

Liquation Cracking in Full-Penetration Welds of 2219 Aluminum Alloy

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The partially melted zone (PMZ) is the region immediately outside the fusion zone where liquation occurs along grain boundaries during welding. Aluminum alloys are known to be susceptible to liquation-induced cracking in the PMZ during welding. Liquation and liquation cracking in aluminum welds has been a subject of great interest in welding.

In the present study, liquation cracking in the partially melted zone (PMZ) of full-penetration welds of alloy 2219 (Al-6.3Cu) is investigated. The effect of the Cu content on the crack susceptibility is studied.

The circular-patch test was used to evaluate the crack susceptibility. Full-penetration gas-metal arc welds were made with filler metals 1100 (Al), 2319 (Al-6.3Cu) and 2319 plus extra Cu. The weld-metal composition was determined from the dilution ratio measured. The macrostructure and microstructure of the resultant welds were examined. The curves of temperature vs. solid fraction were calculated for both the PMZ and the weld metal at the observed dilution ratios.

Significant grain-boundary liquation was observed in the PMZ of all the welds. The weld with an Al-0.93Cu weld metal showed severe liquation cracking along the outer edge of the weld. The weld with an Al-2.32Cu weld metal showed solidification cracking as well as liquation cracking, though liquation cracking was less in this weld than in the Al-2.32Cu weld. The weld with an Al-3.43Cu weld metal showed severe solidification cracking and no liquation cracking. The welds with Al-6.3Cu and Al-7.55Cu weld metals showed no cracking at all.

These results showed a significant effect of the weld-metal composition on liquation cracking in full-penetration welds in alloy 2219. The closer the weld metal is to pure Al in composition, the more severe liquation cracking can be. As the weld-metal Cu content increases, liquation cracking decreases.

The curves of temperature (T) vs. solid fraction (f_s) were calculated for both the weld metal and the PMZ (same as the base metal) of these welds. The curves were essentially parallel to each other, without any intersections among

them. The curves showed that both the Al-0.93Cu weld metal and the Al-2.32Cu weld metal had a much higher solid fraction than the PMZ throughout solidification. The Al-3.43Cu weld metal also had a significantly higher solid fraction but not as much as the first two. The Al-6.3Cu weld metal had a solid fraction identical to that of the PMZ throughout solidification. The Al-7.55Cu weld metal had a lower solid fraction than the PMZ throughout solidification.

Based on both the experimental results and the curves of temperature vs. solid fraction for both the weld metal and the PMZ, it appears that liquation cracking can occur if: (1) PMZ is liquated severely, (2) The workpiece is restrained severely, (3) The weld-metal solid fraction is greater than the PMZ solid fraction throughout PMZ solidification, and (4) There is no solidification cracking in the adjacent weld metal.

Since the strength of the semisolid of a given material is likely to depend primarily on the solid fraction, a weld metal with a higher solid fraction than the PMZ is likely to be stronger than the PMZ. In circular-patch testing, the workpiece is severely restrained to keep the weld metal from contracting (due to solidification shrinkage and thermal contraction) and thus to induce tensile stresses/strains at the outer fusion boundary of the weld, where the weld metal and the PMZ are in contact with each other. As such, a solidifying and contracting weld metal higher in solid fraction and hence strength than the PMZ has the potential to pull the PMZ and cause it to crack.

The conclusions are as follows:

1. Liquation cracking can occur in alloy 2219 when the Cu content is significantly lower in the weld metal than in the base metal, but can shift to solidification cracking or no cracking as the Cu content increases.
2. Liquation cracking tends to be absent when solidification cracking is present in the adjacent weld metal, probably because solidification cracking relaxes the tensile strains in the adjacent PMZ.
3. Based on the results of circular-patch testing and the curves of temperature vs. solid fraction, it appears that liquation cracking has the potential to occur if: (1) PMZ is liquated severely, (2) The workpiece is

restrained severely, (3) The solidifying and contracting weld metal is higher in solid fraction and hence strength than the PMZ throughout PMZ solidification, and (4) There is no solidification cracking in the adjacent weld metal.