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Analyzing microstructural evolution and wear behavior of friction stir welded dissimilar joints of SS304 and 2024-T3 Al alloy

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ABSTRACT

This study employs friction stir welding (FSW) on SS304 and 2024-T3 Al alloy to enhance the microstructure and wear resistance of the resulting joint. FSW yielded an ultra-refined microstructure with a 4.2 μm average grain size, achieved through severe plastic deformation. In the dry sliding reciprocating wear test, specific wear rates for the base materials Al alloy, SS304, and FSWed specimens were determined to be 9.203×10^{-13} m^3/Nm, 4.024×10^{-13} m^3/Nm, and 2.072×10^{-13} m^3/Nm respectively. Notably, the FSWed specimen exhibited an improved wear behavior, showing increased stability in the tribolayer and a reduced occurrence of severe delamination. The enhancements result from grain refinement and the inclusion of finely dispersed stainless steel (SS) particles, comprising around 5–6 % of the material, with an average grain size of 1 μm to 1.2 μm, within the stir zone (SZ), encased by thin layers of $FeAl_3$ and Fe_2Al_5. These factors contribute to the heightened microhardness of the specimen and a decrease in wear rate.

1. Introduction

The automotive, aerospace, and marine industries necessitate lightweight structures with superior wear resistance to ensure optimal performance and durability [1]. These specific applications underscore hybrid structures combining lightweight materials such as aluminium (Al) with stainless steel (SS). Strategically utilizing joints made from SS and Al alloys in critical areas provides a practical solution [2]. Despite the attractive qualities of Al and its alloys, their practical use is hindered by inadequate wear resistance. The inferior wear resistance of Al and its alloys is attributed to their softer surface and the absence of a protective passive oxide layer [3]. Researchers have explored microstructure refinement as a promising strategy to address these limitations [4]. Wear performance is typically influenced by various factors such as the welding route, post-welding processes, plastic deformation, and grain size modification. Researchers provided the mechanism behind the wear behavior in FSWed dissimilar Al alloy joints with varying track dimensions, emphasizing lower wear rates in the welded samples compared to that of base materials [5]. Kumar et al. [6] reported reduced material removal in wear tests on FSWed 6061-T6 Al alloy compared to the BM, indicating a notable influence of FSW on joint wear performance. However, current literature primarily focuses on the surface properties and tribological behavior of dissimilar materials, particularly Al alloys, in FSW. Despite their potential applications, there is limited research on the surface and tribological properties of FSW joints involving dissimilar materials such as SS and Al alloys. To bridge this gap, this study represents an attempt to investigate the relationship between microstructure and wear performance in welded joints comprising SS304 and 2024-T3 aluminium alloy, offering a visual representation of the wear mechanism for reader comprehension.

2. Material and methods

Present study utilized 3 mm thick sheets of AA2024-T3 and SS304 with composition (in wt. %) as 0.04Zn–1.33 Mg–0.25Fe–0.07 Si–3.87Cu–0.01Cr–0.58Mn–0.05Ti–0.014Ni–94.1Al and 18Cr–8.72Ni–

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