WELDING

INTRODUCTION:

Welding consists of heating two metal surfaces to liquid form and joining them with or without th addition of other molten metal(filler metal).Welding has been used throughout the ages (since 3000 years). Actually it started with forging.Metals were heated up and then hammered together.This way most of the weapons of the iron age were made.

Arc welding as used in engineering uses an electric arc to produce the heat necessary to join the metals. Electric arc was invented by Sir Humphrey Davy in 1801.Earliest arcs were of carbon. These produced very brittle welds.Metal electrodes were introduced much later.Welding has been in wide use since the last 50 years.

In the beginning engineers were sceptical.They thought welded connections had poor fatigue strength.However tests have shown that properly made welded connections have fatigue strengths at least as good as riveted or bolted connections.Strict weld specifications ensure good quality.

Advantages of welding:

1)ECONOMY = There are fewer or no gusset plates in welded connections.This may result in saving of 15% in material cost.Economy also in the sense that welding is more suitable for automatic fabrication.

2)Greater application than other connection means.

3)More rigid connections are possible since connections are direct. (member to member).

4)Welded connections provide greater continuity and make for slenderer structures.

5)Easier to make changes in design,easier to correct fabrication errors.

6)Silence of operation.(compared to riveting)

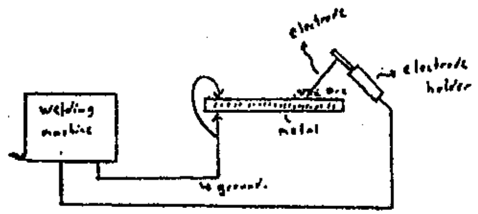
7)Fewer pieces to deal with,in design and in erection.Moreover no deductions in areas.

2.) BASIC PROCESSES:

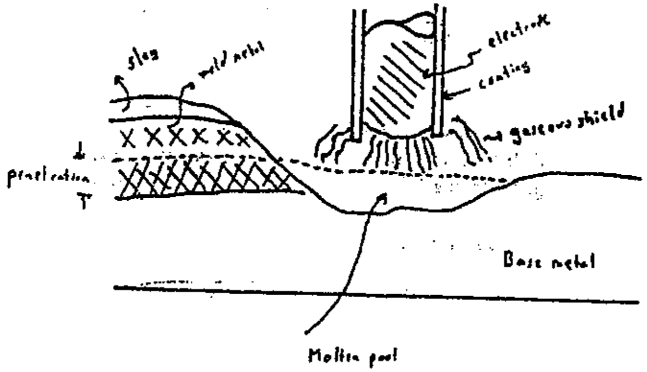
In structural engineering only electric arc welding and for light gage steel,resistance welding is commonly used.Gas welding (using a gas torch to heat metal surfaces without the use of an electric arc and without an electrode.) is not an acceptable means of making load carrying connections.

2.1. Electric arc welding:

2.1.1.Shielded metal arc welding:

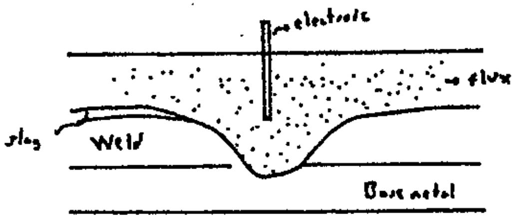


In its manual form shielded metal arc welding produces an arc between the electrode and the metal.The heat produced by the arc is about 3500 C . This heat melts the metal and the electrode fuses them.Usually the electrode is coated.Under the heat of the arc the coating provides a gaseous shield so that air (oxidation)doesn't enter into the connection.Otherwise weld becomes brittle and porous with pockets of air.



2.1.2. Submerged (hidden) arc welding. (tozaltı kaynak)

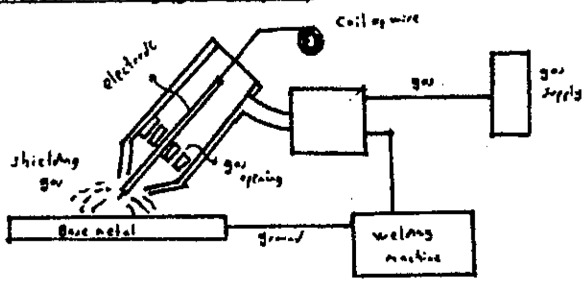
In this process the arc is not visible.It is covered with a layer of granular,agglomerated flux.A bare electrode wire coiled on a rod is fed continuously into the arc by mechanically driven rolls. Current is fed to the wire through contact jaws between which the wire passes.



This process is most adaptable for automatic operations,"shop welding".The quality of welds produced this way is high (good ductility,high impact strength,high density,good corrosion resistance)

This process is used to fabricate plate girders,columns,built up sections.

2.1.3.Gas Metal Arc Welding:(gazaltı kaynak)

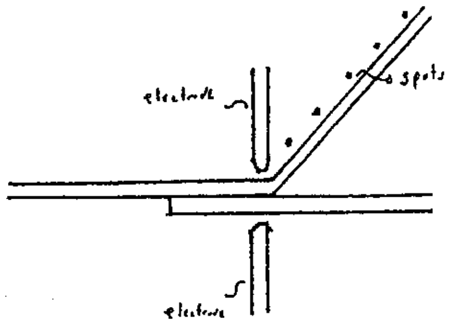


Electrode is a continuous wire fed from a coil to a gun shaped device and shielding is provided by an external gas source,or gas mixture.Usually CO_2 or argon is used as shielding.By mixing CO_2 with an inert gas metal spatter is reduced.

This is used to weld structural shapes,pipes etc.

2.2.Resistance Welding:

This type of welding is used to join light gage members.In its most common form two electrodes are used to clamp to this plates together.A current passed through the electrodes melts the pieces locally and the clamping pressure forms a fused spot.



3.SHRINKAGE AND RESIDUAL STRESSES:

Due to presence of heat in welding metals ,sometimes shrinkage occurs.If the elements are not restraint and if they are slender they may deform(especially thin plate elements)If they are restraint then residual stresses may develop.Engineer uses his judgement to strike a tolerance between the two effects.

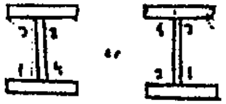
3.1.Shrinkage control:

These are highly exaggerated drawings illustrating the shrinkage disHxrtions in welds.

To avoid the distortions, elements may be

- Preset and restraint

- Order of welding may be arranged so as to minimize distortions.



- Element may be preheated so as to limit differential cooling.

- By proper designs engineers do not specify over-welding .This is particularly important for this country.

Since many designers think that more weld area make for better stronger connections.This totally false.

To reduce residual stresses:

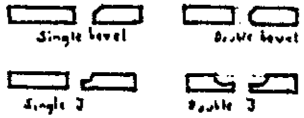
Heat treatment after welding (stress relieving) is one technique used for this purpose.Welded pieces are put in stress relieving ovens and then cooled slowly.
Sometimes its better to preheat elements rather than post heat them.

4.WELD INSPECTION:

Every important weld needs to be inspected to ensure good quality.Inspection techniques are:
- Visual Inspection - welds should be the same color as the base metal.Its size should be right.
-Radiographic inspection (x rays)
is used to detect air pockets.It is good but expensive.
-Magnetic particle,dyepenetrant methods
are used to check fillet welds.
-Ultrasonic techniques
Use sound waves to determine detect the presence of cracks and air pockets.

5.WELD TYPES

5.1.Butt welds

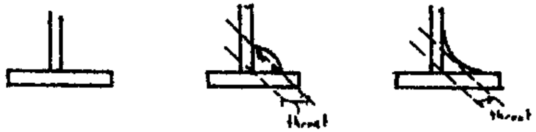


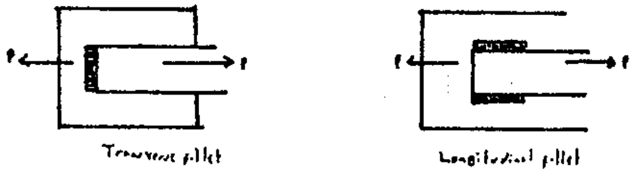
Butt welds have same allowable stresses as the metals they connect.

Usually joints are prepared for butt welding.Design is made by using the same allowable stresses as the connected elements.Butt or groove welds may involve several passes.It is a more expensive type of weld.

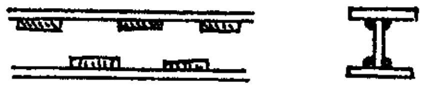
5.2.Fillet welds:

Most common weld type is fillet welds.Joints do not require any preparation.Critical dimension of the fillet is the throat and the critical stress in the throat is shear.

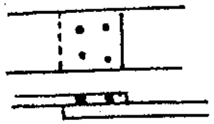




In the American practice all loads are combined in a single resultant and the weld throat dimension*length*weld shear allowable is checked against the load.



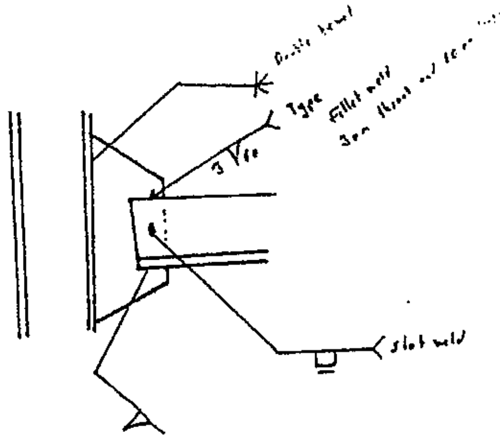
5.3. Plug welds, slot welds



Plug welds

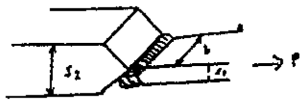
Slot welds.

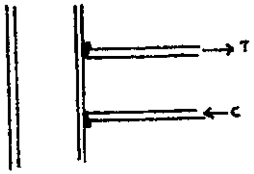
Sometimes clearance requirements do not permit fillet welds they plug or slot welds may be used. It is more difficult to inspect such welds.

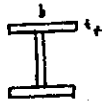


6. DESIGN OF WELDS:

Butt welds:

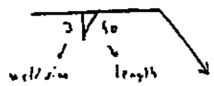




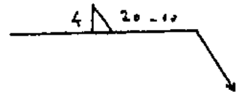


$P_{max} = S_1 . b . \sigma_{all}$

$C = T = b . t_f . \sigma_{all}$



Fillet weld on near side



Fillet weld on far side

20 mm length with 10 mm spacing.

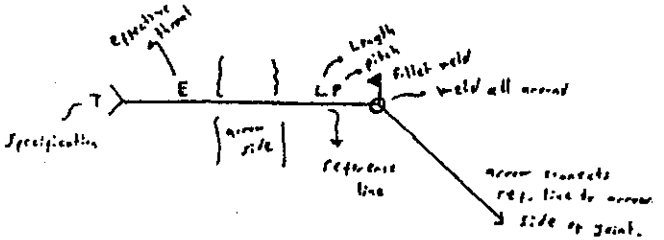
Recommended a

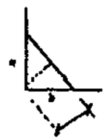
$$a = \sqrt{t_2 - 0.5} \geqslant 3 \text{ mm}$$

(t_2: thicker plate)

WELD SYMBOLS:

Back	Fillet	Plug or slot	Groove or butt					
			Square	Bevel	V	U	J	Flare V
◠	◺	▭	||	|/	V	Y	|/	Y



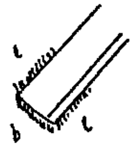


$$t_e = \frac{ab}{\sqrt{a^2+b^2}}$$

Length of fillet welds

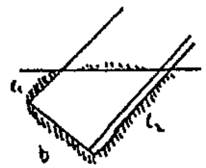
$100\text{ mm} \geqslant \ell \geqslant 15\text{ mm}$

$L = 2\ell$



$100\text{ mm} \geqslant \ell \geqslant 10\text{ mm}$

$\ell = b + 2\ell$



$\ell_1 \geqslant 10\text{ mm}$

$\ell_2 \leqslant 100\text{ mm}$

$\Sigma \ell = \ell_1 + \ell_2 + 2b$

TS 3357 (DIN 4100) PROVISIONS

FILLET WELDS

Recommended a (throat dimension) is given by $a = \sqrt{t_2 - 0.5} \geqslant 3\,mm$

where t_2 is the thicker part joined (mm)

$a_{max} = 0.7\, t_{min}$

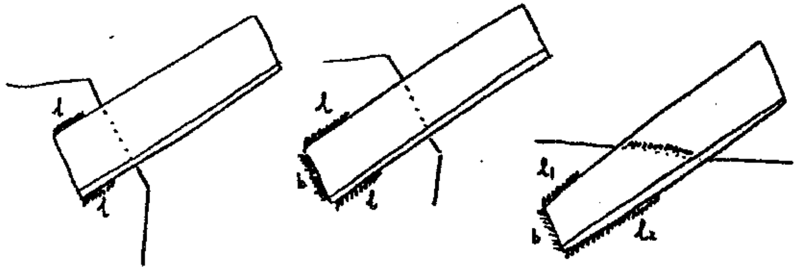
BUTT WELDS a must be equal to the thickness of the thinnest plate being welded.

NOTE: ① Only St 37 and St 52 can be welded according to DIN 4100

② The a values are different for submerged welding:

Because of deeper penetration $a_{nominal} = a + \frac{\min e}{2}$

LENGTHS OF FILLET WELDS (All welds assumed with throat "a")



Total weld length: $(2l)$ $(2l+b)$ $(l_1 + l_2 + 2b)$

Here the length of an individual weld must satisfy:

$15a < l < 100a$ $10a < l < 100a$ $10a < l_1$

$l_2 < 100a$

NOTE: $l_{net} = l_{1,2} - 2a$ OR $l_{1,2} = l_{net} + 2a$
(See Ex. 1)

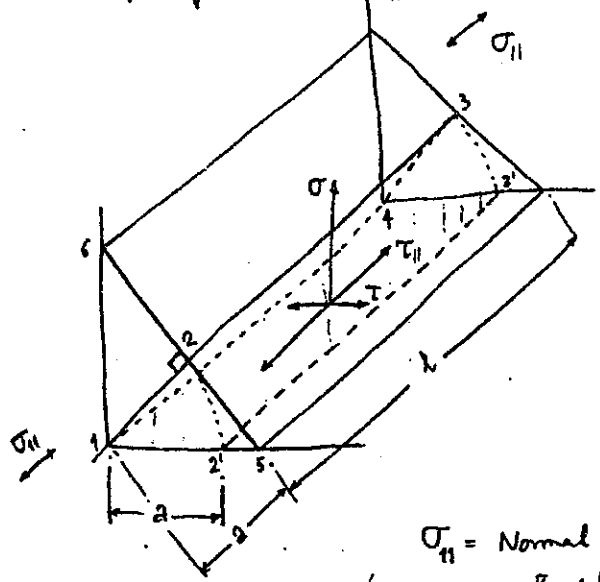
Where the provisions of Section 3.4.2 do not apply the resultant stress σ_V shall be less than the allowable stress as given in Table VII.6

DESIGN EQUATIONS (BASED ON DIN 4100) FOR FILLET WELDS

At a point in a weld, there are, in general, 3 stresses due to forces [one normal and two shear, denoted by σ', τ' and τ'_{11}] and 3 stresses due to moments [denoted by σ'', τ'' and τ''_{11}]. The algebraic addition of these stresses gives, respectively, σ, τ and τ_{11}.

DIN 4100 calculates an equivalent stress σ_V as:

$$\sigma_V = \sqrt{\sigma^2 + \tau^2 + \tau_{11}^2}$$



On an idealized version of a fillet weld as shown

σ = Normal stress on plane 1 2'3'4

τ = Shear stress (transverse)

τ_{11} = Shear stress (longitudinal)

σ_{11} = Normal stress on face 156 (not used in the calculation of the equivalent stress)

From Section 3.4.2 of DIN 4100:
There is no need to check the σ_V value for the following cases:

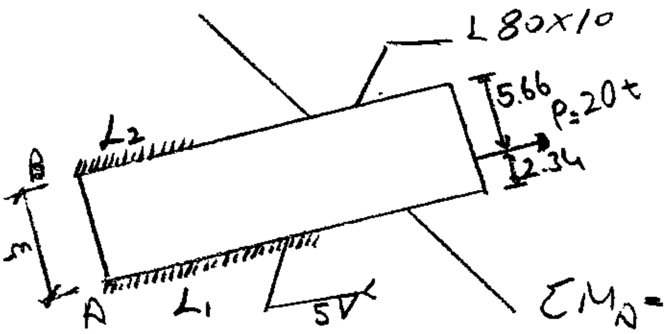
(i) In fillet welds where $\sigma = 0$ and $\tau = 0$.

(ii) In a connection which is subject to moment, shear force and axial force, if the following assumptions are satisfied:
1. Moment is carried by the flange welds
2. Shear force is carried by the web welds
3. Axial force is carried by all welds

iii) Table VII.5 is satisfied

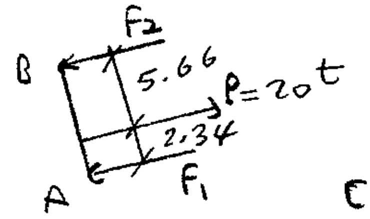
WELDING

EXAMPLE PROBLEM #1



Design 5mm welds to reduce the eccentricity to a minimum. ST 37 steel. TS 3357, EY loading

$\Sigma M_A = 0$



$20 \times 2.34 - F_2 \times 8 = 0 \qquad F_2 = \dfrac{20 \times 2.34}{8} = 5.85 \text{ ton}$

$F_1 = 20 - F_2 = 20 - 5.85 = 14.15 \text{ ton}$

CHECK $\Sigma M_B = 0$

$F_1 \times 8 - 5.66 \times 20 = 0 \therefore F_1 = \dfrac{5.66 \times 20}{8} = 14.15 \text{ tons}$ OK

DESIGN THE WELD LENGTH

ALLOWABLE STRESS $(\tau_{\parallel})_{all} = 750\ kgf/cm^2$ (TABLE 4, TS 3357)
(TABLE VII-5 p 307)

$$(L_1)_{net} = \frac{F_1}{(\tau_{\parallel})_{all} \times 0.5} = \frac{14.15}{0.75 \times 0.5} = 37.73 \text{ cm}$$

$$(L_2)_{net} = \frac{F_2}{(\tau_{\parallel})_{all} \times 0.5} = \frac{5.85}{0.75 \times 0.5} = 15.6 \text{ cm}$$

End craters $= a = 0.5$ cm $\Rightarrow L_1 = (L_1)_{net} + 2a = 37.73 + 1.0 = 38.73 \sim 39$ cm

$L_2 = (L_2)_{net} + 2a = 15.6 + 1.0 = 16.6 \sim 17$ cm

CHECK MIN & MAX LENGTH

$15a = L_{min} = 15 \times 0.5 = 7.5$ cm OK

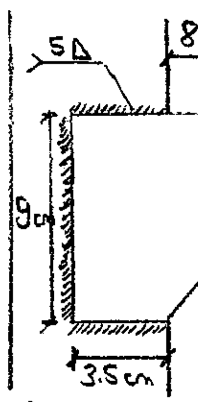
$100a = L_{max} = 100 \times 0.5 = 50$ cm OK

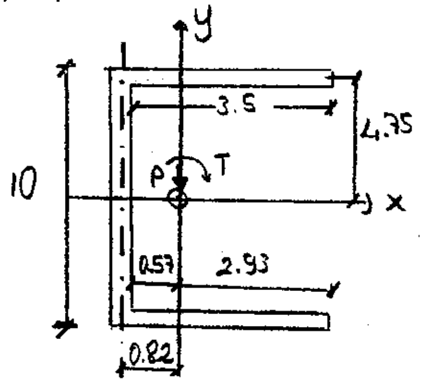
USE $L_1 = 39$ cm

$L_2 = 17$ cm

EXAMPLE PROBLEM # 2

Determine P_{all} for the short cantilever shown.





Notes: 3.5 cm $\angle$ 10 × 0.5

$\angle$ 5 cm

Weld length is not OK.

$A = (10 + 2 \times 3.5)\,0.5 = 8.5\ cm^2$

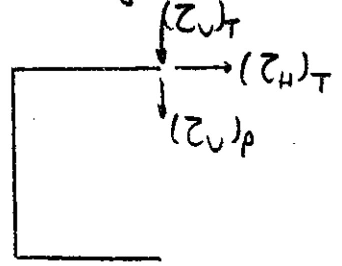
$$\bar{x} = \frac{(2 \times 3.5 \times 0.5)(3.5/2 + 0.25)}{8.5} = 7/8.5 = 0.82\ cm$$

$e = 2.93 + 8 = 10.93\ cm \qquad T = 10.93 \times P$

$$I_x = \frac{0.5 \times 10^3}{12} + (2 \times 3.5 \times 0.5) \times 4.75^2 = 120.6\ cm^4$$

$$I_y = (10 \times 0.5) \times 0.82^2 + 2 \times 0.5 \times \frac{1}{3}(2.93^3 + 0.57^3) = 11.8\ cm^4$$

$I_z = I_x + I_y = 120.6 + 11.8 = 132.40\ cm^4$



$$\downarrow \tau_V \text{(Due to P)} = \frac{P}{A} = \frac{P}{8.5} = 0.118P \downarrow$$

$$\downarrow \tau_V \text{(Due to T)} = \frac{Tx}{I_z} = \frac{10.93P \times 2.93}{132.40} = 0.24P \downarrow$$

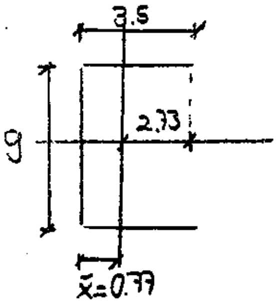
$$(\tau_H)_T = \frac{Ty}{I_z} = \frac{10.93P \times 5}{132.4} = 0.41P$$

$$\tau = \sqrt{(0.118P + 0.24P)^2 + (0.41P)^2} = 0.54P$$

Since there is no $\delta \rightarrow \tau_{all} = 0.75\ t/cm^2$ (TABLE VII-5)

$0.54P_{all} = \tau_{all} = 0.75 \quad \therefore P_{all} = 1.39$ ton

ALTERNATE ; WELD AREAS ARE CONCENTRATED AT THE ROOT :



$A = (2 \times 3.5 + 9) \times 0.5 = 8$

$$\bar{x} = \frac{2 \times 3.5 \times 0.5 \times 3.5/2}{8} = 0.77 \qquad e = 2.73 + 8 = 10.73\ cm$$

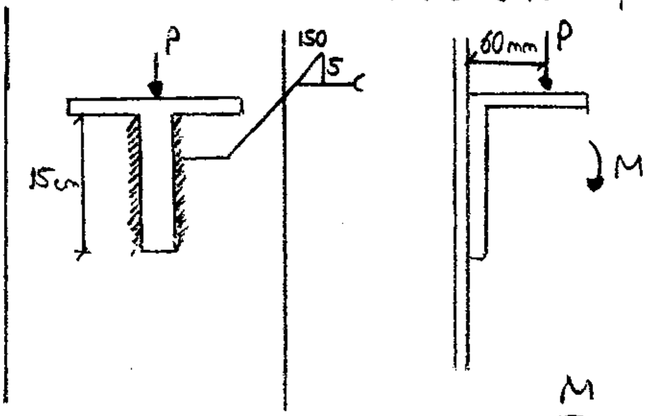
$T = 10.73\ P$

$I_x = 0.5 \times 9^3/12 + (2 \times 3.5 \times 0.5)\,4.5^2 = 101.24\ cm^4$

$$I_y = (9 \times 0.5) \times 0.77^2 + 2 \times 0.5 \times \frac{1}{3}(0.77^3 + 2.73^3) = 9.6\ cm^4$$

EXAMPLE PROBLEM #3

For the welded connection. Compute P_{all}, ST 37, $a = 5$ mm, E4 loading



$A_w = 2 \times 15 \times 0.5 = 15\ cm^2$

$I = 2 \times \frac{0.5 \times 15^3}{12} = 282\ cm^4$

$W = \frac{I}{y/2} = \frac{282}{15/2} = 37.5\ cm^3$

$$\sigma_n = \frac{\overset{M}{\frown}{6P}}{37.5} = 0.16 P = \frac{M}{W}$$

$$\tau_{||} = \frac{P}{A} = \frac{P}{15} = 0.067 P$$

Since σ combined with $\tau_{||}$

$$\sigma_v = \sqrt{(0.16P)^2 + (0.067P)^2} = 0.173 P$$

From Table VIII-6, P 307 $\sigma_v = 1100\ kg/cm^2$

$0.173\ P_{all} = 1.1 \quad \therefore \quad P_{all} = 6.36$ ton.