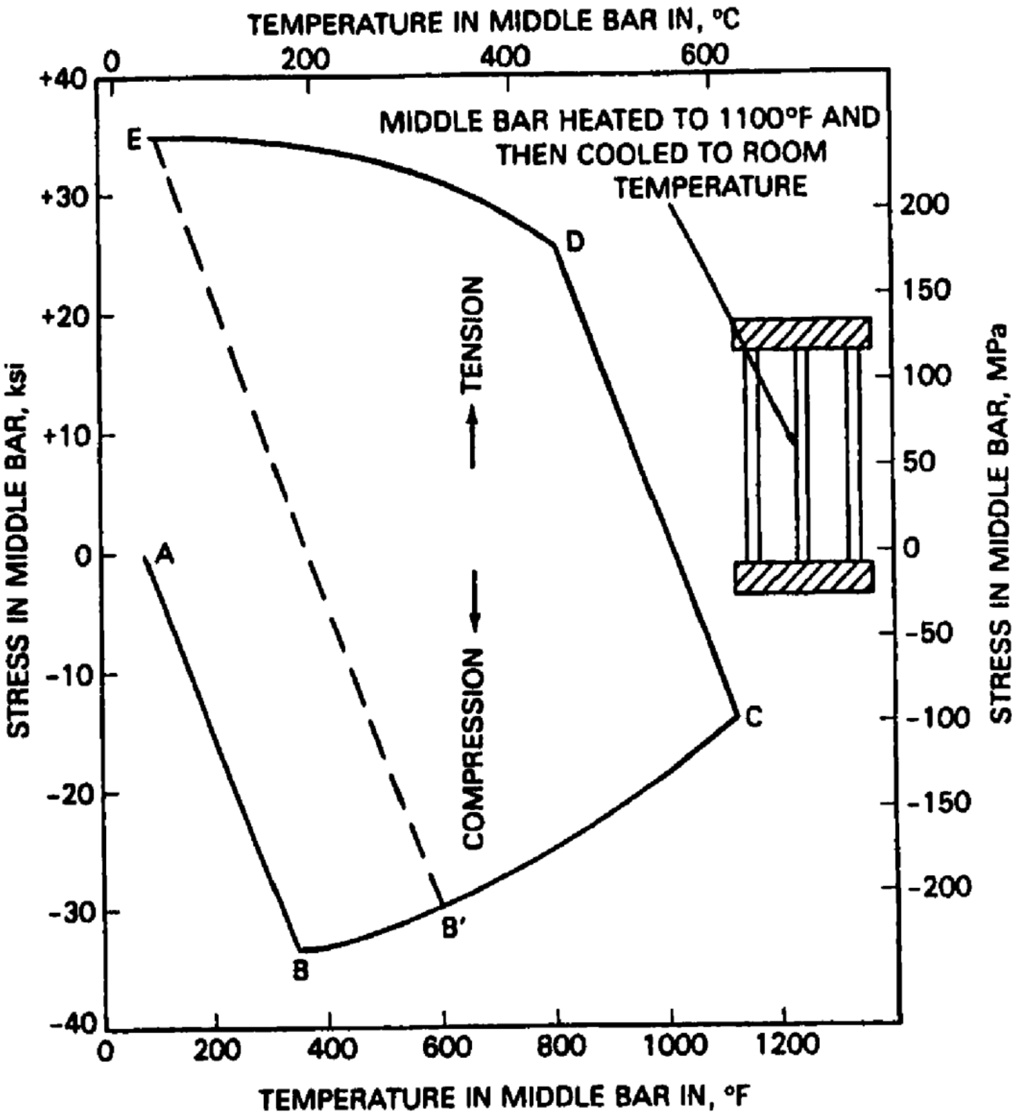
Residual stress and distortion in welded joint



(A) Free State (B) Stressed State

Let’s look more closely at the generation of residual stresses in a part. If we first look at the samples above, and heat the middle bar of the “free state” sample, we would notice that the middle bare would expand, but there would be not stress built up in the outer bars as long as the expansion was not great enough to have the two faces on the middle bar touch. The case is not the same with the stress state sample. If the middle bar here were heated without heating the two outer bars, the middle bar would try to expand, but it would be constrained by the two outer bars. The middle bar would be under compression, while it forced the two outer bars into tension. In the next slide we will go through a heating and a cooling cycle of this middle bar. We will heat so much that the bars will not only experience tension and compression the elastic region where we learned before that taking the load off causes the bars to go back to their original position, but we will heat to a point where plastic deformation occurs. It is also instructive to note before we begin this exercise that the three bars represent a model of a weldment where the heated middle bar is the weld and the cooler outer bars are the base metal on either side of the weld.

Residual stress and distortion in welded joint



Starting at A where there are no stresses, we heat the middle bar, it expands and causes compressive stress in the middle bar as temperature increases. At point B, the stress in the bar exceeds the yield point at that temperature and plastic deformation begins. As temperature continues to increase the yield point at that temperature decreases causing the stress in the bar to follow path BC. At point C we begin to cool, and the bar begins to contract. At first this reduces the compressive stresses built up in the bar until the stress now equals zero (but the bar is still at about 1000F). With further cooling, the bar continues to contract but now it is putting itself into tension. This continues to point D where the tensile yield stress at that temperature is exceeded and further cooling and contraction causes tensile deformation until room temperature is reached and the tensile residual stresses of magnitude E are reached. What do you think was happening during this cycle in the two outer bars? The load in the opposite sense was divided between them. Can you draw the respective figure for the outside bar? In the final analysis, the center bar has residual tensile stress and the outside bars have residual compress when the sample has returned to room temperature.

Residual stress and distortion in welded joint

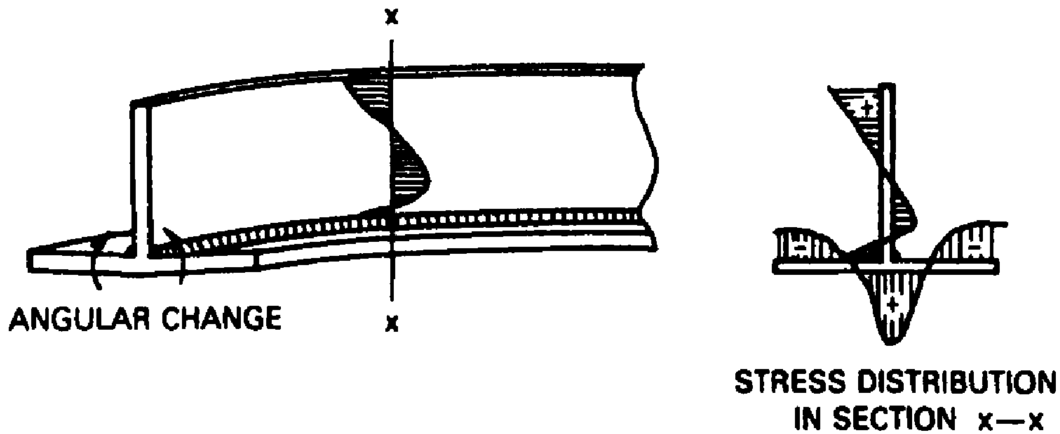


Fig. Residual Stresses and Distortion of a Welded 1-Shape

The effect of residual stress can be summarized as follows:
1. The effect of weld-induced residual stresses on the performance of a welded structure is significant only for phenomena that occur at low applied stresses, such as brittle fracture, fatigue, and stress-corrosion cracking.
2. As the level of applied stress increases, the effect of residual stresses decreases. (This is because higher applied stresses overwhelm residual stresses by causing generally yielding).
3. The effect of residual stress on the performance of welded structures under applied stresses greater than the yield strength is negligible.
4. The effect of residual stress tends to decrease after repeated loading.

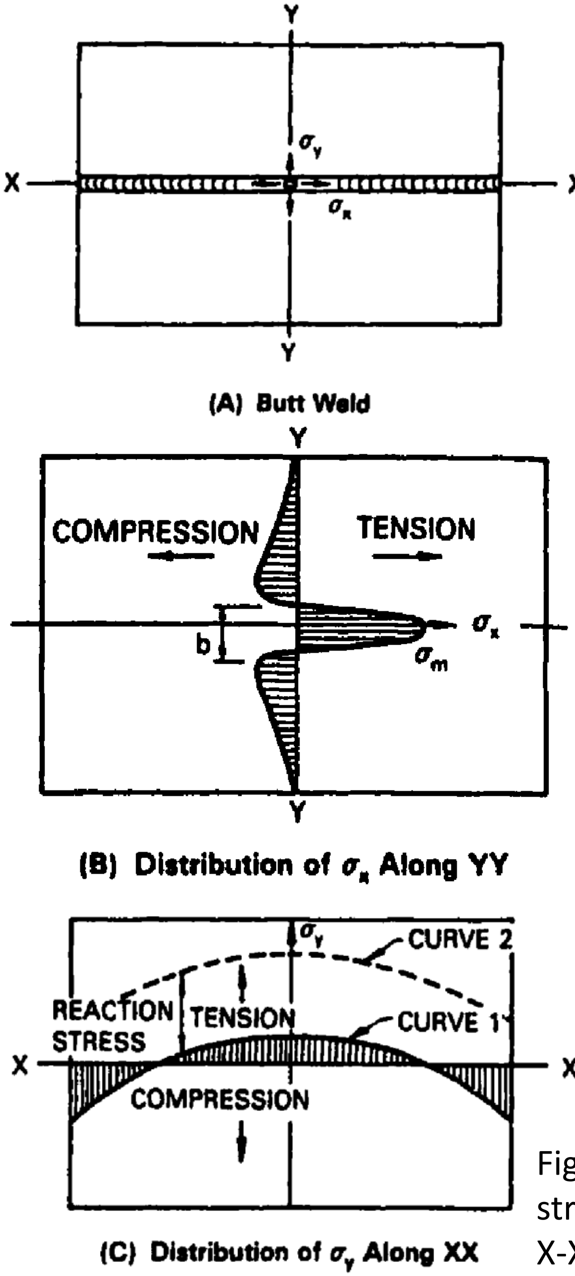
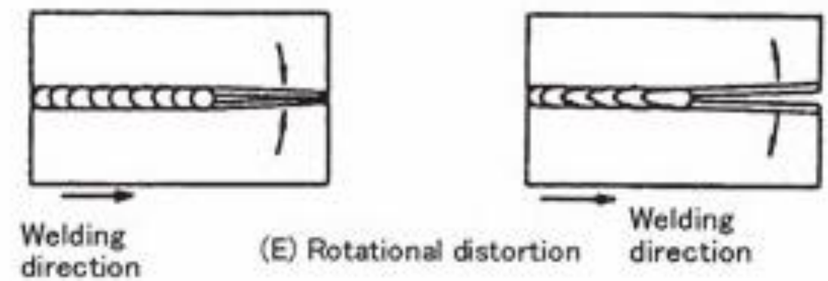


Fig. Typical distribution of residual stresses (a), section Y-Y (b), section X-X (c)

Residual stress and distortion in welded joint

Distortions , that are related to the shrinkage of the weld metal during cooling, can be subdivided into:

1. Transverse shrinkage – shrinkage perpendicular to the weld seam.
2. Longitudinal shrinkage – shrinkage in direction of the weld seam.
3. Angular distortion – transverse uplift caused by a non-uniform temperature distribution in the through-thickness direction. For instance in case of butt-joints with a V-groove.
4. Rotational distortion – in-plane angular distortion due to the localized thermal expansion and contractions. Very relevant for overlap joints, for instance.
5. Bending distortion – longitudinal uplift. The same causes as angular distortion.
6. Buckling distortion – caused by compressive stresses inducing instabilities in the plates.

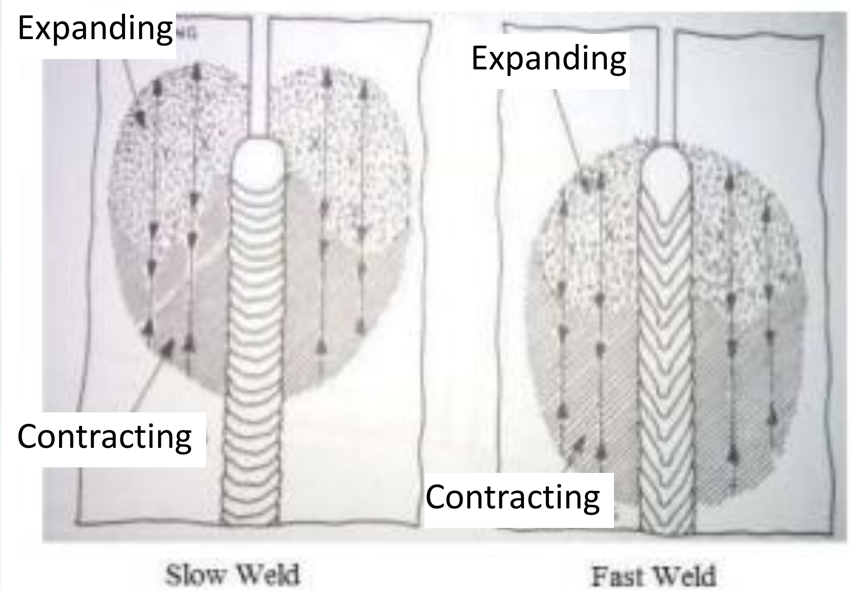


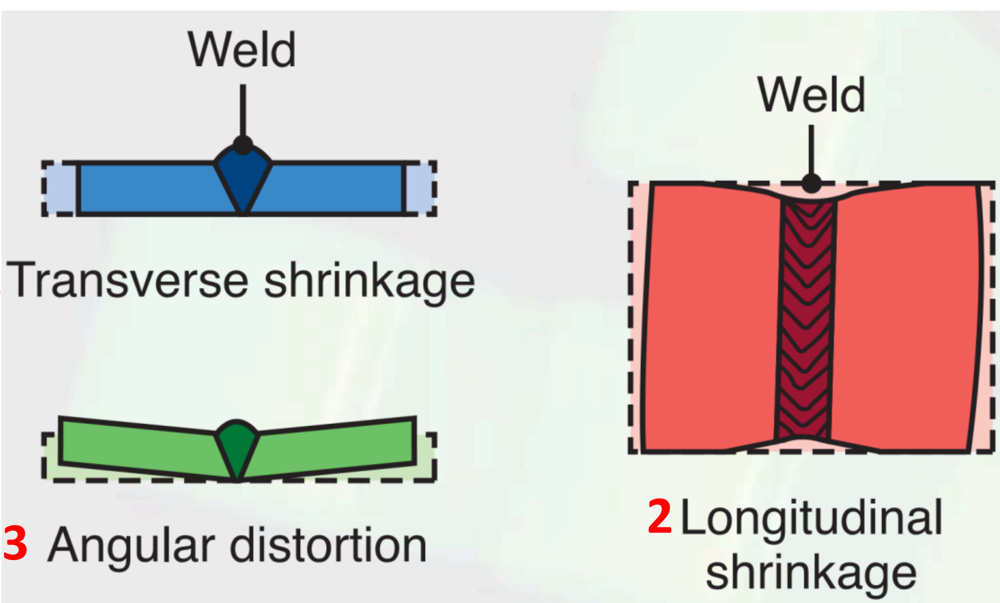
Slow weld - manual

Fast weld - automatic

4 Rotational distortion

Expanding & Contracting Zones in arc butt welding





Residual stress and distortion in welded joint

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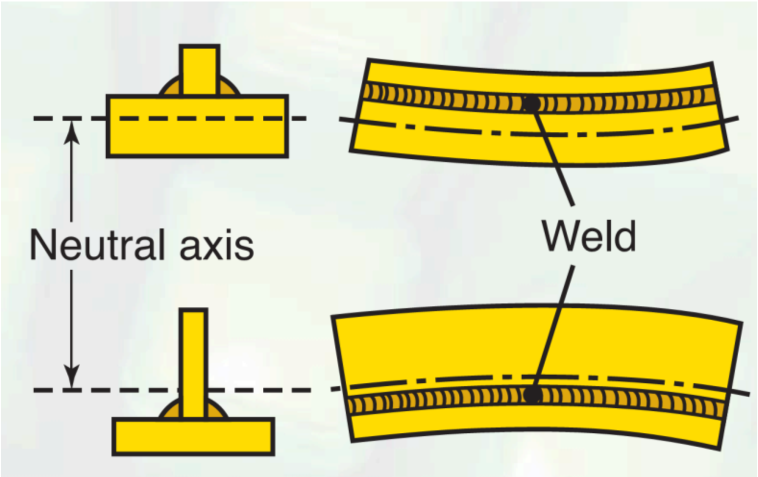
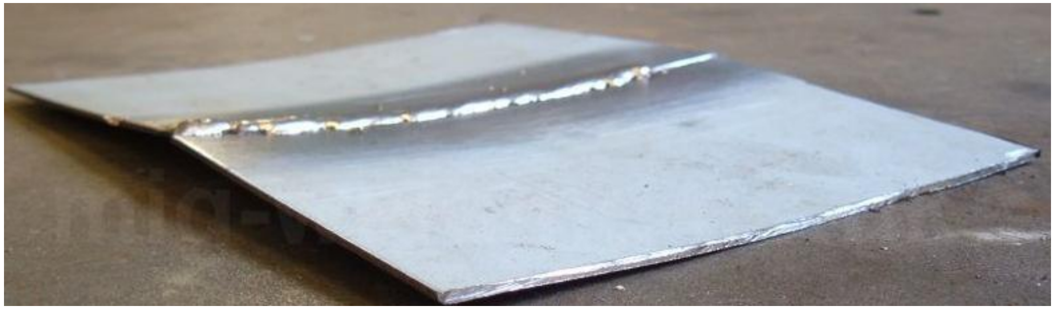
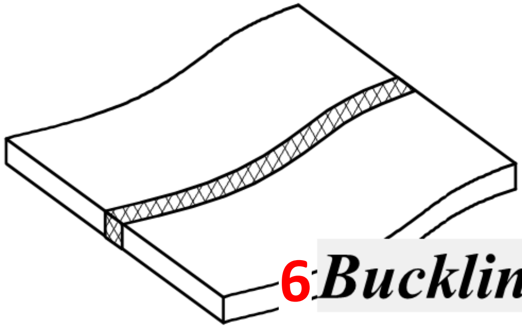


5 Longitudinal bending distortion





6 Buckling

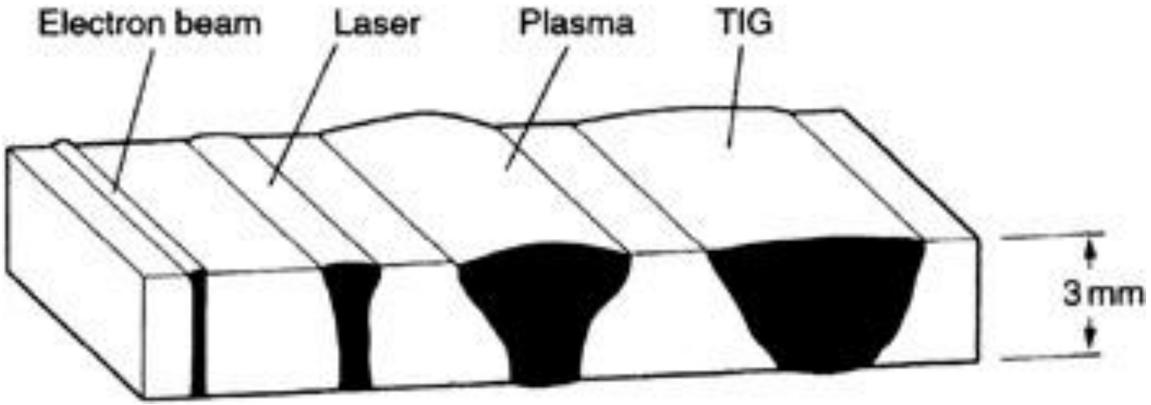
Residual stress and distortion in welded joint

Preventing residual stress (R) and distortions (D)

1. Pre-welding methods.
2. In-situ welding techniques.
3. Post-welding methods.

1. Pre-welding methods **(design engineer, process engineer)**

- use minimum required weld size (J or U preparations give smaller weld areas) (R $\downarrow$,D$\downarrow$),
- limit the heat input can also reduce distortion. A more intense heat source allows higher speed, lower heat input and less distortion (R $\downarrow$,D$\downarrow$),
- minimize constraint during welding (R $\downarrow$, D$\uparrow$).

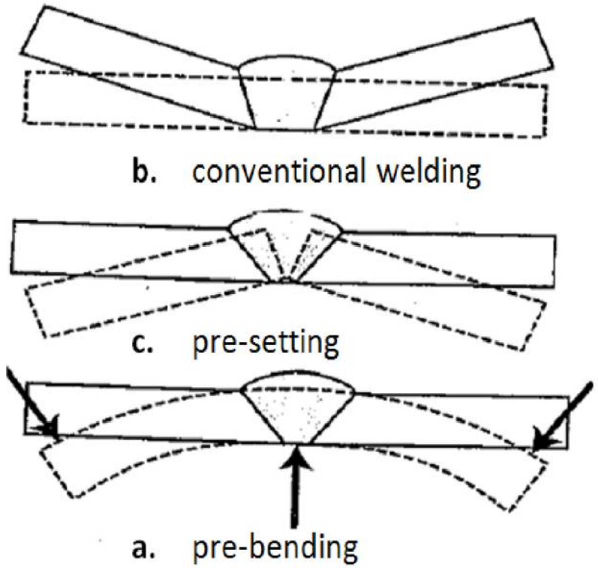


Residual stress and distortion in welded joint

Preventing residual stress (R) and distortions (D)

1. Pre-welding methods.
2. In-situ welding techniques.
3. Post-welding methods.

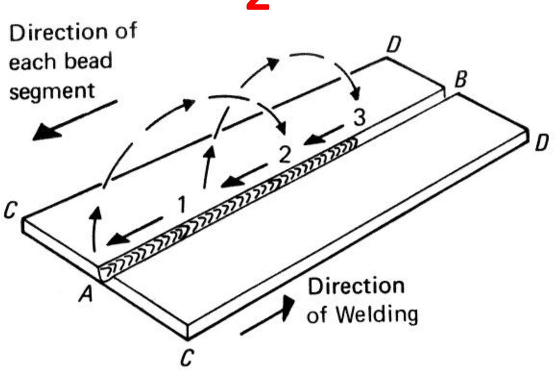
1



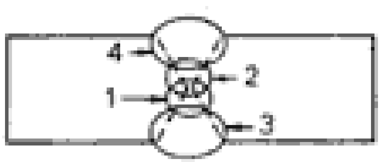
2. In-situ welding techniques

1. pre-shaping (D↓),
2. welding sequence/ backstep welding technique (R ↓,D↓),
3. rolling applied during welding (R ↓,D↓),
4. in-situ thermal tensioning stress/distortion mitigation techniques (D↓),
5. clamping (R↑,D↓).

2

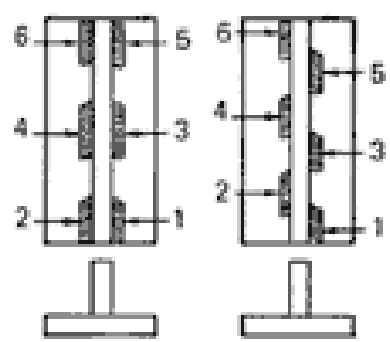


2



(k) Sequence Welds

2



(l) Sequence Welds

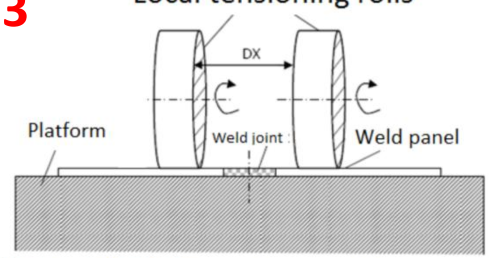
Preventing residual stress (R) and distortions (D)

1. Pre-welding methods.
2. In-situ welding techniques.
3. Post-welding methods.

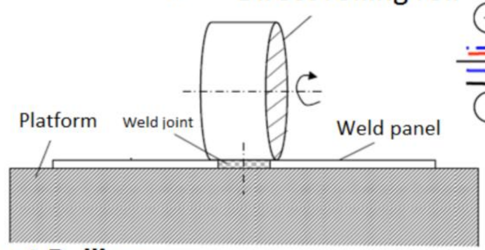
2. In-situ welding techniques

1. pre-shaping (D↓),
2. welding sequence/ backstep welding technique (R ↓,D↓),
3. rolling applied during welding (R ↓,D↓),
4. in-situ thermal tensioning stress/distortion mitigation techniques (D↓),
5. clamping (R↑,D↓).

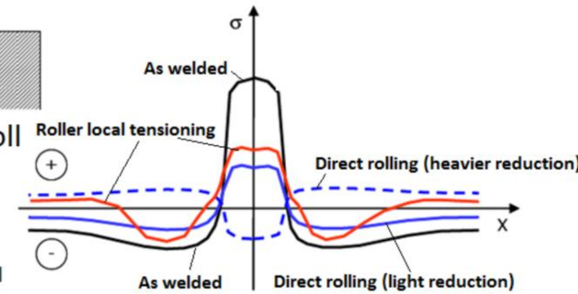
3



Roller tensioning



Direct Rolling



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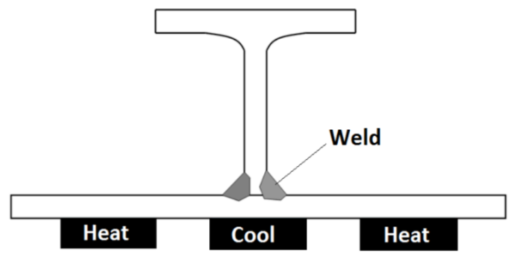
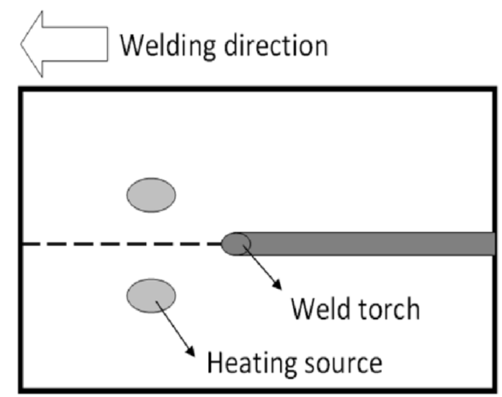


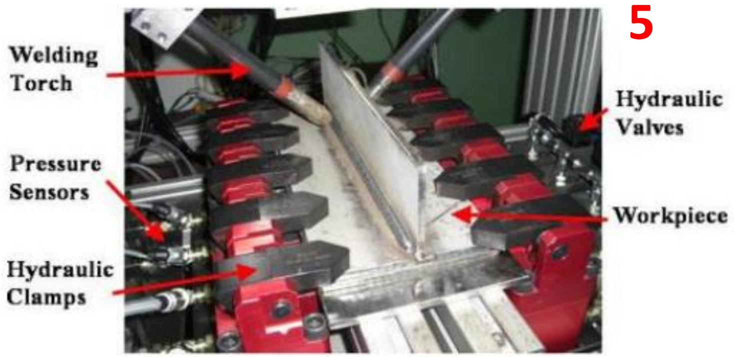
Schematic representation of static thermal tensioning process

4



Schematic presentation of dynamic thermal tensioning using heat sources

5

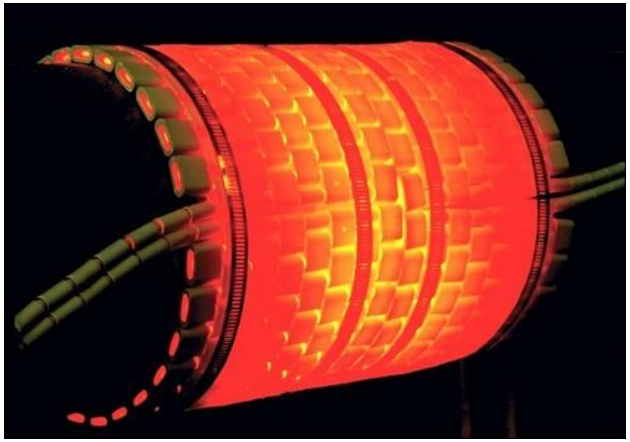


Residual stress and distortion in welded joint

Preventing residual stress (R) and distortions (D)

1. Pre-welding methods.
2. In-situ welding techniques.
3. Post-welding methods.

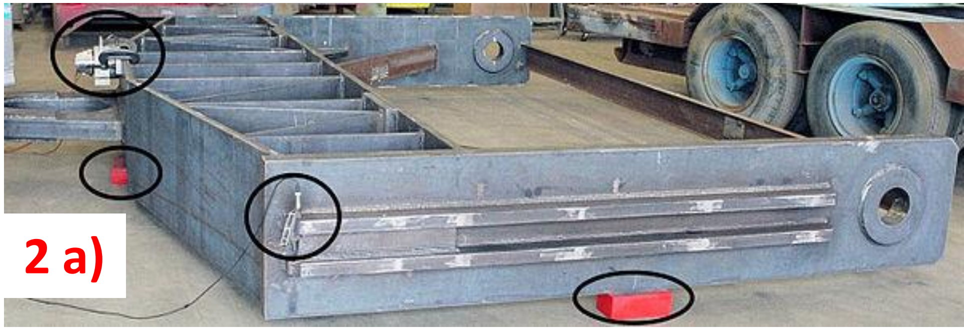
1



3. Post-welding methods

1. thermal method (e.g. annealing) (R ↓, possibly D ↑),
2. a) mechanical e.g. vibratory (R ↓), b) peening of weld area (R ↓), c) using external force (e.g. hydraulic press) (D ↓).

Vibration stress reduces the residual stresses by vibrating the material of its eigenfrequency with a small amplitude. In this method the residual stresses are reduced as a result of global or local plastic deformation.

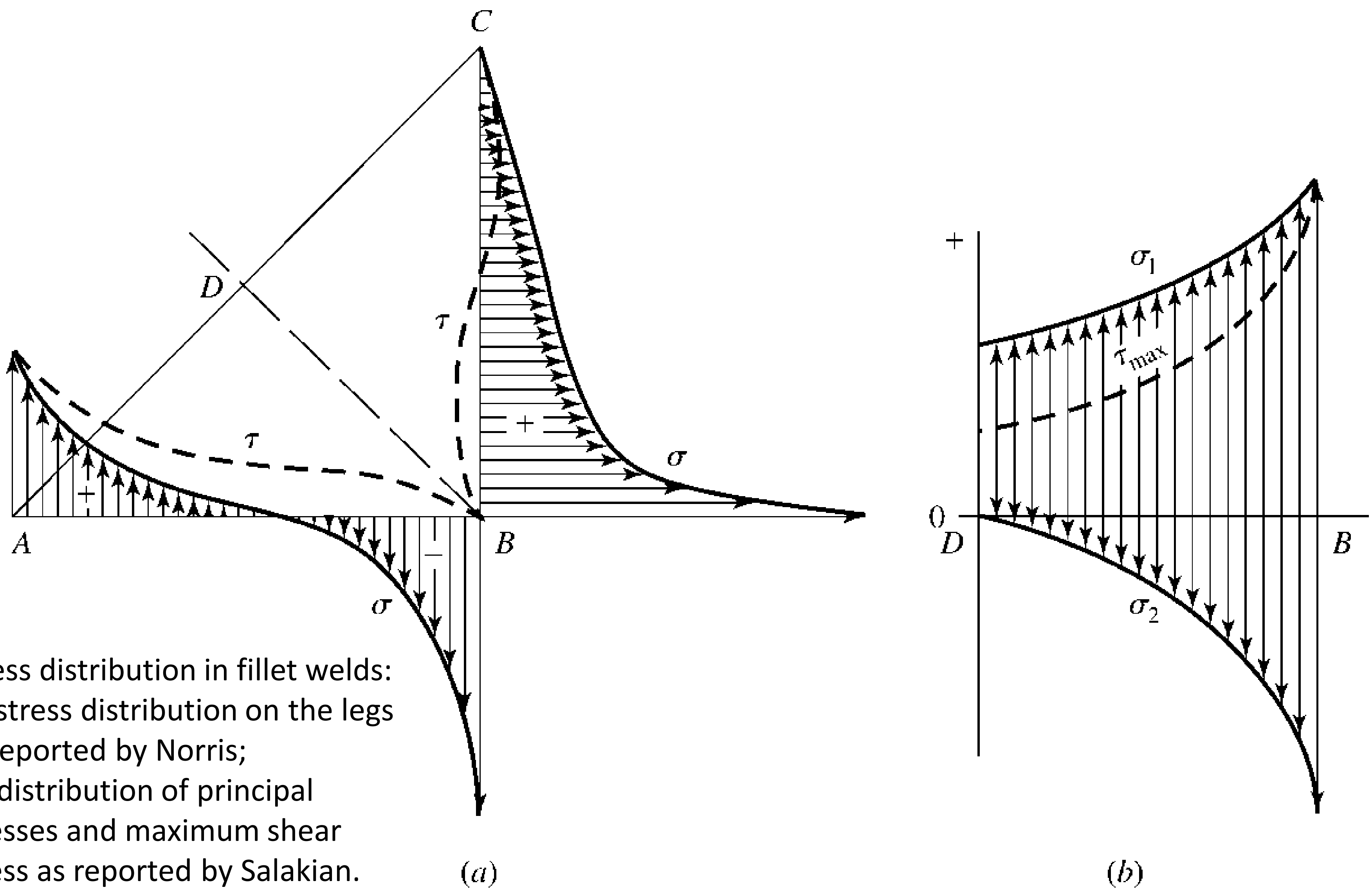


2 a)

Peening the weld bead stretches it and relieves the residual stresses. However, peening must be used with care. For example, a root bead should never be peened, because of the increased risk of concealing or causing crack. Also, peening is not permitted on the final pass, because it can cover a crack and interfere with visual inspection.

2 b)

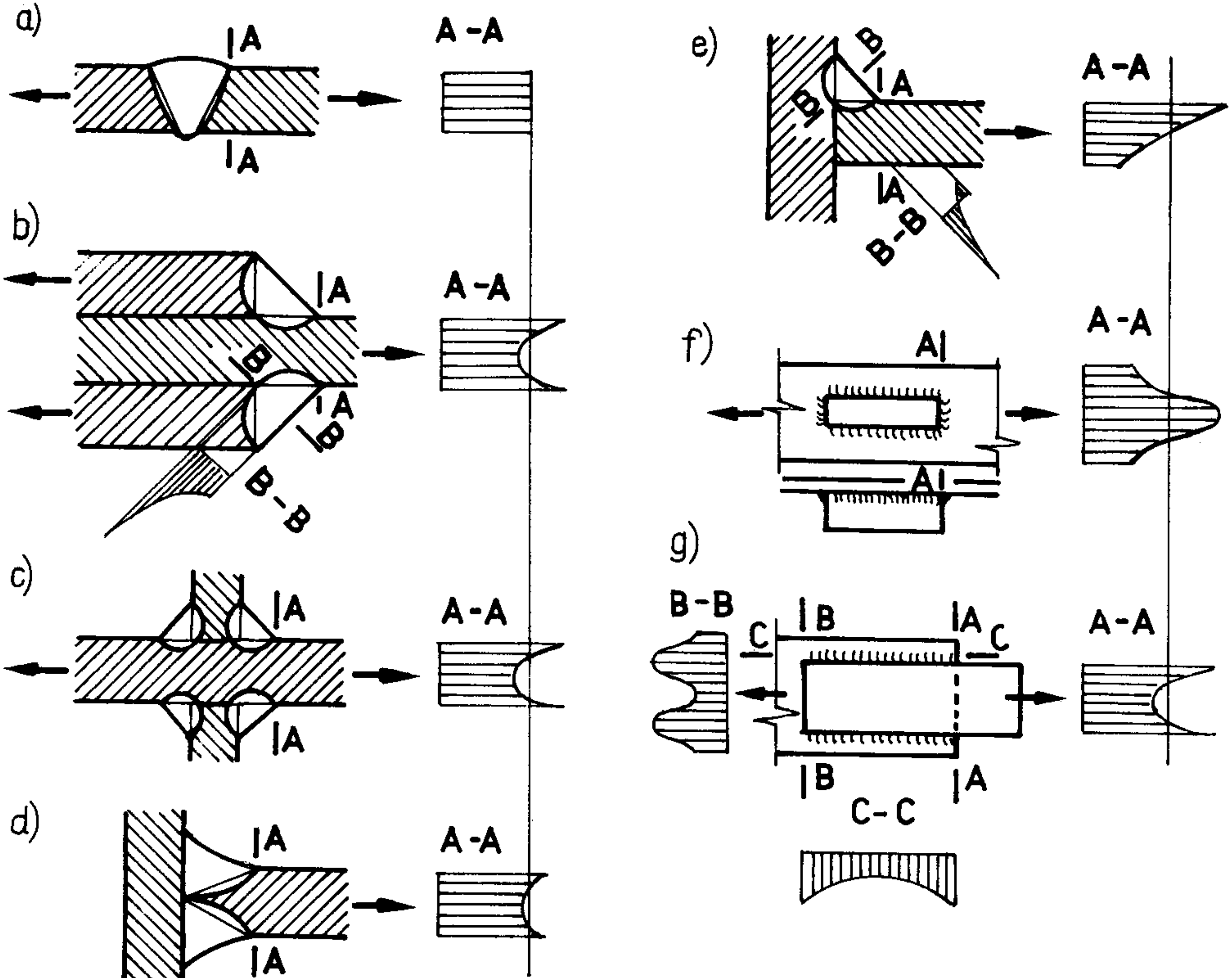
Distribution of compound stress in fillet weld



Stress distribution in fillet welds:
(a) stress distribution on the legs as reported by Norris;
(b) distribution of principal stresses and maximum shear stress as reported by Salakian.

Stress in welds

Distribution of compound stress in welds



Stress in welds

Stress in groove welds - static load

$$\sigma_t' = \frac{F}{A} \le k_t' = s \cdot k_t \text{ tensile stress}$$

$$\sigma_c' = \frac{F}{A} \le k_c' = s \cdot k_t \text{ compressive stress}$$

$$\sigma_b' = \frac{M_b}{W_x} \le k_b' = s \cdot k_t \text{ bending stress}$$

$$\tau_s' = \frac{F}{A} \le k_s' = s \cdot k_t \text{ shear stress}$$

$$\tau_{tor}' = \frac{M_t}{W_o} \le k_{tor}' = s \cdot k_t \text{ torsional stress}$$

$$\sigma_r' = \sqrt{\sigma^2 + 3\tau^2} \le k' \text{ compound stress}$$

$$k_t = \frac{S_y}{x_e}$$

k_t – permissible (allowable) tensile stress

S_y – yield strength

x_e – factor of safety (1,15 – 1,25), 1,6 in case where elastic-plastic deformation are not acceptable

s – factor of weld strength

Stress in welds

Stress in groove welds - static load

Tab. Values of *s* factor for steel*

Type of stress	$S_y \leq 255$ [MPa]	255 [MPa] $\leq S_y \leq$ 355 [MPa]	355 [MPa] $\leq S_y \leq$ 460 [MPa]
Compressive, compressive + bending	1,0	1,0	1,0
Tensile, tensile + bending	0,85*	0,8*	0,8*
shear	0,6	0,6	0,6

*For welds checked (controlled) by defectoscopy methods (radiography, ultrasonic) value is equal 1

Value of factor of weld strength ***s*** have to be decreased:

a) 10 % for field or site weld
b) 20 % for overhead weld
c) 30 % when case a) and b) occur simultaneously

Stress in welds

Stress in fillet welds - static load

$$\tau_t' = \frac{F}{A} \le k_t' = s \cdot k_t \text{ tensile stress}$$

k_t – permissible (allowable) tensile stress

$$\tau_c' = \frac{F}{A} \le k_c' = s \cdot k_t \text{ compressive stress}$$

$$\tau_b' = \frac{M_b}{W_x} \le k_b' = s \cdot k_t \text{ bending stress}$$

$$\tau_s' = \frac{F}{A} \le k_s' = s \cdot k_t \text{ shear stress}$$

$$\tau_{tor}' = \frac{M_t}{W_o} \le k_{tor}' = s \cdot k_t \text{ torsional stress}$$

Compound stress – we are adding stress like vectors e.g.

$$\tau_r' = \sqrt{\left(\tau_t' \pm \tau_b'\right)^2 + \tau_s'^2} \le k' = s \cdot k_t$$

Stress in fillet welds - static load

Tab. Values of *s* factor for steel [Dietrich]

Type of stress	$S_y \leq 255$ [MPa]	255 [MPa] $\leq S_y \leq$ 355 [MPa]	355 [MPa] $\leq S_y \leq$ 460 [MPa]
All types of stress	0,8	0,7	0,6

Tab. Values of *s* factor for steel [Skoć]

Type of stress	$S_y \leq 255$ [MPa]	255 [MPa] $\leq S_y \leq$ 355 [MPa]	355 [MPa] $\leq S_y \leq$ 460 [MPa]
All types of stress	0,65		

Value of factor of weld strength ***s*** have to be decreased:

a) 10 % for field or site weld

b) 20 % for overhead weld

c) 30 % when case a) and b) occur simultaneously

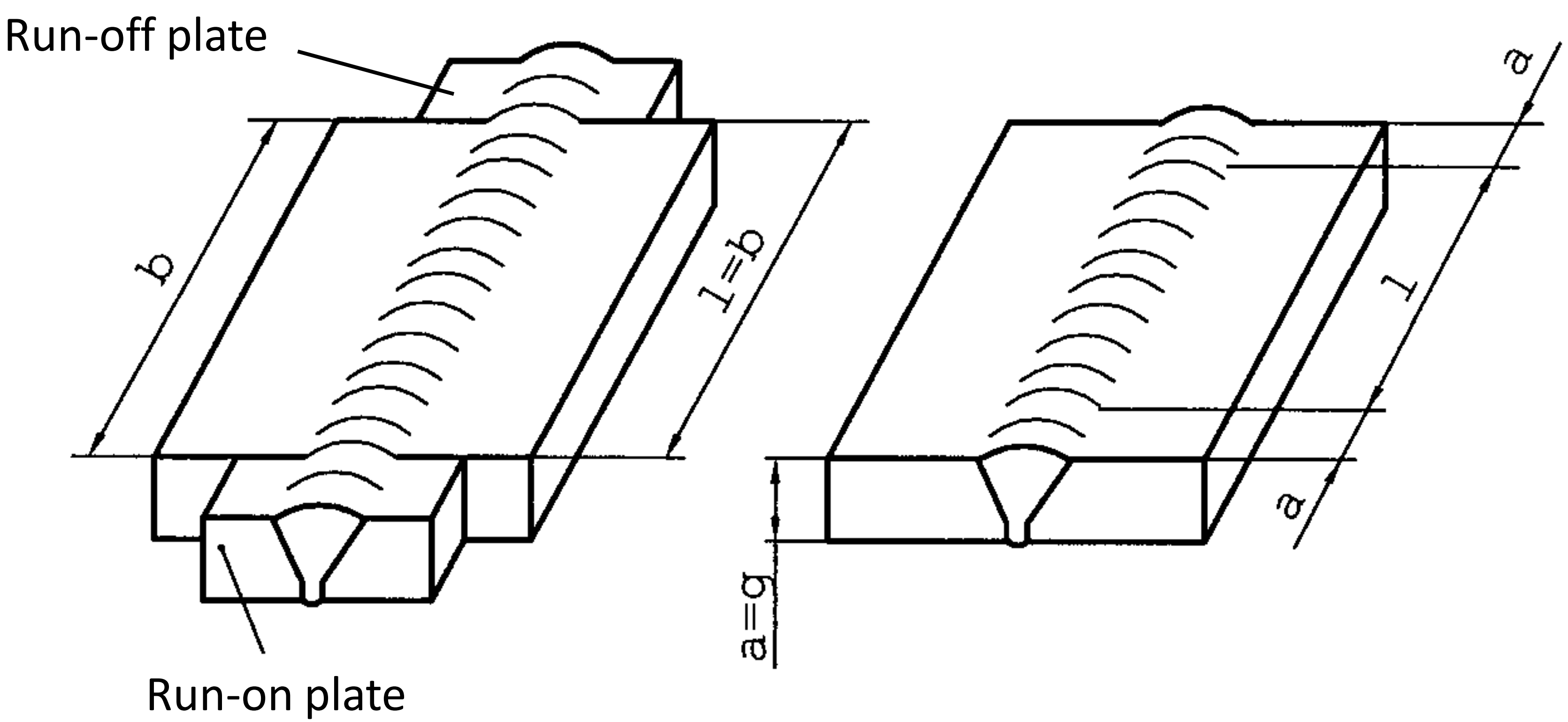
Effective weld area

Groove welds – effective length *l*

With run on and off plates $l = b$

Without run on and off plates $l = b - 2a$

(Craters are formed at the ends of the weld. Crater – part of weld that has not proper dimensions and incomplete penetrates the material)



Effective weld area

Crater

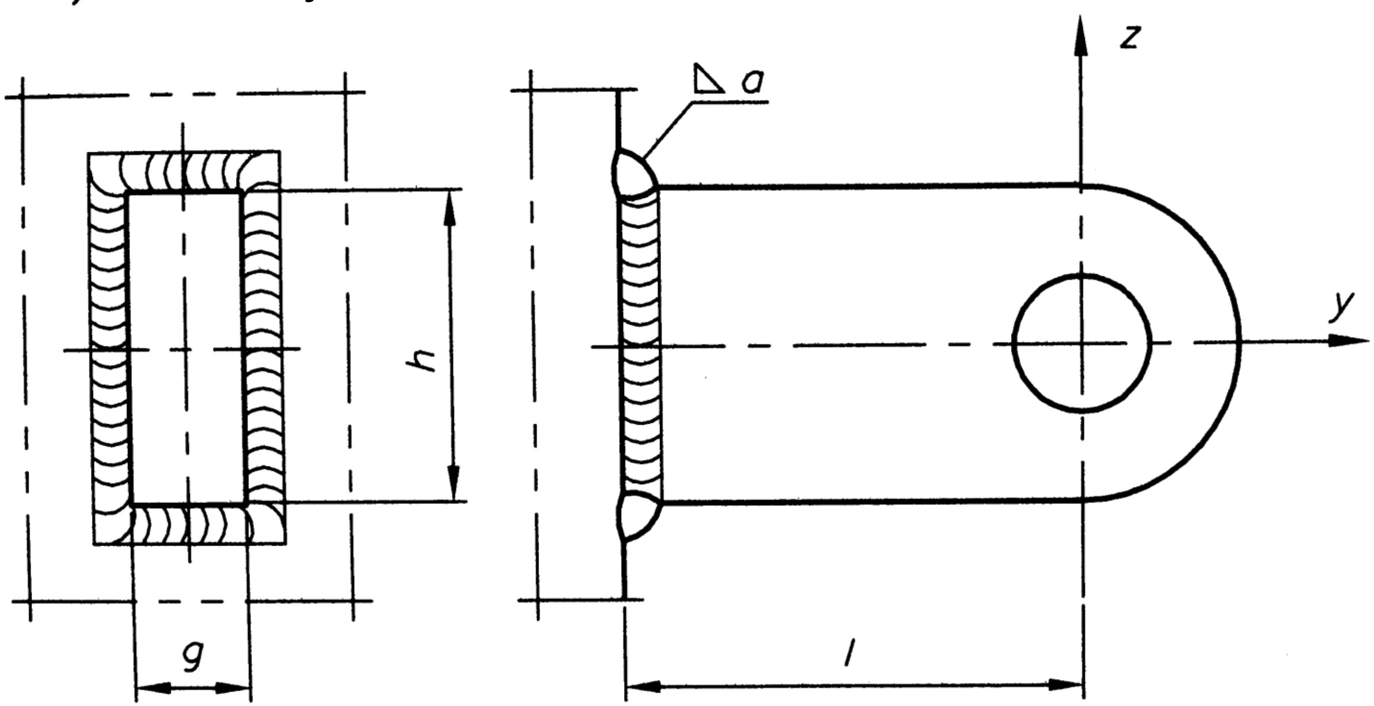
Effective weld area

Fillet welds – effective length *l*

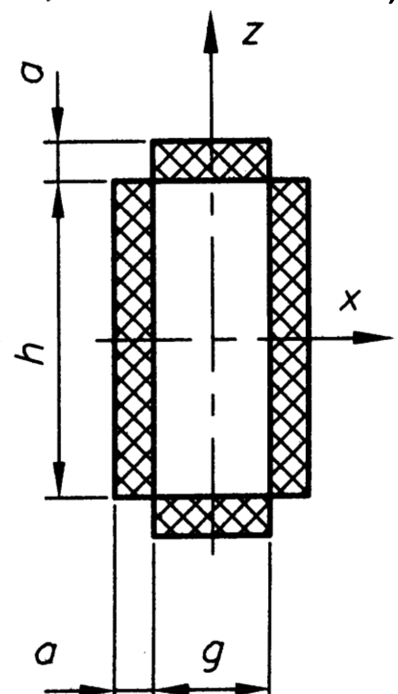
Effective length of fillet weld is calculated similar like groove weld. With run on and off plates $l = b$. Without run on and off plates $l = b - 2a$.

For welds that have the same start and stop location length is equal the dimensions of the element (see figure below).

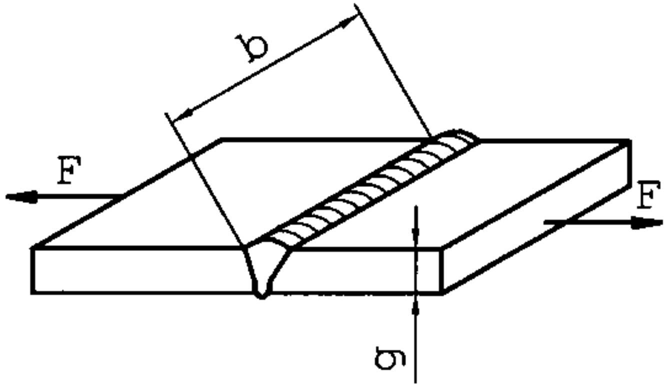
a) View of joined elements



b) Effective length of fillet weld ***h***, ***g***

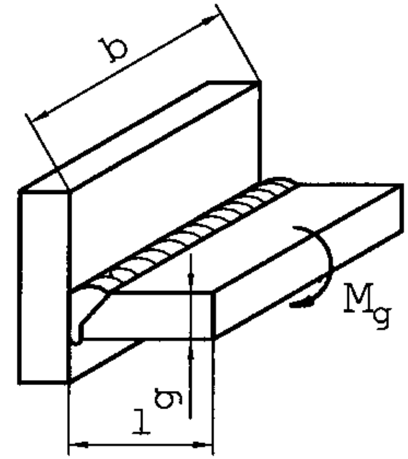


Stress analysis for common type of loading – groove weld



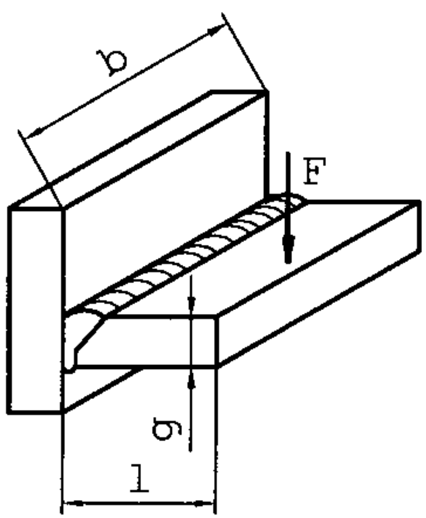
$$\sigma_t' = \frac{F}{A} \le k_t' = s \cdot k_t \text{ tensile stress}$$

A - cross section area of weld

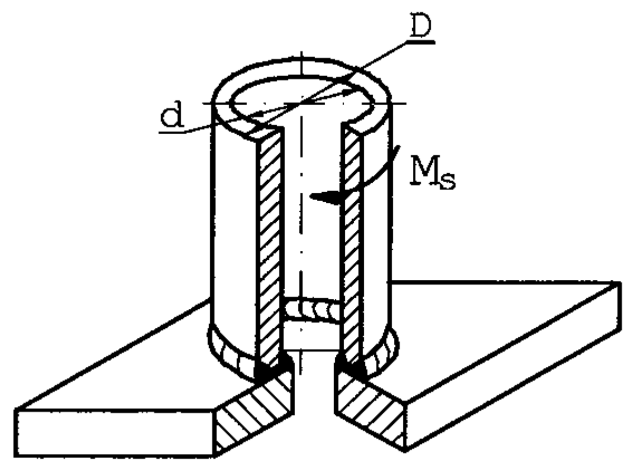


$$\sigma_b' = \frac{M_b}{W_x} \le k_b' = s \cdot k_t \text{ bending stress}$$

W_x – section modulus of bending



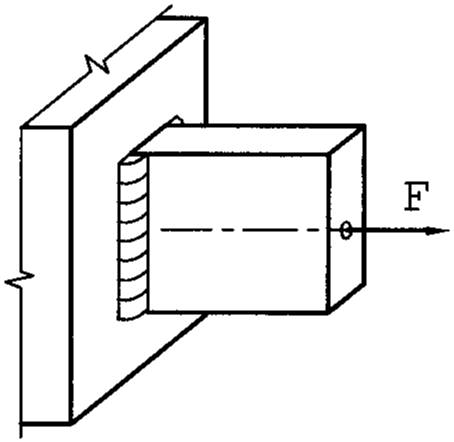
$$\sigma_{red}' = \sqrt{\sigma_b'^2 + 3\tau_t'^2} \le k_b' = s \cdot k_t \text{ bending and shear stress}$$



$$\tau_{tor}' = \frac{M_t}{W_o} \le k_{tor}' = s \cdot k_t \text{ torsional stress}$$

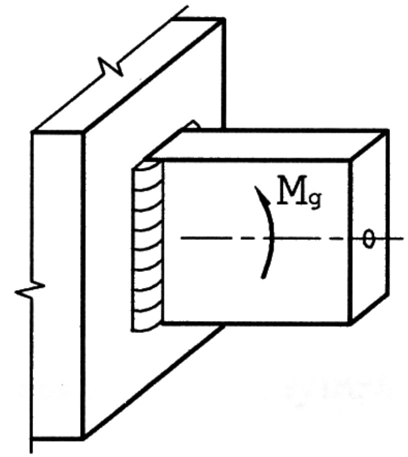
W_o – section modulus of torsion

Stress analysis for common type of loading – fillet weld



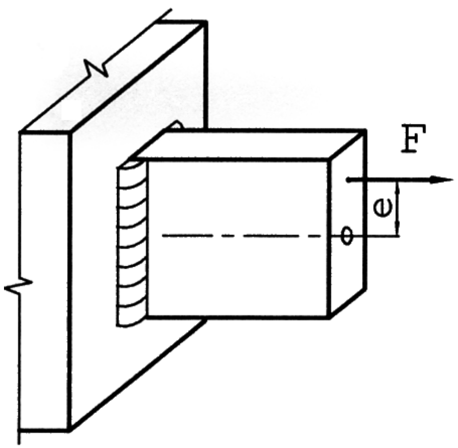
$$\tau_t' = \frac{F}{A} \le k_t' = s \cdot k_t \text{ tensile stress}$$

A - cross section area of weld(s)

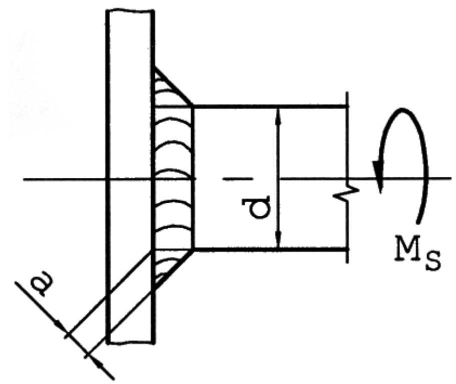


$$\tau_b' = \frac{M_b}{W_x} \le k_b' = s \cdot k_t \text{ bending stress}$$

W_x – section modulus of bending



$$\tau_{red}' = \tau_b' + \tau_t' \le k' = s \cdot k_t$$

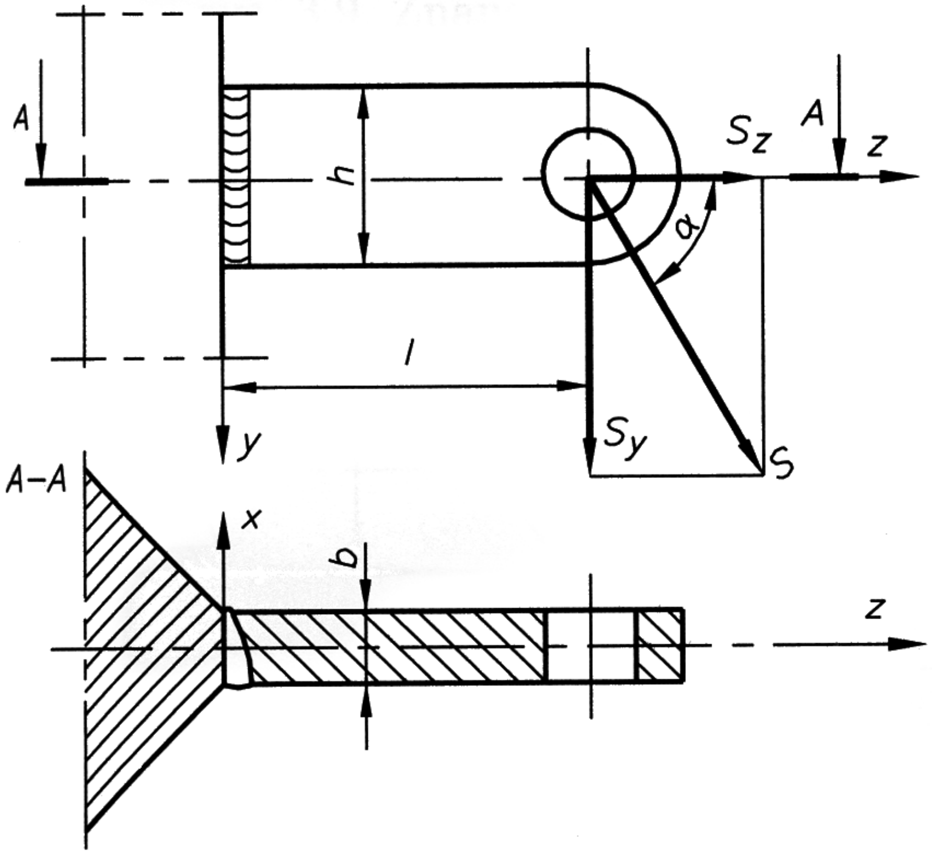


$$\tau_{tor}' = \frac{M_t}{W_o} \le k_{tor}' = s \cdot k_t \text{ torsional stress}$$

W_o – section modulus of torsion

Stress analysis for common type of loading

Example



Calculate maximum stress in a groove weld and check if this weld is design properly (compare max. stress with permissible stress)

Components of force *S*

$$S_z = S\cos\alpha$$

$$S_y = S\sin\alpha$$

Cross section of groove weld *A*

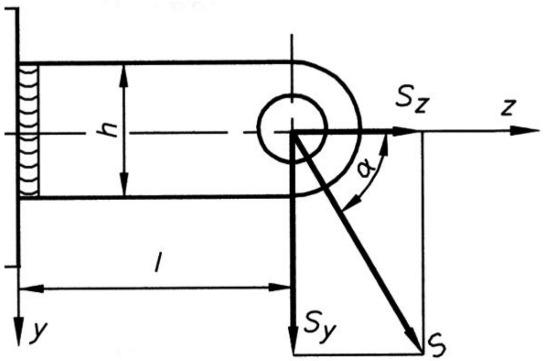
$$A = bh$$

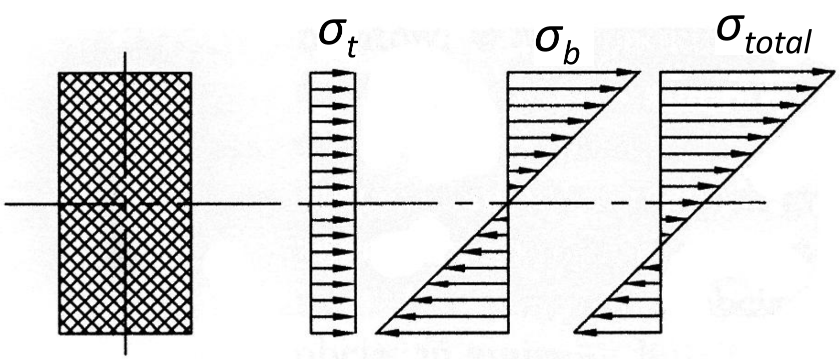
Section modulus of bending W_x

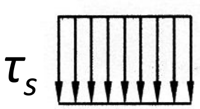
$$W_x = \frac{bh^2}{6}$$

Stress analysis for common type of loading

Example







Tensile stress

$$\sigma_t' = \frac{S_z}{A}$$

Bending stress

$$\sigma_b' = \frac{S_y \cdot l}{W_x}$$

Shearing stress

$$\tau_s' = \frac{S_y}{A}$$

Reduced stress

$$\sigma_{red}' = \sqrt{(\sigma_b' + \sigma_t')^2 + 3\tau'^2_s} \leq k_b' = s \cdot k_t$$