Fillet Weld Leg Measurements

Fillet welds, perhaps the most common type of welds made in manufacturing, provide and endless source of challenges for analysis and interpretation. Related topics were discussed in two prior newsletters regarding identification of weld root (Summer 2022; Root Con-Fusion) and failure modes of fillet welds in tensile loading (Winter 2022, Shear Failure in Fillet Welds). In this Summer 2023 edition, we will review issues related to measurement of the leg dimension of a fillet weld.

Fillet welds can be made at multiple joints types including T-joints, edge of lap welds, and inside of corner joints. Fillet welds will typically be first measured visually using fillet gauges to ensure they meet the minimum leg length requirement. While external visual measurement provides the opportunity to non-destructively inspect welds, the interpretation is based on the assumption that the welds have complete fusion along the leg, which may not be true. GMAW-P (pulsed), a welding mode that is popular for making welds with very low spatter, is prone to producing welds that often have deep root penetration but can have poor fusion at the toes, especially for aluminum welds.

The second component of weld inspection, which includes weld sectioning, provides additional information but is a destructive technique and obviously can only be used on a sampling basis. After the welded sample is cut, polished, etched, and photographed to reveal the fusion zone, the extent of leg fusion can be measured with an optical microscope. Figure 1. shows a weld section as inset and the corresponding enlarged sketch of the same fillet weld shown for clarity.
Assuming continuous fusion, fillet leg is measured from the face of the other component to the farthest point where fusion can be observed near the toe of the weld; this measurement is defined as leg size, as per AWS 3.0 Standard Welding Terms and Definitions. (As per AWS, length measured visually by the fillet gauges is defined as fillet leg, and length measured in weld section is defined as fillet size.)

Interpretation of the fusion length can lead to a couple of points of confusion. At the root end of the fusion zone, leg size measurement, as defined by AWS, stops at the parent metal surface of the adjoining part. AWS does not provide an allowance for effective leg size, which would correspond to the effective weld throat, which is defined by AWS. However, the leg size on the horizontal component that would be of concern to the design engineer would be the effective leg size which would sustain any shear force on the weld along the face; corresponding measurement on the vertical component does not have such an incongruity.

On the other end of the leg near the toe of the weld, there can be a region marked “A” on Figure 1, and shown magnified in Figure 2, that can be tricky to interpret. Region A requires high quality polish and close inspection to check if it can be included in fusion length, as
defined by either actual fusion into the base material, or grain growth across the interface. In some cases, the filler material appears to sit on the surface without fusion, and thus cannot be included in measurement of weld size.

If the toe profile has an acute angle (less than 90°), then it would indicate good wetting of the molten metal onto the base metal although without much fusion; similar to a braze joint. While region A cannot be included in size measurement, presence of an acute angle may indicate a reduced risk of debonding at the toe. However, if the toe angle is obtuse (more than 90°), then the risk will be heightened as the quality of wetting may be debatable as well as likelihood of high stress resulting in crack growth at the toe will be elevated.

Figure 2. Schematic shows enlarged version of location A, showing acute and obtuse wetting angles at the toe of the weld.

In summary, we now have three different leg measurements:

1. Fillet weld leg length, measured externally with a fillet gauge.
2. Fillet weld leg size, as measured on a weld section per AWS.
3. Effective fillet weld leg size, as measured from the weld root.

As a weld design engineer, it will be your call to correctly specify the length making sure what you have in mind is the same as interpreted by the manufacturing and quality personnel. You want to have clear communication across the organization including with suppliers so as not let anyone pull your leg on this one 😊.