



## DEFECTIVE WELDS

*Revealing welding flaws through visual inspection.*

One element critical to a weld quality system is the final examination of the weld. Fabricators rely on radiography or ultrasound to check weld integrity. However, deficient welds can often be identified through visual inspection.

Visual weld inspection has the benefits of being able to be done in-house, causes minimal production delays and provides immediate feedback to welders and designers.

This article identifies the various types of weld discrepancies and discusses some visual weld inspection methods.

### Dimensional Discrepancies

Dimensional discrepancies can be found by verifying the structure against drawings or specifications. Defects often include warpage, misalignment, and incorrect joint preparation and weld size or profile discrepancies.

Even if a weld passes a "fit" check, they can create serious performance problems by introducing severe weld stresses where little stress is expected.

Centerline mismatch may create a stress riser, which could exceed the design strength of the assembly. Likewise, specialized or forceful weld fixturing can be used to compensate for imprecise dimensioning. This causes high locked-in stresses in the weld itself, increasing the potential for weld failure.

Dimensional defects can be avoided by the proper application of fixtures, welding sequences and preforms. Be sure to check the structural specifications before you begin. Dimensional discrepancy issues should also be addressed with the design or manufacturing engineers.

### Weld Undercut

A notch in the base metal characterizes a weld undercut. The notch can be in a stress-sensitive location in the weld. Being in the heat-affected zone has altered the mechanical properties. When changes from the base metals exposure to heat are combined with the reduction in cross-sectional notched area, the mechanical strength is greatly reduced.

This is critical in applications that involve impact, low temperature or fatigue conditions. A weld with an undercut should be repaired.

### Surface Porosity

Like a weld undercut, surface porosity can often be detected by eye. Gas bubbles trapped in the weld material cause this porosity. Surface porosity indicates porosity throughout the weld.

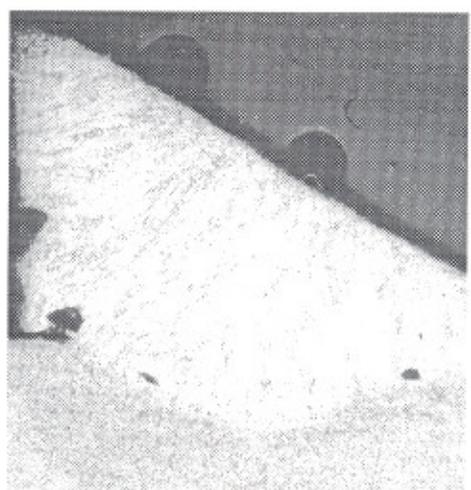
A polished cross-section of a weld, when examined under a microscope is distinguished by its "Swiss-cheese" appearance.

The gas bubbles can come from low quality or gassy metals or from interaction among weld materials. However, contaminant's oil or rust on the weld surface more commonly causes it. Minor internal porosity does not significantly effect weld performance but surface porosity is a serious condition.

Almost all fatigue fractures begin at the surface of the metal; anything that interrupts the surface of the metal is a fatigue crack nucleation point. This would include the craters created by surface porosity. Welds with surface porosity should always be replaced.

### Slag Inclusions

Like porosity, slag inclusions replace the weld material with a non-metallic component. These slag inclusions resemble black shards of glass on the top of the fillet. Lighter than the weld material, they tend to



**Fillet Weld Cross-Section 10X**

*Weld cross-section shows good penetration at bottom but poor penetration at root and no fusion at left. Some porosity is present.*

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- Standing weld seam findings
- Excessive convexity



float to the top of the molten metal. If the slag cannot escape they become trapped in the weld. The number, size and distribution directly determine the weld strength.

Electrode, flux debris and non-metallic inclusions also produce slag. These entrapped particles reduce the strength of the weld, reducing tensile strength and tensile ductility. Close attention should be paid to properly working the molten puddle to ensure that the slag surfaces. The risk of slag inclusions can also be reduced by properly preparing the weld surfaces.

Preparing the weld surface can reduce the risk of slag inclusions. This may include grinding metal protrusions to ensure no slag is caught in undercuts and gaps. Time should be allowed for the slag to rise to the surface of the molten metal. Rapid solidification is most likely to trap the inclusions.

Flux has a significant influence on the type of foreign materials that may form in the weld. A more fluid-like flux will enable the slag to reach the surface before the weld has solidified.

Slag inclusions weaken the weld because of a lack of metal homogeneity and lack of fusion. Lack of fusion occurs when the base metal fails to melt or mix with the weld material. Surface oxides, such as rust or scale often cause this. Unless these oxides are removed, lack of fusion becomes likely. In some cases, these discontinuities can be identified by a small gap between the fillet and the base metal or along the toe edge.

If no visual discrepancies are observed and if proper material preparation and welding practices are observed, it is generally assumed that the weld is solid. Radiography and ultrasonic inspection are most successful in determining porosity but less reliable in determining lack of fusion.

### **Weld Cracks**

Weld cracks are serious defects that have little margin of safety. The two types of cracking most likely to occur are hot cracking (Just after the weld has solidified) and cold cracking (which occurs near room temperature after the weld has cooled).

Most weld cracks are caused by hot cracking, with the weld being pulled apart during cool-down. If the configuration of the part does not allow the weld area to contract as it cools, then hot cracking becomes likely. If the width-to-depth ratio in the weld cross section is too high, edge cooling can pull the bead apart,

causing centerline cracking.

Hot cracking is common when high phosphorus, sulfur or lead content is present in the base metal. Chromium steels are particularly sensitive to microcracking, but this can be avoided with appropriate preheating procedures.

Methods to control or eliminate hot cracking are usually detailed in work instructions or weld procedures. Variables such as the type of alloy or type of weld can effect the weld sequence and the parts susceptibility to cracking.

In general, microcracking is less of a problem in metals that show good elongation in tensile tests. If you work with certified materials, be sure the elongation measurements of the lot meet or exceed the elongation specification for the type/grade of material.

Unlike hot cracking, which occurs right away, cold cracking can occur in the weld metal, hours or even days after welding. A single visual part inspection made directly after a weld may not be adequate to detect cold cracking.

The most damaging form of cold cracking is hydrogen embrittlement. This occurs when hydrogen is absorbed into the metal. Hydrogen embrittlement is usually associated with dust and dirt that has accumulated on the weld surface or from using a damp electrode.

This embrittlement is extremely harmful in alloy steels and it often happens in carbon steels. Structures suffering from hydrogen embrittlement lose their toughness and often fail. If you suspect hydrogen embrittlement, especially if porosity is present in alloy steel, invest in a metallographic examination of a weld sample.

### **Insufficient Leg**

Insufficient leg reduces the static and dynamic strength of the weld. As with insufficient throat, the weld may be too small to meet service strength requirements. This profile can often be repaired with an additional pass.

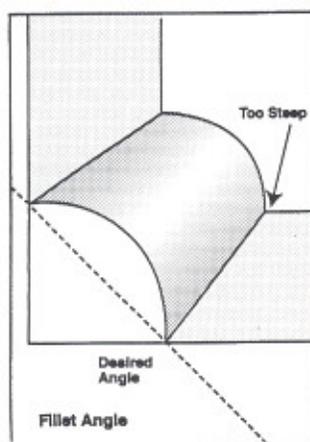
### **Excessive Convexity**

The opposite of insufficient throat is excessive convexity, distinguished by a thick, rounded fillet. Often, this convexity has a sharp approach into the toe of the weld. (angles greater than 45 degrees) In some cases, the weld material can approach at nearly a perpendicular angle.

***If you don't use certified materials, consider testing a sample of the material to see if the weld performance is what the design engineer expected.***

FIGURE 1

This illustrates the desired angle as compared to a weld with a sharp angle of approach.



In butt welds, this extra metal creates a stiff spot. This stiffness may cause a failure in dynamic conditions. The rounded weld shape creates stress risers at the toe of the material. If the toe is too sharp, it may be necessary to grind and redo the weld. If the angle into the base metal is shallow, engineering may permit the excess material to be removed to reduce the effect of the stiff spot.

In convex welds, bead edge cracking cannot be detected by x-ray examination. This fillet must be removed and replaced. If the approach to the toe of the weld is acceptable to engineering, then there may be little need to address the convexity.

It is important to remember that fillet welds are designed to handle stress; therefore the stress introduced by excessive convexity may be tolerable. On the other hand, butt welds may not have been designed for a stress concentration. The weld convexity may introduce a stress concentration that cannot be accommodated by the design and it may just encroach on the design strength of the assembly.

This lack of material weakens the weld joint and it may not be able to withstand normal operating stresses. Adding more metal can often repair thin flat beads on thick sections. Although, it often makes sense to replace the weld completely.

The centerline groove is the result of poor fit-up of the weld members, often caused by the members being too far apart. The weld must bridge them together. If the weld is wider than normal, the centerline groove creates a weak spot in the weld. Welds with this profile often fail.

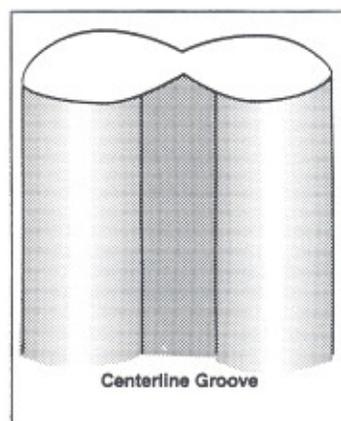


FIGURE 3

This illustration represents the appearance of a standing seam weld with a centerline groove.

### Weld rejection during visual inspection avoids added expense down the road.

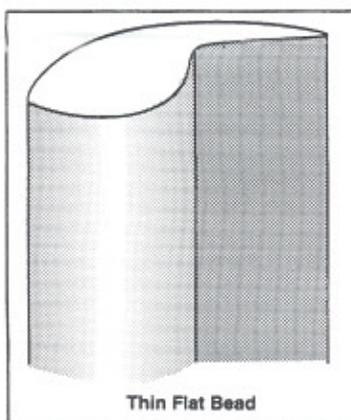


FIGURE 2

This illustration represents the general appearance of a thin flat bead.

#### Standing Seam Welds

Unlike butt and fillet welds, standing seam welds have unique profiles. Such welds are found on small and mid-sized tanks and in

some structural applications. They are subject to several types of profile discrepancies, all of which can be detected by visual inspection.

A thin, flat bead does not have the normal convex shape of a sound weld bead. This may be the result of either poor preparation or poor welding technique.

#### Summary

Visual inspection needs good lighting, low-power magnification, and a dental mirror. Possibly a borescope along with a conscientious attitude on the part of the examiner. Of the greatest value is prompt feedback to the welder to recognize good work and to enhance quality in the future. Additionally, weld rejection during visual inspection avoids added expense down the road.

The techniques and issues surrounding weld inspection are broad. If you suspect a problem, check it out. It is always better to err on the side of caution.

Many sources are available for more information. Start with your resident engineers. Contact your welding equipment suppliers or the American Welding Society (AWS).

Certified welding inspectors are available to help you and nondestructive and destructive weld testing services are available from reputable laboratories throughout the country. The routine confirmation of welds and practices will help you to ensure a safe, reliable product is reaching your customer.

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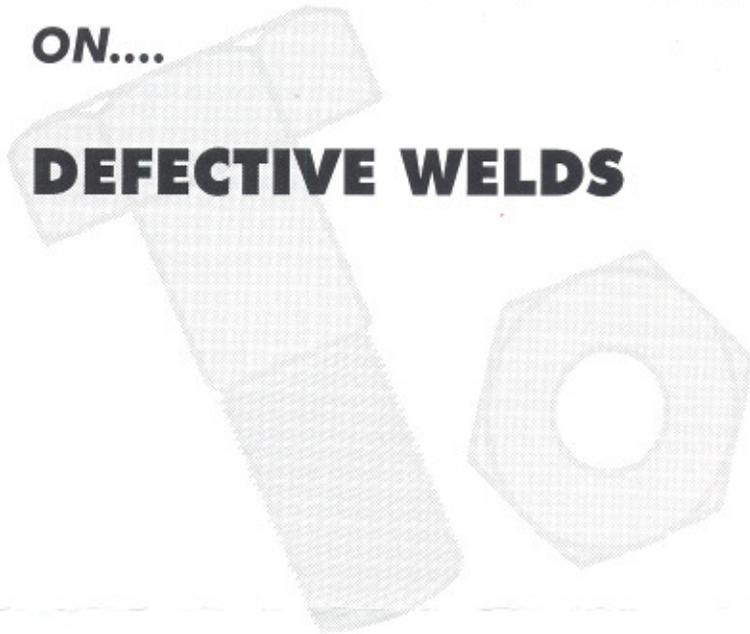
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### DEFECTIVE WELDS



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