Weld quality

A flowing weld of constant width can be admired – a lumpy, discontinuous weld not so much (I have a friend who refers to the latter as a haemorrhoid weld). In simple terms, a welded joint has adequate quality if it performs satisfactorily throughout its design life. But how can this be predicted? This article is intended to educate the observer about the factors that determine weld quality. Good weld practice is fundamental to safety. Welds hold suspensions onto axles, connect extended chassis rails, attach kingpin housings onto the skidplates and are key in many other safety-critical applications. Successful welding is a demanding job that requires well-trained welders, using good-quality welding equipment.

Repair to an aluminium sub-frame on a tanker, note the longitudinal weld crack. The weld is no substitute for a reinforcement plate to spread loads.

The strength of the weld, including the zones on either side, will not be greater than the base metal strength. Therefore, the welded joint is likely to be the weakest link in the structural chain and thereby deserving of scrutiny.

First I want to talk about the hand welding techniques that are used in the road transport industry. The four main welding technologies used for hand welding are:

1. Metal inert gas (MIG) arc welding.
This technology creates an electric arc between a continuous and consumable metal filler wire (electrode) and the sheet-metal workpieces. An inert gas protects the molten metal and the arc from the atmosphere. MIG welding is applicable to most metals and alloys including carbon steels, low-alloy steels, stainless steel and 3000-, 5000- and 6000-series aluminium alloys. The properties and width of the filler wire are selected for the particular situation.

2. Tungsten inert gas (TIG) welding.
This technology creates an electric arc between a non-consumed tungsten electrode and the sheet-metal workpieces. Optionally, a filler wire can be used. TIG can produce higher quality welds and produces less spatter than MIG. Unlike MIG welding, TIG welding can produce welded joints without filler metal, resulting in strong joints with less eruption of the base metal.

3. Oxyfuel welding (OFW).
This technology uses intense heat generated by burning acetylene gas with oxygen. A filler metal is supplied via a welding rod. This method is losing favour to MIG welding because MIG produces lower heat distortion and is more economical.

4. Electric arc welding without gas (EAW, or stick welding).
This technology uses the heat of the electric arc to melt the steel, and a filler rod provides the weld material. This technology should not be used for structural welds. The weld strength is less than for MIG and TIG welding.

Virtually all ferrous and non-ferrous metals can be MIG or TIG welded to themselves or to similar metals. The TIG technique can be used to weld dissimilar metals. Cast iron, which typically has ten times more carbon content than mild steel, can be welded but it is a specialist task. Welds in cast iron are usually repaired to stop crack propagation.

Welding produces a heat-affected zone (HAZ) of base metal either side of the weld that has not melted but which has been very hot. The phase composition can be changed in the HAZ because alloying components can migrate in very hot metal. For example, martensite, which is hard and brittle, can form in steel. In high-strength steels, there can also be hydrogen embrittlement – depending upon the welding wire used – and a propensity to crack. Preheating of metal prior to welding can minimise the tendency to crack.

Preheating is an essential stage of a quality welding procedure. It is done using a heat torch to prevent rapid cooling of the metal after it is welded, which helps minimise the brittle phases (martensite) that can develop in the HAZ zone in steel, avoid rapid shrinkage stresses that can distort the weld or crack the HAZ, promote fusion of the metals, avoid distortion when the parts cool and remove moisture, allowing hydrogen to de-fuse from the metal structure, thereby minimising the risk of hydrogen embrittlement.

Note that there are some high-strength steels for which preheating is not appropriate.

Preheating of low- and mid-strength steels before welding is an essential operation. Typically the metal is preheated to between 200°C and 250°C before welding – different steels require different pre-heat temperatures. No pre-heating risks cracks and poor weld quality.

The diagram on the following page identifies common defects. If you are an operator, demand top-quality welding. If you run a workshop, make sure that you deliver it.

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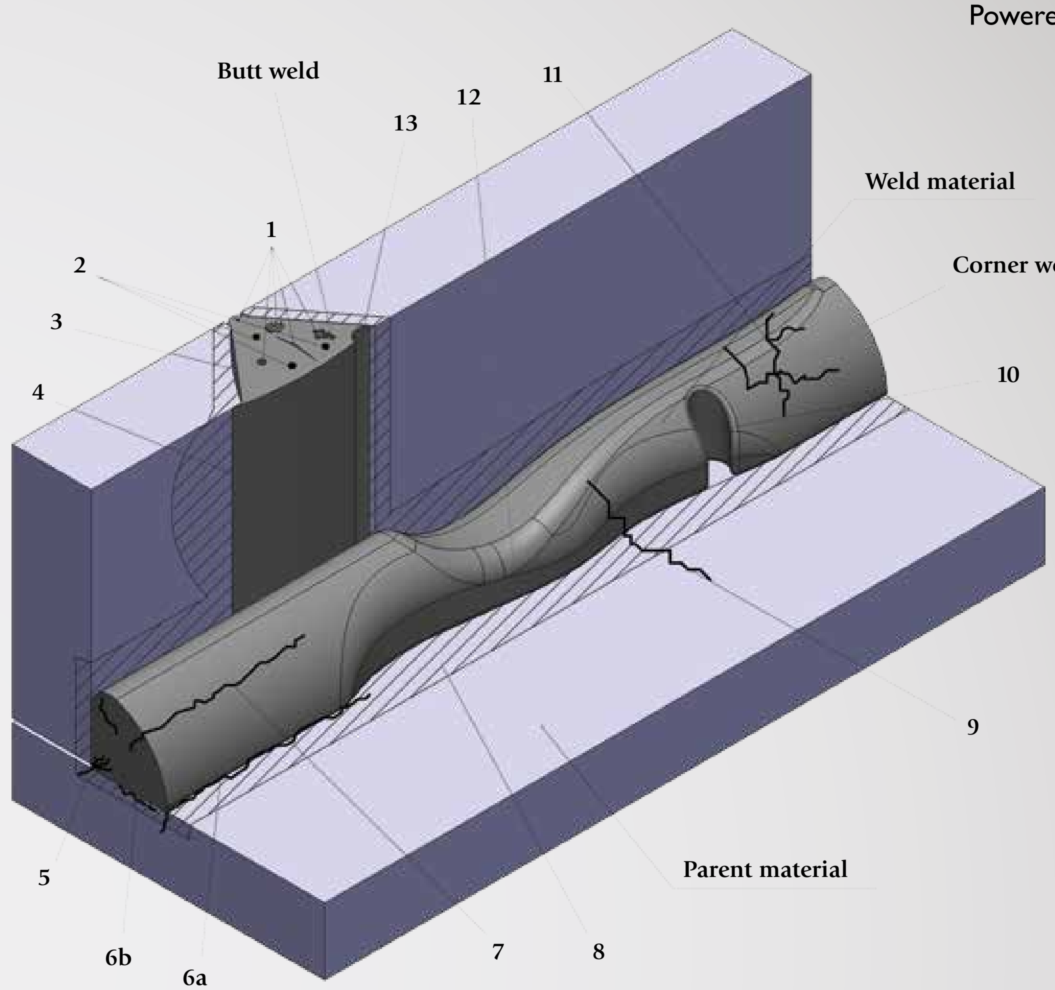

1. Fine/coarse cluster porosity/blow holes and hollow root beads:
Craters, cavities, wormholes and pores in the weld as the result of gas inclusion when the weld solidifies from poor gas settings, water on parts, contamination.

2. Slag inclusions:
Foreign materials such as slag or pieces of tungsten (TIG welding). Inclusions can be due to repeat welds that cover surface contamination from the first weld.

3. Lack of fusion:
The weld does not extend into the base metal by a distance comparable to the width of the weld. This is due to poor welder settings/incorrect filler rod.

4. Overlap and overwelding:
The long side of a joint weld need be no longer than the thickness of the thinner material being welded. Overwelding, which is making the weld too thick, can results in distortion and a large Heat Affected Zone (HAZ).

5. Root crack:
These are generally due to hydrogen embrittlement and poor welder settings at the commencement of welding.

6. HAZ cracking:
Usually longitudinal cracks in the HAZ, the result of excessive heat input, hydrogen embrittlement or residual stress in material. HAZ cracking can often occur when the parent material is cooled down quickly. Preheating helps avoid HAZ cracking.
6a) Toe cracking
6b) Underbead cracking

7. Longitudinal crack:
These are cracks that run the length of the weld bead. They are usually caused by high transverse shrinkage. Preheating the part helps.

8. Heat Affected Zone (HAZ):
The parent material region surrounding the weld experiences material property changes due to heating when welding. The intensity and duration of the heat will change the properties of the material. Strength can be reduced in high strength alloy steels.

9. Transverse crack:
Cracks across the weld are due to longitudinal shrinkage stresses acting on a low-ductile weld material.

10. Crater:
These occur due to gas porosity and shrinkage during weld pool solidification.

11. Radiating crack:
These are cracks originating from a common point. These can occur due to excessive heating, cooling and residual stresses within the weld material.

12. Inconsistent welding:
Inconsistent weld profile due to poor welding technique.

13. Undercut:
The weld reduces the thickness of the base metal and draws it into the weld. It creates a drain-like impression. Such imperfections are the result of poor welder settings, and poor-fitting metal parts can also lead to undercutting.

Note: Joint types are described as butt, lap corner, edge, puddle, tacking, T-joints, bevel groove, V-groove.