Micro-structure and micro-analysis of FSW 2024-t3 al alloy using electron microscopy

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A friction stir welding (FSW) method has been used in the industrial field, since the method is simple and convenient, and the surface conditions of the welded productions are desirable. In order to investigate mechanical properties in parts jointed by this method, micro-structures observation and EDS analysis in the welded (nugget) part of 2024-T3 Al alloy were carried out using electron microscopy.

FSW processing of 2024-T3 Al (Al-Cu-Mg system) alloy plates was performed under the following condition: tool tilt angle = 3 degrees, rotation speed = 1,300 rpm and welding speed = 330 mm/min. Thin foil specimens cut from the nugget part and the base material were prepared. A JEM 2010F electron microscope operated at 200 kV was used.
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Helical dislocations are visible in the nugget part. The existence of helical dislocations suggests that the friction-stir welded part was heated to near the melting temperature during the processing, and lots of vacancies were formed. Hardness testing results of the nugget and the matrix parts (outside the nugget) indicate that hardness value in the nugget part is lower than that in the matrix. The origin of this softening will be concerned with the results of EDS analysis about the nugget and the matrix parts.

Rod-shape precipitates are visible both in the base material and the nugget part. These results indicate rod-shape precipitates remain after FSW processing. In the nugget part, round-shape precipitates are also visible. The size of the precipitates is 100-200 nm in diameter. Although round-shape precipitates are visible in the base material, the density in the nugget part is higher than that in the base material. This fact suggests that the formation of round-precipitates might contribute lowering hardness value in the nugget part.

EDS spectra of rod-shape and round-shape precipitates in the base material and the nugget part indicate Al, Cu, Mg, Cr, Si and Mn peaks. In EDS spectra from many precipitates in the nugget part, Fe peak appears. This result suggests that Fe elements segregate into the precipitates. The increase of Cu content in the precipitates is also recognized. It is reported that precipitates in the FSW parts of the same alloy are S-phase (Al_2MgCu) and Ω-phase (Al_2Cu) [1]. The present results suggest the precipitates are different from S-phase and Ω-phase.

One of the origins of softening recognized in the nugget part is considered as role of segregation of solute elements Fe and Cu; that is, Cu and Fe in the matrix segregate into precipitates during the FSW processing, and the effect of solution hardening due to these elements decreases. Moreover, the spacing of precipitates is over 200 nm and it is considered that the contribution of precipitation hardening based on Orowan-mechanism is almost negligible. A possibility of annealing effect in the heated nuggst part might remain.

[1] M.J. Jones, P. Heurtier, C. Desrayaud, F. Montheillet, D. Allehaux, J.H. Driver: Scr Mater 53 (2005) 693-697.