WELDING

Welding is the process of permanently joining two or more metal parts, by melting both materials. The molten materials quickly cool, and the two metals are permanently bonded. Spot welding and seam welding are two very popular methods used for sheet metal parts. Dissimilar materials cannot be welded due to different melt properties and thermal conductivities.

Grooves (Kaynak ağzi ve dikiş şekilleri):
Welds can be geometrically prepared in many different ways. The four basic types of weld joints are the butt joint, corner joint, edge joint, and T-joint. Other variations exist as well—for example, double-V preparation joints are characterized by the two pieces of material each tapering to a single center point at one-half their height. Single-U and double-U preparation joints are also fairly common—instead of having straight edges like the single-V and double-V preparation joints, they are curved, forming the shape of a U.

Figure 1. Connection types (a-single V groove, b-edge weld for sheet metal and light loads, c- T joint for thick plates, d- corner)

Figure 2. Weld grooves and symbols
Figure 3. Weld grooves and symbols

**Welding rules**

a) Fill out the grooves.
b) Instead of thick and short weld, use thin and long weld.
c) Weld seam should be far from the sections which have high stress and stress concentration.
d) The weld concentrations should be eliminated.

Figure 4. Weld locations

**Weld Quality:**
Many distinct factors influence the strength of welds and the material around them,
- the welding method,
- the amount and concentration of energy input,
- the weldability of the base material,
- filler material,
- post weld processes,
  - the design of the joint, and the interactions between all these factors.

To test the quality of a weld, either destructive or nondestructive testing methods are commonly used to verify that welds are free of defects, have acceptable levels of residual stresses and distortion, and have acceptable heat-affected zone (HAZ) properties.

Types of welding defects include cracks, distortion, gas inclusions (porosity), non-metallic inclusions, lack of fusion, incomplete penetration, lamellar tearing, and undercutting.

Welding always causes some distortion, shrinkage along with changes to the micro-structure of the parent material. After the weld process is done the entire part is re-heat-treated (heat, quench, temper) so the weld and heat affected zone is restored to the properties of the parent metal. Such processes are slow, expensive and performed in only the most crucial applications.
1. **Quality**: all the factors which affect the weld strength are considered in welding (For high magnitude of dynamic loads)

2. **Quality**: some of the factors which affect the weld strength are considered in welding (For high static loads and dynamic loads with mean amplitude)

3. **Quality**: During welding, the factors which influence the strength are not paid attention.

**The weld throat (a) and the length of the weld** ($\ell_k$):

<table>
<thead>
<tr>
<th>Joint Type</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt joint</td>
<td>$a = \delta_{\text{min}}$</td>
</tr>
<tr>
<td>T joint</td>
<td>$a = 0.7\delta_{\text{min}}$</td>
</tr>
</tbody>
</table>

In butt weld, $a = \delta_{\text{min}}$ \(\delta_{\text{min}}\): minimum plate thickness.

In T joints, $a = 0.7\delta_{\text{min}}$

If the fastened components are thick, thickness of the parts is not considered as references in the weld throat. The height of the triangle is taken as weld throat.

Length of the weld for closed weld, $l_k = 1$.

The throat area of all the welds, $A_k = \sum (a \cdot l_k)$

**Determination of allowable stress:**

$$(\sigma_{\text{em}})_{\text{kay}} = V \cdot (\sigma_{\text{em}})_{\text{som}} \quad (\tau_{\text{em}})_{\text{kay}} = V (\tau_{\text{em}})_{\text{som}}$$

$(\sigma_{\text{em}})_{\text{kay}}$: Allowable normal strength of deposited weld material.

$(\tau_{\text{em}})_{\text{kay}}$: Allowable shear strength of deposited weld material.

$(\sigma_{\text{em}})_{\text{som}}$, $(\tau_{\text{em}})_{\text{som}}$: Allowable stresses of the parent materials.

$V = V_1 \cdot V_2$

$V_1$: Weld factor found according to weld seam, connection type and loading condition from Table 1.

$V_2$: Quality factor,

for 1st Quality: $V_2 = 1$, for 2nd quality $V_2 = 0.8$, for 3rd quality $V_2 = 0.5$
Table 1. $V_1$ factor for various dynamic loading conditions and weld grooves.

(Niemann deney sonuçları)

<table>
<thead>
<tr>
<th>Gösterilishi</th>
<th>Bütün sac</th>
<th>V-dikişi</th>
<th>V-dikişi altın kaynaklı</th>
<th>V-dikişi işlenmiş</th>
<th>X-dikişi</th>
<th>Eşik V-dikişi</th>
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<tbody>
<tr>
<td>Kaynak işaretleri</td>
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<tr>
<td>Kaynak şekli</td>
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<td>$\times$</td>
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</tbody>
</table>

| V. katsayıları | | | | | | |
|--------------|--------------|-------------|-------------|-----------------|-------------|
| Çeki · bası | 1 | 0,5 | 0,7 | 0,92 | 0,7 | 0,8 |
| Eğilme | 1,2 | 0,6 | 0,84 | 1,1 | 0,84 | 0,98 |
| Kesilme | 0,8 | 0,42 | 0,56 | 0,73 | 0,56 | 0,85 |

<table>
<thead>
<tr>
<th>Gösterilishi</th>
<th>Tek tarafı düz köşe dikişi</th>
<th>Çift tarafı düz köşe dikişi</th>
<th>Köşe alın dikişi</th>
<th>Köşe X-dikişi</th>
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<td>Kaynak kalınlığı</td>
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| V. katsayıları | | | | | | |
|--------------|--------------|-------------|-------------|-----------------|-------------|
| Çeki · bası | 0,22 | 0,3 | 0,45 | 0,6 | 0,35 |
| Eğilme | 0,11 | 0,6 | 0,55 | 0,75 | 0,7 |
| Kesilme | 0,22 | 0,3 | 0,37 | 0,5 | 0,35 |

<table>
<thead>
<tr>
<th>Gösterilishi</th>
<th>Bombeli köşe dikişi</th>
<th>Çift tarafı düz köşe dikişi</th>
<th>Tek tarafı küçük köşe dikişi</th>
<th>Köşe alın dikişi</th>
<th>Çift tarafı köşe alın dikişi</th>
<th>X-dikişi</th>
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| V. katsayıları | | | | | | |
|--------------|--------------|-------------|-------------|-----------------|-------------|
| Çeki · bası | 0,32 | 0,35 | 0,41 | 0,22 | 0,63 | 0,56 | 0,7 |
| Eğilme | 0,32 | 0,35 | 0,41 | 0,22 | 0,63 | 0,56 | 0,7 |
| Kesilme | 0,32 | 0,35 | 0,41 | 0,22 | 0,63 | 0,56 | 0,7 |

<table>
<thead>
<tr>
<th>Gösterilishi</th>
<th>Kapak alın dikişi</th>
<th>Kapak yan dikişi</th>
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<td>Kaynak kalınlığı</td>
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</table>

| Çeki | 0,22 | 0,25 | 0,25 | 0,48 |
Stresses in Welded Joints

1) Tension, compression stress:

\[ \sigma_t = \frac{F}{a \cdot l_k} \leq (\sigma_{em})_{kay} \]

Length of the weld, \( l_k = l - 2a \)

\[ a = \delta_{min} \]

a: weld throat

2) Shear stress: While assembled parts are under tension, weld is under the effect of shear.

\[ \tau_k = \frac{F}{\Sigma(a \cdot l_k)} \leq (\tau_{em})_{kay} \quad a = 0.7 \delta_{min} \]

3) Bending stress: Parts and weld are under the effect of bending.

\[ \sigma_{ek} = \frac{M_e}{W_{ek}} \leq (\sigma_{em})_{kay} \]

\[ W_{ek} : a \cdot l_k^2/6 \]

4) Bending and tension stresses

\[ \sigma_{tk} = \frac{F}{a \cdot l_k} + \frac{M_e}{W_{ek}} \leq (\sigma_{em})_{kay} \]

\[ W_{ek} = \frac{1}{6} a \cdot l_k^2 \]

5) Torsional stress:

\[ \tau_{bk} = \frac{M_b}{W_{bk}} \leq (\tau_{em})_{kay} \]

\[ W_{bk} = \frac{\pi}{16} \left[ \frac{(d + 2a)^4 - d^4}{d + 2a} \right] \]
6) Bending and shear stresses

\[ \sigma_c = \frac{M_c}{W_e} = \frac{F_c}{2,1, a.l_k^2} \]

\[ \tau_k = \frac{F}{A} = \frac{F}{2, a.l} \]

\[ \sigma_{es} = \sqrt{\sigma_c^2 + 3, \tau_k^2} \leq (\sigma_{em})_{kay} \]

7) In the case of combined stress:

Equivalent stress is calculated according to von-Misses criterion: For Example: Tension, bending and torsion are acting on the weld,

\[ \sigma_{es} = \sqrt{(\sigma_{ck} + \sigma_{ek})^2 + 3, \tau_{bk}^2} \leq (\sigma_{em})_{kay} \]

8) If the load is dynamic,

Stress amplitude

\[ \sigma_{gk} = \sigma_{uk} - \sigma_{nk} \leq (\sigma_{em})_{gkay} \]

\[ (\sigma_{em})_{gk} = V_1 \times V_2 \times \sigma_s / S \]

\( \sigma_s \): Fatigue strength of the parent material

\( S \): Safety factor \( (S = 2 \div 3) \)

Bending and torsional section modulus \( (W_e \text{ and } W_b) \) for different weld seams

\[ W_e = 2, \frac{1}{6} a.l^2 = \frac{1}{3} a.l^2 \]

\[ D = d + 2a \]

\[ W_e = \frac{1}{32} \cdot \frac{D^4 - d^4}{D}, \quad W_b = \frac{1}{16} \cdot \frac{D^4 - d^4}{D} \]

\[ W_b = 2, a, \pi, (d + a)^2 / 4 \]
Example 1- Plates made of Fe37 are welded by V groove. Control the connection for $F = 60000$ N static tension loading. Quality of the weld seam is 2nd quality. Safety factor is 2.

Weld thickness $a = \delta = 10$ mm

Length of the weld $l_k = l - 2a = 150 - 2 \times 10 = 130$ mm

Stress in the weld; $\sigma_k = \frac{F}{a.l_k} = \frac{60000}{10 \times 130} = 46$ N/mm$^2$

Allowable stress:

For static loadings, $V_1 = 0.8 \ldots 1$. $V_1 = 0.8$ is chosen. $V_2 = 0.8$ (2nd quality)

Fe 37 : $\sigma_{Ak} = 235$ N/mm$^2$ (Page 1/16, Table 1.9 from MEP), $\sigma_{em} = 120$ N/mm$^2$ ($s \approx 2$)

$(\sigma_{em})_{kay} = V_1.V_2 (\sigma_{em})_{som} = 0.8 \times 0.8 \times 120 = 76.8$ N/mm$^2$

Since $\sigma_k < (\sigma_{em})_{kay}$, the weld seam is safe.

Example 2.
Dynamic load \( (F = 100000 \text{ N}) \) is acting on I 240 profile welded as shown in the figure. Thickness of the weld, \( a = 8 \text{ mm} \) and quality is 2\(^{\text{nd}}\). Control the weld seam. Profile material is Fe42.

Bending stress:

Moment of moment, \( M_e = F.l = 100000\times 250 = 250.10^5 \text{ Nmm} \)

Moment of inertia of the weld seam,

\[
I = \frac{106(256^3 - 240^3)}{12} + 2.\frac{8.192^3}{12} = 355.10^5 \text{ mm}^4
\]

\[
W_e = \frac{I_k}{(240+2.a)^2} = \frac{355.10^5\times 2}{256} = 277.10^3 \text{ mm}^3
\]

Bending stress, \( \sigma_e = \frac{M_e}{W_e} = \frac{250.10^5}{277.10^3} = 90.25 \text{ N/mm}^2 \)

**Shear stress is neglected.**

Determination of allowable stress for weld seam,

Given connection can be considered as T shape weld and for bending

\( V_1 = 0,69 \) (both sided bumped T joint) (Page 7/8, Table 7.1), \( V_2 = 0,8 \) (II. quality)

Profile Fe 42, \( \sigma_{\text{elD}} = 220 \text{ N/ mm}^2 \) (Page 1/10, Table 1.1)

\( (\sigma_{\text{em}})_{\text{som}} = \sigma_{\text{elD}}/S = 220/2=110 \text{ N/mm}^2 \)

\( (\sigma_{\text{em}})_{\text{kay}} = V_1\cdot V_2 \cdot (\sigma_{\text{em}})_{\text{som}} = 0,69\times 0,8 \times 110 = 60,72 \text{ N/mm}^2 \)

Since \( \sigma_e > (\sigma_{\text{em}})_{\text{kay}} \), the weld seam is not safe.