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Short Communication

Effect of welding speed on microstructures and mechanical properties of underwater friction stir welded 2219 aluminum alloy

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ABSTRACT

Underwater friction stir welding (underwater FSW) has been demonstrated to be available for the strength improvement of normal FSW joints. In the present study, a 2219 aluminum alloy was underwater friction stir welded at a fixed rotation speed of 800 rpm and various welding speeds ranging from 50 to 200 mm/min in order to clarify the effect of welding speed on the performance of underwater friction stir welded joint. The results revealed that the precipitate deterioration in the thermal mechanically affected zone and the heat affected zone is weakened with the increase of welding speed, leading to a narrowing of softening region and an increase in lowest hardness value. Tensile strength firstly increases with the welding speed but dramatically decreases at the welding speed of 200 mm/min owing to the occurrence of groove defect. During tensile test, the joint welded at a lower welding speed is fractured in the heat affected zone on the retreating side. While at higher welding speed, the defect-free joint is fractured in the thermal mechanically affected zone on the advancing side.

1. Introduction

Friction stir welding (FSW) has been widely utilized to weld heat treatable aluminum alloys that were difficult to fusion weld. However, a soften region composed of the weld nugget zone (WNZ), the thermal mechanically affected zone (TMAZ) and the heat affected zone (HAZ) tends to be created due to the deterioration (coarsening or dissolution) of strengthening precipitates caused by FSW thermal cycles [1–4]. As a consequence, the tensile strength of the joint is lower than that of the base metal. In order to improve the joint performances by controlling the temperature level, external liquid cooling has been applied during FSW by several researchers. Benavides et al. [5] developed FSW experiment of 2024 Al using liquid nitrogen cooling to decrease the starting temperature of plates to be welded from 30 °C to −30 °C. The hardness in the TMAZ and HAZ was improved compared to the normal joint, but void defect was formed in the nugget and the cooling effect on mechanical properties of the joints was not stated in detail. Fratini et al. [6] considered in-process heat treatment with water flowing on the top surface of the samples during FSW. The tensile strength of the joint was found to be improved by the cooling action. In order to take full advantage of the heat absorption effect of water, underwater friction stir welding (underwater FSW) was proposed and conducted by the present authors [7]. The results indicated that the tensile strength of the underwater joint was significantly higher than that of the normal joint, confirming the feasibility of underwater FSW to improve the mechanical properties of the normal joints. Although external water cooling has been demonstrated to be available for the strength improvement in the previous studies, the relationship between the process variables and the performance of the cooled joint has not yet been developed. Therefore, a 2219 aluminum alloy was underwater friction stir welded in the present study, and the effect of welding speed on joint quality was investigated in terms of microstructures, hardness distributions and tensile properties.

2. Experimental procedure

The base metal (BM) utilized in the experiment was a 2219-T6 aluminum alloy plate with the thickness of 7.5 mm. The chemical compositions and mechanical properties of the BM are listed in Table 1. The plate was machined into rectangular welding samples with dimension of 300 mm long by 100 mm wide. After cleaned by acetone, the samples were clamped to the backing plate in a vessel, and then the water at room temperature was poured into the vessel to immerse the top surface of the samples. Underwater FSW was performed using an FSW machine (FSW-3LM-003) along the longitudinal direction (perpendicular to the rolling direction) at a fixed rotation speed and various welding speeds. The conical welding tool size and welding parameters are listed in Table 2.

After welding, the joints were all cross-sectioned perpendicular to the welding direction for metallographic analyses and Vicker's hardness tests using an electrical-discharge cutting machine. The cross-sections of the metallographic specimens were polished using a diamond paste, etched with Keller's reagent and observed

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