C. Liquation, Cracking and Backfilling in Partial-Penetration Welds of Aluminum Alloys - Comparing Alloys 2024, 6061 and 7075

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Introduction

The partially melted zone (PMZ) is the region immediately outside the fusion zone where liquation can occur along grain boundaries and cause intergranular cracking under the tensile strains induced in the workpiece during welding. Alloys 2024, 6061 and 7075 are known to be susceptible to liquation cracking. In the present study the extents of liquation, liquation cracking and backfilling near the weld root of partial-penetration, gas-metal arc (GMA) welds of these alloys are examined and compared, and explained based on the curves of temperature (T) vs. solid fraction (f_S) of the PMZ and the weld metal during their solidification.

Procedure

Bead-on-plate welding was carried out perpendicular to the rolling direction of the workpiece. The workpiece was 20 cm (8 in) long, 10 cm (4 in) wide and 9.5 mm (3/8 in) thick. The welding parameters were: 7.41 mm/sec (17.5 ipm) travel speed, 30 V arc voltage, 250 A average current and Ar shielding. The filler-metal diameter was 1.2 mm (3/64 in) and the feeding rate was 18.6 cm/sec (440 ipm). Curves of temperature (T) vs. solid fraction (f_S), based on the multicomponent Scheil model, were calculated for both the solidifying PMZ (same as the base metal) and the solidifying weld metal.

Results and Discussion

All welds exhibited the papillary- (nipple-) type penetration common in GMAW with Ar, with a wavy weld root along the welding direction. Liquation, liquation cracking and PMZ grain deformation were severe in alloys 7075 and 2024. In alloy 6061, however, no liquation cracking occurred, liquation was slight, and PMZ grains were not deformed.

The T-f_S curves showed that the freezing range and the fraction of liquid ($1 - f_S$) decreased in the order of alloys 7075, 2024 and 6061, and were much lower in alloy 6061. This explained the much less liquation and hence the absence of liquation cracking in 6061.

With filler metal 1100, cracking in alloys 7075 and 2024 was most severe, and cracks were open with little backfilling. The T-f_S curves showed that the weld metal was significantly higher in f_S and hence strength than the PMZ throughout solidification. This explained the severe cracking observed. The fraction of the interdendritic liquid ($1 - f_S$) in the weld metal diminished quickly after the start of solidification, dropping to only 0.15 at 40-50 ^oC below the liquidus temperature. This suggested that little interdendritic liquid was available for backfilling liquation cracks. This explained the open cracks.

With filler metal 4043, cracking in alloys 7075 and 2024 was also though less severe and cracks were partially backfilled. The T-f_S curves showed that the weld metal was lower in f_S and hence strength than the PMZ but this trend was reversed during PMZ terminal solidification. This explained the liquation cracking in 7075 and 2024 welds made with filler metal 4043. The fraction of the weld-metal interdendritic liquid was much higher with filler metal 4043 than with 1100, suggesting that 4043 made more interdendritic liquid available for backfilling. This explained the partially backfilled cracks.

Conclusions

Under the same welding condition, liquation, liquation cracking and PMZ grain deformation near the weld root decrease in the order of alloys 7075, 2024 and 6061. With filler metal 1100 cracking in alloys 7075 and 2024 appears most severe, and cracks tend to be open with little backfilling. With filler metal 4043, cracking can still be severe but cracks tend to be partially backfilled. These results can be explained with the help of the T-f_S curves calculated for the PMZ and the weld metal based on the multicomponent Scheil model.