Fillet welded joints - a review of the practicalities

Fillet welded joints such as tee, lap and corner joints are the most common connection in welded fabrication. In total they probably account for around 80% of all joints made by arc welding.

It is likely that a high percentage of other joining techniques also use some form of a fillet welded joint including non-fusion processes such as brazing, braze welding and soldering. The latter techniques are outside the scope of this article.

Although the fillet weld is so common, there are a number of aspects to be considered before producing such a weld. This article will review a number of topics that relate to fillet welded joints and it is hoped that even the most seasoned fabricator or welding person will gain from this article in some way.

Common joint designs for fillet welds are shown below in *Fig.1*.

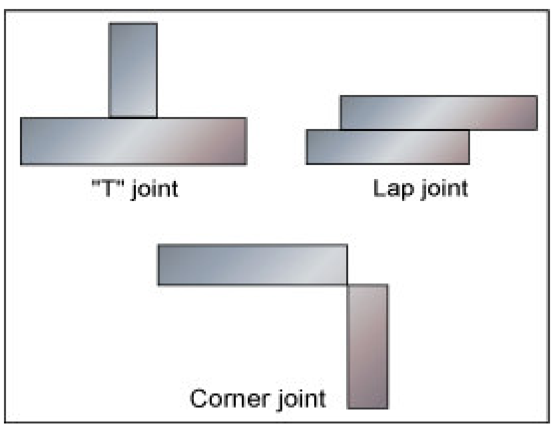


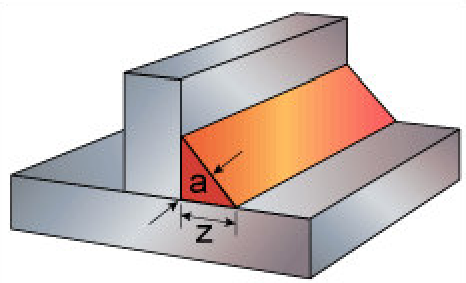
Fig.1

Fillet weld features

ISO 2553 (EN 22553) uses the following notation as *Figs.2* and *3* show.

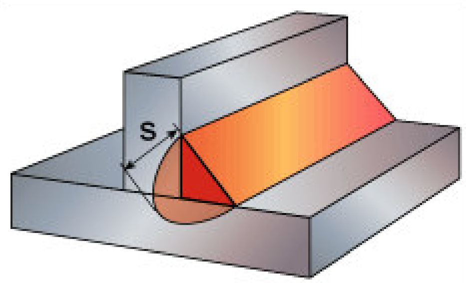
a = throat thickness
z = leg length
s = deep penetration throat thickness
l = length of intermittent fillet

Fig.2



Mitre fillet

Fig.3



Deep penetration fillet

Fillet weld shapes

Over specified fillet welds or oversized fillet welds

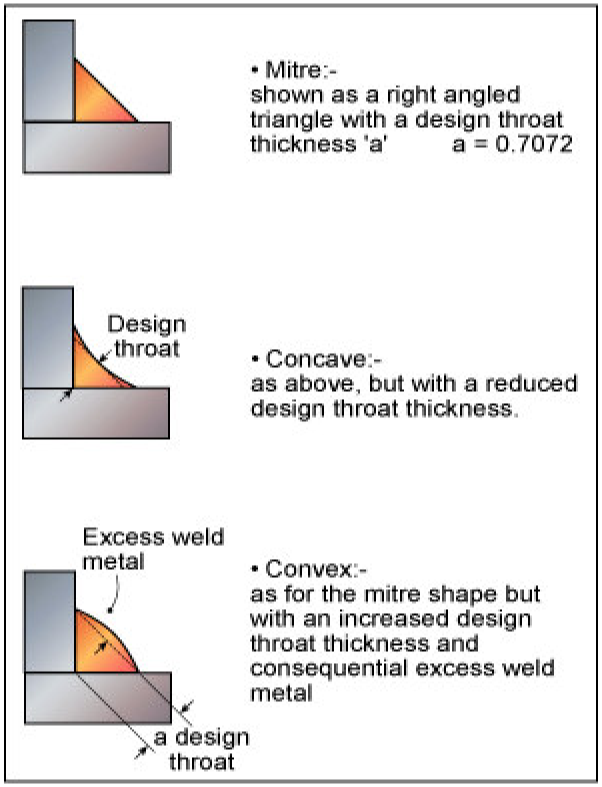


Fig.4

One of the greatest problems associated with fillet welded joints is achieving the correct weld size in relation to the required leg lengths or throat thickness (*Fig.4*).

The designer may calculate the size and allow a 'safety factor' so that the weld specified on the fabrication drawing is larger than is required by design considerations.

The weld size is communicated by using an appropriate weld symbol.

In the UK the weld size is frequently specified by referring to the leg length 'z' in ISO 2553 where the number gives the weld size in millimetres as shown in *Fig.5*.

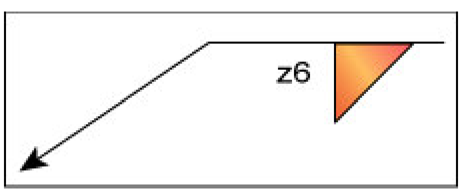


Fig.5

In Europe, it is more common to find the design throat thickness, 'a' specified (*Fig.6*).

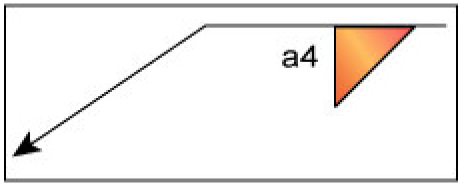


Fig.6

Once the drawing has been issued to the shop floor, it is usual to find an additional safety factor also being applied on by the welder or inspector. It is also common to hear 'add a bit more it will make it stronger'.

The outcome is an oversized weld with perhaps an 8mm leg length rather than the 6mm specified by the designer. This extra 2mm constitutes an increase in weld volume of over 80%.

This coupled with the already over specified weld size from the designer's 'safety factor' may lead to a weld that is twice the volume of a correctly sized fillet weld.

By keeping the weld to the size specified by the drawing office, faster welding speeds can be achieved, therefore increasing productivity, reducing overall product weight, consumable consumption and consumable cost.

The other benefit is that, in the case of most arc welding processes, a slight increase in travel speed would in most cases see an increase in root penetration so that the actual throat thickness is increased:

An oversized weld is therefore very costly to produce, may not have 'better strength' and is wasteful of welding consumables and may see other fabrication problems including excessive distortion.

Lap joints welded with fillet welds.

As discussed earlier, oversized welds are commonplace and the lap joint is no exception. The designer may specify a leg length that is equal to the material thickness as in *Fig.7*.

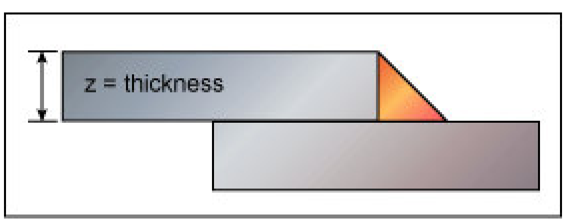


Fig.7

Strength considerations may mean that the fillet weld size need not be anywhere near the plate thickness. In practice the weld may also be deficient in other ways for example:

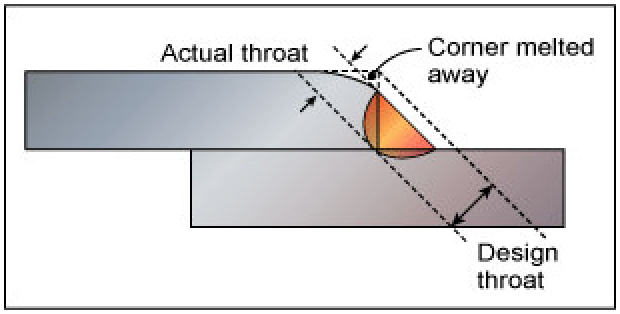


Fig.8

Due to melting away of the corner of the upper plate (*Fig.8*), the vertical leg length is reduced meaning that the design throat has also been reduced; therefore an undersized weld has been created. Care is therefore needed to ensure that the corner of the upper plate is not melted away. Ideally the weld should be some 0.5-1mm clear of the top corner (*Fig.9*).

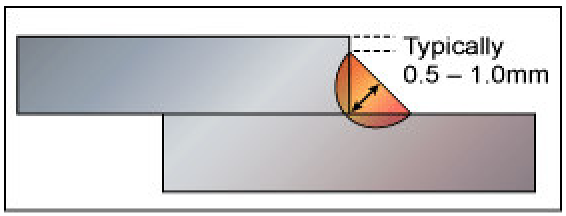


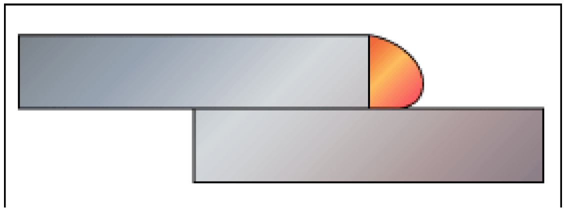
Fig.9

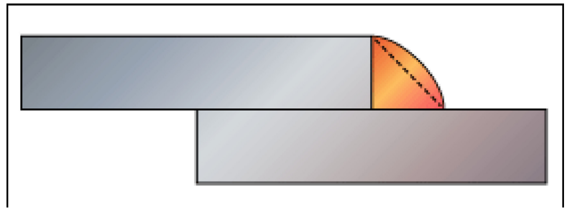
It may be the designer may therefore specify a slightly smaller leg length compared to the thickness of the component.

To compensate for this reduction in throat thickness it may be necessary to specify a deep penetration fillet weld. This amount of additional penetration would need to be confirmed by suitable weld tests. Additional controls may also be needed during production welding to ensure that this additional penetration is being achieved consistently.

In addition to the reduction in throat thickness there is the potential for additional problems such as overlap at the weld toe due to the larger weld pool size (*Fig.10*) or an excessively convex weldface and consequential sharp notches at the weld toe (*Fig.11*).

Fig.10 **Fig.11**





Both the potential problems shown in *Figs.10* and *11* could adversely influence the fatigue life of the welded joint due to the increased toe angle, which acts as a greater stress concentration.

Poor fit-up can also reduce the throat thickness as in *Fig.12*. The corner of the vertical component has been bevelled in the sketch in an exaggerated manner to illustrate the point.

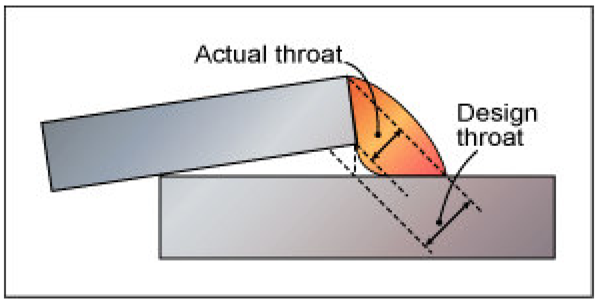


Fig.12

Summary

Fillet welded joints are not only the most frequently used weld joints but are also one of the most difficult to weld with any real degree of consistency. Fillet welds require a higher heat input than a butt joint of the same thickness and, with less skilled welders this can lead to lack of penetration and/or fusion defects that cannot be detected by visual examination and other NDT techniques.

Fillet welded joints are not always open to NDT or are indeed time consuming to many non-destructively testing techniques such as radiography or ultrasonic testing and the results are often difficult to interpret. Inspection methods such as visual inspection, magnetic particle inspection and penetrant inspection are surface examination techniques only and with visual inspection, much of the effort is expended in measuring the size of the weld rather than identifying other quality aspects.

Fillet welded joints are therefore much more difficult to weld and inspect. Often the welds that are produced are larger than they need to be or they may be of a poor shape which can adversely influence their service performance.

To overcome these difficulties, designers need to specify accurately the most appropriate throat size and welding personnel should strive to achieve the specified design size. Welders also need to be adequately trained and sufficiently skilled to be capable of maintaining an acceptable weld quality.

This article was written by **Mark Cozens of Weld-Class Solutions**. Any enquiries regarding the content of the article should be addressed initially to the Editor, *Connect*.
