SPC-3 Study of Mechanical Properties & Precipitation Behavior in Friction Stir Welded Thin Sheet 2024: Effect of Parameters on Microstructure and Properties of a thin sheet Al-Cu-Mg Alloy

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Introduction

Since the development of the process, Friction Stir Welding of aluminum alloys has most widely been studied in plates with thickness ranging from 6 mm to 25 mm (0.25 to 1 inch). As the thickness decreases, the range of effective welding parameters becomes narrower. Parameters including the tool design, tool rotation speed, welding speed, normal force, plunge depth, backing plate material, and dwell time before traverse must be significantly modified to achieve high-integrity FS welds. The purpose of this study was to optimize the welding parameters for FSW of thin sheet 2024-T3 alloy, to examine the effect of welding parameters on the microstructure of the welds, and to understand how these microstructural changes across the weld influence weld mechanical properties.

Procedure

A Design of Experiments (DOE) approach using Taguchi's orthogonal arrays was employed to optimize welding parameters for the FSW of 1 mm thick 2024-T3 sheet using three variable parameters: tool rotation, traversing speed and plunge depth. Mechanical properties of the welds were studied with the help of tensile and hardness measurements. After identifying regions of interest from the hardness profiles, TEM foils were prepared and examined at 200 kV using a Philips CM200 TEM.

Results and Discussion

The weld nugget showed equiaxed, recrystallized grains with diameters between 0.5 to 1 µm, with some helical dislocations and a very low dislocation density. The microstructure shows breaking up of the $Al_{20}Cu_2Mn_3$ dispersoids into smaller-sized particles. From the hardness profiles, three distinct areas in the HAZ can be identified: 1) a hardness minimum just outside the TMAZ which decreased with increasing heat input (region A), 2) a hardness peak in the HAZ (region B) and 3) a second hardness minimum farther away in the HAZ (region C). Coarse S precipitates were observed in region A, corresponding to the lower hardness in this region. In the region B, corresponding to the hardness peak, very faint reflections and streaks were observed only after long exposures, which correspond to the GPB II zones. The microstructure in region C of the HAZ was comparable to that of the base metal, and SAD analysis did not reveal evidence of GPB II or S′. The slight decrease in hardness in this region relative to the base material is attributed to dissolution of GPB zones.

Conclusion

It has been demonstrated that friction stir welding can be successfully used to make high integrity welds in 1 mm thin sheet age hardenable alloy 2024 with weld efficiency (UTS_{FSW} /UTS_{parent}) of up to 100%. The plunge depth was the most critical parameter for obtaining defectfree welds. The hardness minima at the TMAZ/HAZ boundary, percentage elongation, and the UTS of the welds generally increased with a decrease in heat input. However, it should be noted that very low heat input welds were prone to tunnel defects. Various regions of the welds were characterized using transmission-electron microscopy and changes in the type, size and density of precipitates were related to the changes in hardness across the weld.