Design for welding: Design recommendations

Arc welding can be used to weld almost any kind of assembly, including even complex structures. Arc weldments use a wide variety of ferrous and non ferrous metals. Commonly produced devices by arc welding are tube fittings, storage tanks, pressure vessels, machine frames, structures for industrial equipment, railroad cars etc.

If well designed, welded components exhibit excellent strength characteristics equal to or even stronger than the base components. Other benefits include light weight, economical and pleasing appearance. However, it is a bit difficult to attain the long sweeping curves, rounded contours, and relatively smooth surfaces as those exhibited by castings and forgings.

The most common classes of weld joints are: butt joints, lap joints, T joints, corner joints, and edge joints, which are shown in Figure M6.2.1. In this figure, butt, lap, T, and corner joints are shown with two fillets, though use of one fillet is also quite common.

![Diagram of welded joints](image)

**Figure M6.2.1**: Common types of welded joints

**DESIGN RECOMMENDATIONS**

**Cost Reduction**

Following are some design recommendations to reduce costs:

1. Welded assemblies should have few parts.

2. Weld joints should be placed in such a way that there is easy access of the welding nozzle. If the nozzle is close to the welding point, the molten metal will be well shielded.
3. Provide minimum amount of weld filler, with respect to both fillet size and length that meets functional requirements of the assembly. Specify tack welds and intermittent welds if the application does not involve high stresses or a leak proof construction.

4. Whenever possible, welding should be done horizontally, with the stick or electrode holder pointing downward during welding. This position is the most rapid and convenient with all welding methods.

5. The designer should be aware of poor and good fit-up of parts (shown in Figure M6.2.2) at the weld joint. It is essential not only for welding speed but also for minimizing distortion of the finished weldment.

![Figure M6.2.2](image)

**Figure M6.2.2:** Poor and good fit-up of weld joints.

6. The buildup of weld fillets should be kept to a minimum as it doesn’t add significant strength to the joint. (Refer Figure M6.2.3.)

![Figure M6.2.3](image)

**Figure M6.2.3:** A buildup of filler material in weld joints does not add materially to joint strength.

7. If forgings or castings are part of a welded assembly, one should ensure good fit-up of the parts to be welded. For example untrimmed parting-line areas shouldn’t be included in the welded joint. In the cast part the wall thickness of both parts to be joined should be equal at the joint. This ensures a more rapid and less distortion-prone welding. (See Figure M6.2.4.)
Figure M6.2.4: The wall thickness of parts to be joined should be equal at the joint.

8. Locating welds out of sight is better; rather than in locations where special finishing operations are required for the sake of appearance.

9. The joint should be designed so that it requires minimal edge preparation. For this, one should use slip or lap joints in welded assemblies to avoid the cost of close edge preparation and to simplify fit-up problems. Use of lap or slip joints are illustrated in Figure M6.2.5.

Figure M6.2.5: Joints on the right require less edge preparation.

10. Curved edges or sides of parts comprising the assembly provide the equivalent of a grooved edge for the welded joint. In such case little or no edge preparation is therefore needed. Few such examples have been illustrated in Figure M6.2.6.
Figure M6.2.6: Joints that have natural grooves and thus need little or no edge preparation. (From Metals Handbook, vol. 6, 8th ed., American Society for Metals, Metals Park, Ohio, 1971.)

11. If machining after welding is required, it is advisable to place welds away from the material to be machined to avoid machining problems (Refer Figure M6.2.7).

Figure M6.2.7: Weld metal outside the portion of the weldment to be machined.
12. It is better to utilize a number of welded subassemblies while fabricating a large, complex assembly as subassemblies can be handled more easily. For example they can be positioned for easy access of the electrode, and the joint can be kept horizontal during welding.

13. Sometimes it is advantageous to include a weld backup strip as an integral part of one of the component to be welded. (See Figure M6.2.8)

![Figure M6.2.8: Backup strip as internal parts](image)

**Minimizing Distortion**

Distortion can be minimized by the following design recommendations:

1. Good fit of parts minimizes welding time and control the distortion. It is better to have maximum contact of mating surface as evident in Figure M6.2.9. The more gaps to fill, the greater the possible weldment distortion.

![Figure M6.2.9: Poor and good fit-up of weld joints.](image)

2. Use thicker, rigid components to reduce distortion from welding.

3. Short flanged butt joints are preferable to join thin materials. Unless joints have good supports long sections of thinner material, when welded together, are apt to distort and buckle. (Refer Figure M6.2.10)
4. If possible, place welds opposite one another to reduce distortion. This balances the shrinkage forces in the weld fillets as they tend to offset one another. Figure M6.2.11 shows some examples.

5. If sections of unequal thickness are to be welded, distortion can be reduced by equalizing wall thickness at the joint by machining a groove in the thicker piece adjacent to the weld joint. (Refer Figure M6.2.12)
6. Consideration should be given to shrinkage inherent in each weld while dimensioning welded assemblies.

**Weld Strength**

The following design recommendations need to be followed for strengthening of welds.

1. Butt joints are most efficient. For deep-penetration welding or for thin stocks, the square-edged butt joint can be employed and edge-preparation time can therefore be saved. Thicker stock or less penetrating methods may require grooved edges. (Figure M6.2.1 and Figure M6.2.5)

2. Welds should be placed to minimise stress concentration in the fillet. Examples have been illustrated in Figure M6.2.13.

![Figure M6.2.13: Design of weldments to minimize stress concentration in the weld fillet.](image)

3. Groove welds should be designed to be in either compression or tension but fillet welds should be designed for shear only. (See Figure M6.2.14 and Figure M6.2.15)

![Figure M6.2.14: Groove welds either in tension or compression.](image)
Figure M6.2.15: Fillet welds should be designed to be in shear only

4. If intermittent welds are used in place of continuous welds for reducing cost, the length of each fillet should be at least 4 times the fillet thickness and should not be less than 40 mm. If the joint is in compression, the spacing of the welds should not exceed 16 times the joint thickness; for the case of tension, the spacing may be as much as 32 times the thickness but not over 300 mm.

Electron and Laser Beam Weldments

Following are some design recommendations for electron and laser beam weldments:

1. Butt joints are preferred to lap joints as the process uses narrow width of the ray and deep penetration

2. Good fit up of the mating surface is essential because of the narrow beam.

3. Electron-beam weldments need to be processed in vacuum chambers and so they should be self-fixturing to permit batches of assemblies to be placed in the welding chamber with minimum space occupancy. This also reduces the cost of multiple fixtures.

Weldments and Heat Treatment

Designers should note the following rules concerning the use of heat treatment in weldments:

1. Carburized or hardened steels should not be welded as they require controlled conditions and proper equipment and supplies.

2. Welding reduces or removes the hardness of carburized or nitride mild (low-carbon) steels in the welded area.
3. Carbon in welded areas will affect the physical and chemical characteristics of the weld bead, resulting in possible cracking or weld failure in or adjacent to the weld.

4. Any straightening operation on carburized and hardened parts may result in some surface cracking in the welded area because of the possible distortion from stress relief and heat treatment.

**DIMENSIONAL FACTORS AND RECOMMENDED TOLERANCES**

The most significant factor that affects the dimensions of welded assemblies is the shrinkage of the weld fillet on cooling. A steel weld bead cools from about 1510°C when it solidifies after being deposited, to a usual ambient temperature of about 20°C with a contraction of 0.22 mm/cm. Fixtures can reduce thermal shrinkage to some extent, but shrinkage cannot be completely eliminated. Some dimensional tolerances are provided for arc weldments produced under average production conditions in Table M6.2.1.

**Table M6.2.1**: Recommended Dimensional Tolerances for Arc Weldments. (Source: Design for Manufacturability Handbook by James G Bralla, 2nd Ed)

<table>
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<tr>
<th>Basic dimension (m)</th>
<th>Assembly with Little welding</th>
<th>Assembly with Moderate welding</th>
<th>Assembly with Heavy welding</th>
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<td>0–0.3</td>
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<td>1.5</td>
<td>1.5</td>
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<tr>
<td>1–2</td>
<td>1.5</td>
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