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Effect of tool–pin offset on microstructure, mechanical properties, and corrosion behavior of friction stir welded AA2024-T3 and SS304 dissimilar joints

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Abstract

The combination of aluminum and steel materials in hybrid structures shows promising applications in the automotive, marine, and aerospace sectors. The present study investigates how the tool–pin offset impacts the microstructural, mechanical, and electrochemical characteristics of friction stir-welded joints between dissimilar AA2024-T3 and SS304 materials. The optimum conditions were achieved at a tool rotation of 560 r/min, a traverse speed of 25 mm/min, and a tool–pin offset of 1 mm towards the Al side. Upon increasing the tool–pin offset to 1.5 mm, insufficient heat input resulted in inadequate plastic deformation and material flow, leading to the creation of flaws like voids, tunnels, and interfacial gaps. However, under optimal conditions, the joint exhibited a well-defined and serrated interface, with fine steel fragments securely embedded in the Al matrix. Additionally, thin intermetallic compounds were observed around the steel fragments within the Al matrix. This favorable combination resulted in enhanced tensile strength and increased ductility in the joint. The Vickers hardness test revealed that the stir zone exhibited the highest hardness values, primarily attributed to the ultra-refinement of grains. Furthermore, the potentiodynamic test revealed that the welded samples show improved corrosion resistance against the base material AA2024-T3, although BM-SS304 exhibited the highest corrosion resistance among all the samples, likely due to its higher chromium content.

Keywords

Friction stir welding, SS304, AA2024-T3, tool–pin offset, mechanical properties, corrosion, microhardness, dissimilar materials

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Introduction

The aerospace and automotive industries have recognized the importance of regulations concerning exhaust emissions and fuel economy, prompting manufacturers to employ advanced methods of reducing overall structural weight.[1,2] One effective strategy to decrease the overall weight of structures while maintaining their quality and safety is implementing hybrid structures, where various components are made of materials with varying thermal, physical, and mechanical properties. However, joining dissimilar materials has posed various challenges and has limited their widespread usage. Various welding techniques have been employed for joining such dissimilar materials, but conventional fusion welding strategies are often unsuitable because of differences in the properties of the materials to be welded, resulting in various solidification defects such as porosity, residual stresses, blowholes, etc.[3] Such challenges can be addressed by adopting solid-state welding methods.[4,5] Friction stir welding (FSW) invented in 1991 by "The Welding Institute" UK has emerged as a promising solution and offers advantages over fusion welding techniques by providing lower heat input and thinner intermetallic compounds (IMCs) interface.[6–11] Lightweight aluminum (Al) and its alloys possess properties like a substantial strength-to-weight ratio, good heat transfer, and adequate formability. While as, stainless steel (SS) possesses promising properties like high strength, good corrosion resistance, high toughness, and creep strength. Thus, the joining of SS and Al alloy pair finds application in automotive, marine, and aerospace industries, and supports overall

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