Methods for Improving the Fatigue Life of Welded Joints

Postweld fatigue life improvement techniques can be used for increasing the fatigue life of welded joints. From the preceding sections, it can be seen that three factors influence fatigue of welded joints: stress concentrations due to joint and weld geometry, stress concentrations due to localized defects, and welding residual stresses. Improvement in fatigue life can be obtained by reducing the effects of one or more of these parameters. This is particularly true for cracks starting from the weld toe, which is by far the most common failure site. However, in load-carrying fillet welds, cracks can start at the weld root and propagate through the weld throat until failure occurs. In this case, additional weld metal to increase the weld throat dimension will result in reduction in shear stress and hence a corresponding increase in fatigue strength.

Because the most common failure site is the weld toe, many postweld treatments for this region have been developed to improve the fatigue life. These techniques rely largely on removing the detrimental intrusions at the weld toe, reducing the joint stress concentration, or modifying the residual-stress distribution. There are primarily two broad categories of postweld techniques: modification of the weld geometry and modification of the residual-stress distribution. A complete list is given in Fig. 24.

Methods that reduce the severity of the stress concentration or removal of weld toe intrusions include grinding, machining, or remelting. These techniques essentially focus on altering the local weld geometry by removing the intrusions and, at the same time, achieving a smooth transition between the weld and the plate. Typical profiles of burr-ground and gas tungsten arc welding (GTAW)-dressed welds are illustrated in Fig. 25. Because weld toe intrusions can be up to 0.4 mm (0.016 in.) in depth, the general guideline is that the grinding or machining operation must penetrate at least 0.5 mm (0.02 in.) into the parent plate. In these procedures, the depth, the diameter of the groove, and the direction of the grinding marks become important issues. In GTAW and plasma dressing, the weld toe is remelted in order to improve the local profile and also to "burn" away or move the intrusions. With these techniques, the position of the arc with respect to the weld toe and the depth of the remelt zone are two critical variables. Controlling the shape of the overall weld profile has also been recognized as a method of improving the fatigue life. The American Welding Society weld profile procedure using the "dime" test reduces the weld geometry K_t and hence increases the fatigue life.

Methods that modify the residual-stress field include heat treatment, hammer and shot peening, and overloading. Postweld heat treatment is known to reduce tensile residual stresses but does not eliminate them completely. The benefits of postweld heat treatment can be realized only if the applied loads are either partially or fully compressive. Overloading techniques rely on reducing the tensile residual-stress field and/or introducing compressive stresses at the weld toe. Exact loading conditions for a complex structure are difficult to establish, so this technique is rarely used.

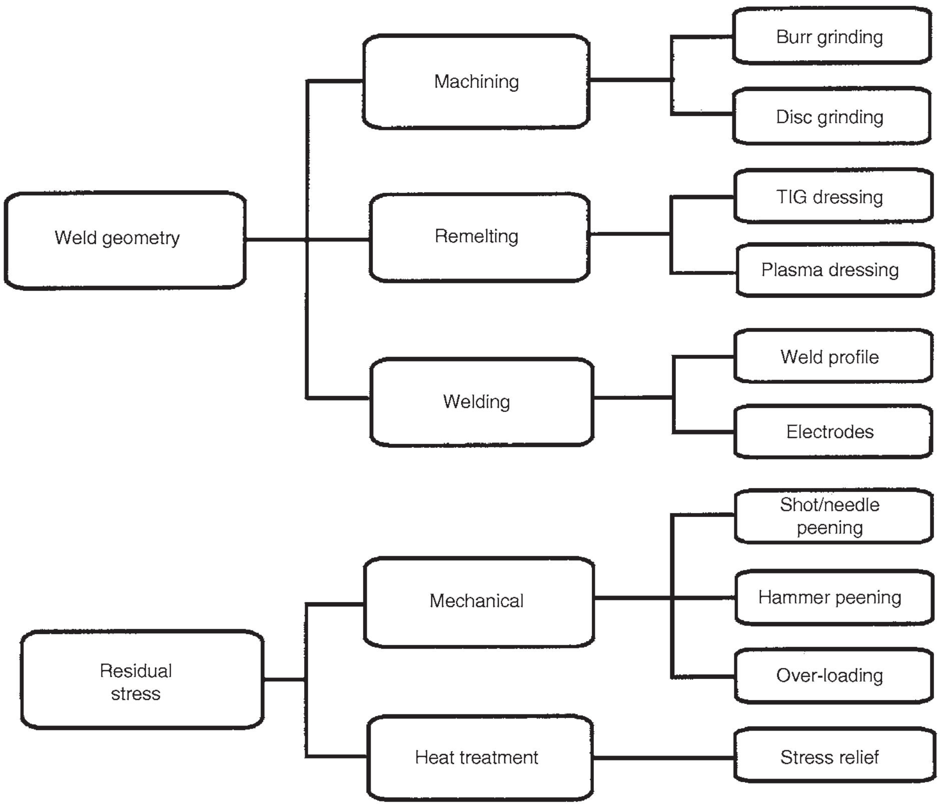

Fig. 24 Range of postweld fatigue life improvement techniques. TIG, tungsten inert gas. Source: Ref 16

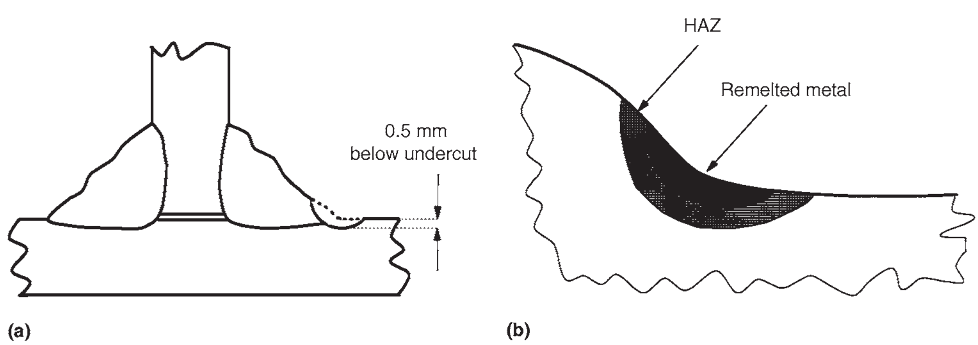

Fig. 25 Typical profiles for (a) burr grinding and (b) gas tungsten arc weld dressing of weld toe. HAZ, heat-affected zone. Source: Ref 16

To obtain significant improvements in fatigue strength, it is necessary to introduce compressive stresses in the local area in a consistent and repeatable manner. The three peening techniques (shot, needle, and hammer peening) aim to achieve this by cold working the surface of the weld toe. As with the grinding methods, it is necessary to penetrate the parent plate and deform to a depth of at least 0.5 mm (0.02 in.). Hammer peening is perhaps the best technique to do this, and it has the advantage of removing the weld toe intrusions by cold working them out. Peening techniques require special equipment and can present safety challenges for noise control. They are very difficult to automate and control in production.

A comparison of the improvement in fatigue strength obtained by some of these techniques is shown in Fig. 26. It can be seen that hammer peening is perhaps the best technique, perhaps because it reduces or eliminates intrusions as well as introduces compressive stresses. Burr grinding, which is easier to implement, also produces significant improvement in fatigue life. Disc grinding and burr grinding are probably the most frequently used methods for improving the fatigue life of welded joints.

Fracture Control in Welded Structures

The brittle fracture of the welded ships during World War II stimulated intensive research into avoiding catastrophic failures in fabricated structures. These early failures led to many studies to identify the parameters that must be controlled to avoid brittle fractures. Toughness of the mate-

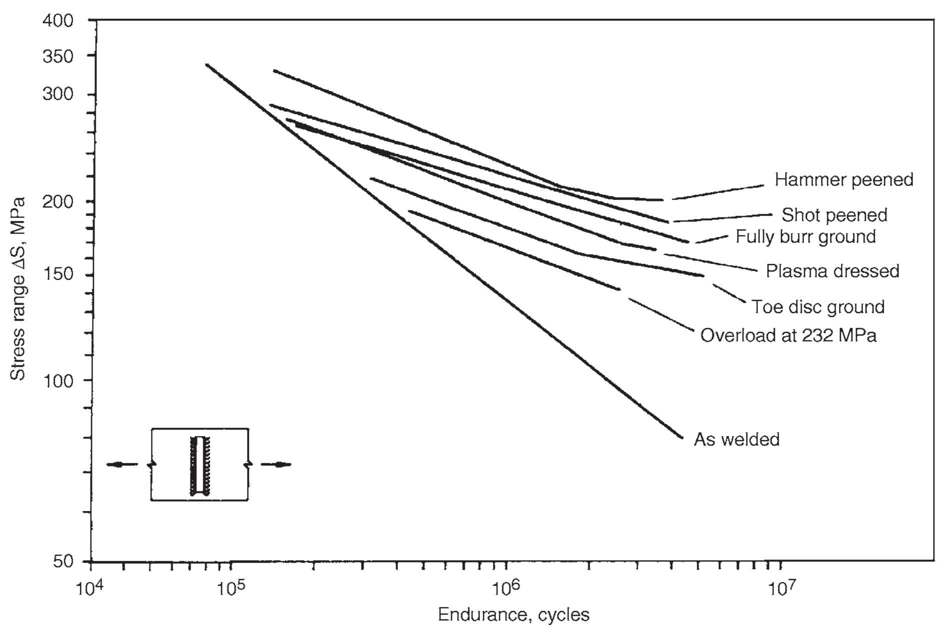

Fig. 26 Comparison of different improvement techniques. Source: Ref 16