Welding is a “permanent” method of joining metallic parts together to form a new part. The three most common methods used in industrial welding applications are gas welding, arc welding and resistance welding. In the welding process, common edges or surfaces of the parts are melted and their molten metal is allowed to pool together. A filler material is commonly melted into this pool. The parts fuse together when the molten metal pool cools.

WELDING METHODS:

Gas welding – oxyacetylene is probably the most common gas used in welding. The heat is generated by the burning gasses. This process is relatively slow compared to other methods, so its primary application is in maintenance and repair work.

Arc welding – an electric arc between the parts being welded and an electrode generates the heat to melt the material. This is a very hot and fast process.

Resistance welding – similar to arc welding, though there is no arc between the parts. A high current is passed between two parts. The electrical resistance of the material causes a lot of heat to be generated which then fuses the parts together. This is a fast process highly suited to mass production work.

BASIC WELDED JOINTS:

WELD TERMINOLOGY:

Fillet Weld

Groove Weld

Plug & Slot Welds
WELDING SYMBOL:
Welds are specified on a drawing through the use of standard symbols. The following figure illustrates the various parts of a typical weld symbol. Note that all welds do not have all of the given information.

**Parts of a Welding Symbol**

**NOTE:** Size, weld symbol, length of weld, and spacing must be read in that order from left to right along the reference line. Neither orientation of the reference line or its location can alter this rule. The perpendicular leg for fillet, bevel, J, and flare bevel welds must be on the left. Arrow- and other-side welds are the same size unless otherwise noted. Symbols apply between abrupt changes in direction of welding unless governed by the "all-around" symbol or otherwise dimensioned.

**BASIC WELD SYMBOLS:**
Basic weld symbols are the symbols use to indicate the type of weld.

**SIGNIFICANCE OF ARROW LOCATION:**
1. For fillet and groove welds, the arrow connects the reference line to one side of the joint. This side of the joint is known as the *arrow side*. The opposite side of the joint is considered the *other side*.
2. When a joint is depicted by a single line, the side of the line with the arrow is considered to be the arrow side.
FILLET WELD EXAMPLES:
This on the drawing:

Means this:

FILLET WELD LENGTH EXAMPLES:
This on the drawing:

Means this:

This on the drawing:

Means this:

INTERMITTENT FILLET WELD EXAMPLE:
This on the drawing:

Means this:

GROOVE WELD EXAMPLE:
This on the drawing:

Means this:

Both parts have to be “prepared” or machined prior to welding. The dashed lines show the limits of the preparation.
GROOVE WELD EXAMPLE:
This on the drawing:

Means this:

SHIELDED METAL ARC WELDING (SMAW):
A pool of molten steel can hold a large amount of gasses. If the weld is not protected from the surrounding gasses, it will chemically react with them. This will create little pockets of gas in the weld after it cools. Such welds are relatively brittle and have much less resistance to corrosion.

The SMAW method of welding uses electrodes which are coated with mineral compounds which create an inert vapor around the weld. This protects the weld from reacting with the oxygen and nitrogen in the atmosphere. Additionally, a slag is deposited over the weld to protect it while it cools. The slag is then removed by peening and a wire brush. This is a VERY common method used in welding.

FILLET WELDS:
Fillet welds are very commonly used in engineering structures.

Tests have shown that fillet welds are stronger in tension and compression than in shear. Because of this, shear is considered to be the critical stress in a fillet weld and it is the only one checked. Fillet welds fail in SHEAR along a plane through the effective throat of the weld as shown in the figure to the right.

The strength of a fillet weld depends in large part on the type of electrode used to create it. Electrodes contain the filler material used to create the weld. They are designated as:

- E60XX
- E70XX
- E80XX
- Etc.

The effective area of a fillet weld is the area of the shear plane that passes through the effective throat of the weld. For welds having equal length legs, the effective area is

\[ A_e = .707 \text{(leg size) } \times \text{L} \]

Where L is the length of the weld and the leg size is the size of the weld as shown in the figure above. The allowable strength of the weld material is .30 times its minimum tensile strength.

EXAMPLE: Determine the load carrying capacity of a 1/4" fillet weld which is 2 inches long. It is made with E70 electrodes.

\[ R_w = .707(\text{leg})(\text{length})(\text{weld strength}) = .707( .25\text{"})(2\text{"})(.30 \times 70 \text{ ksi}) = 7.4 \text{ kips} = 7400 \text{ lbs.} \]
**MINIMUM FILLET WELD SIZE:**

<table>
<thead>
<tr>
<th>Thickness of thickest part joined (inches)</th>
<th>Minimum leg size of fillet weld* (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>t ≤ 1/4”</td>
<td>1/8”</td>
</tr>
<tr>
<td>1/4 &lt; t ≤ 1/2”</td>
<td>3/16”</td>
</tr>
<tr>
<td>1/2 &lt; t ≤ 3/4”</td>
<td>1/4”</td>
</tr>
<tr>
<td>t &gt; 3/4”</td>
<td>5/16”</td>
</tr>
</tbody>
</table>

*Leg dimensions for fillet welds. Single pass welds must be used for structural work. Welds need NOT exceed the thickness of the thinner part.

**MAXIMUM FILLET WELD SIZE:**

- t < 1/4” - the maximum weld is not greater than the thickness of the material
- t ≥ 1/4” - the maximum weld is not greater than the thickness minus 1/16”

**LENGTH OF WELDS:**
The minimum length of a fillet weld, L, is 4 x Leg Size. End welds should have returns, each with a minimum length of 2 x Leg Size. The distance between longitudinal welds, w, can NOT be more than the length of the welds.

**EXAMPLE:** Determine the width of the small plate and design a weld to transfer the load between the plates. Both plates are 1/2” thick A-36 steel (S_y = 36 ksi). Use E70 electrodes.

\[
\sigma_d = 0.60S_y \text{ (AISC Code)}
\]

\[
P = \sigma A
25k = 0.60(36 \text{ ksi})(0.50 \text{ in})w
w = 2.31 \text{ in.}
\]

Use \( w = 2\text{-}3/8” \)

Try 1/4” weld. The load capacity of a 1/4” fillet weld, \( R_w = 0.707(0.25')(0.30)(70 \text{ ksi}) = 3.71 \text{ kips/in.} \) The minimum length of the fillet weld is:

\[
L_{\text{reqd}} = \frac{P}{R_w} = \frac{25 \text{ kips}}{3.71 \text{ kips/in}} = 6.74 \text{ in}
\]

The minimum return, \( r = 2h = 2(0.25") = 0.50". \)

The length of weld = 2(L + r) = 6.74” ⇒ L = 2.87” ⇒ **USE 1/4” Fillet Weld, L = 3.00” with 1/2” returns**

\( (L = 3.00" > w = 2.375" : \text{OKAY}) \)

Check shear stress in wider part: \( \tau = \frac{P}{A} = 25 \text{ kips} / (2(3.00')(0.50")) = 8.33 \text{ ksi} < \tau_d = 0.40S_y = 14.4 \text{ ksi : OKAY} \)
Weld Treated as a Line:

Example: Determine the required fillet weld size for the base of the structural tubing. Use E60xx electrodes.

The fillet weld will experience both “bending” and “shear” from the 4000# load. From Figure 20-8, Case 7:

\[ A_w = 2(b + d) \]
\[ = 2(3" + 4") \]
\[ A_w = 14 \text{ in} \]
\[ S_w = bd + \frac{d^2}{3} \]
\[ = 4"(3") + \frac{(3")^2}{3} \]
\[ S_w = 15 \text{ in}^2 \]

“shear” component:

\[ f_{\text{shear}} = \frac{P}{A_w} = \frac{4000\#}{14 \text{ in}} = 286\#/\text{in} \]

“bending” component:

\[ f_{\text{bending}} = \frac{M}{S_w} = \frac{4000\#(12")}{15 \text{ in}^2} = 3200\#/\text{in} \]

Resultant:

\[ f_{\text{resultant}} = \sqrt{f_{\text{shear}}^2 + f_{\text{bending}}^2} = \sqrt{(286\#/\text{in})^2 + (3200\#/\text{in})^2} = 3213\#/\text{in} \]

\[ f_{\text{allowable}} = \frac{9600\#/\text{in}}{\text{inch of leg}} \quad \text{Table 20-3, Assuming A-36 steel, E60 electrodes} \]

Size the Weld Leg:

\[ \text{Leg} \geq \frac{f_{\text{resultant}}}{f_{\text{allowable}}} = \frac{3213\#/\text{in}}{9600\#/\text{in}} = .335" \quad \text{USE 3/8" fillet weld all around} \]

NOTE: To be able to use this size weld, the thickness of the welded parts has to be 7/16 or larger. IF the thickness cannot be obtained, a larger structural tube (HSS) needs to be selected.