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Investigations on surface properties of friction stir welded dissimilar AA2024-T3 and 304 stainless steel joints

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ABSTRACT

The present study investigated the influence of tool rotational speed on dissimilar joints between AA2024-T3 and SS304 metals using friction stir welding (FSW). Optimal results were achieved at 560 rpm tool rotation, 25 mm/min traverse speed, and 1 mm tool pin offset. This rotation rate facilitated proper heat input, inducing plastic deformation and material flow, resulting in an ultrafine grain structure in the stir zone (SZ). 3D profilometry showed variable surface roughness affected by process parameters. Potentiodynamic tests demonstrated improved corrosion resistance in FSWed samples compared to the base material. Vickers hardness testing revealed increased hardness in the SZ due to grain refinement. Wear behavior evaluation highlighted the significant influence of tool rotation on enhancing wear resistance in welded specimens.

1. Introduction

The escalation in emissions of effluent stands as principal catalyst behind the enduring shifts in climatic conditions and climate change [1,2]. The UN's Sustainable Development Goals, especially Goal 13, also emphasize the need to reduce emissions [3]. Industries like marine, aerospace, and automotive are adopting innovative methods to comply [3,4]. Reducing component weight is a key strategy to cut fuel consumption and reduce emissions. In the automotive sector, a 100 kg weight reduction results in a 9 g CO_2 per km decrease [5–7]. Aerospace vehicles allocate only 5% of weight for payload, with the majority used in structural components and fuel. This weight reduction increases load capacity. The utilization of hybrid structures comprising dissimilar materials exhibiting distinct thermal, physical, and mechanical traits emerge as a promising avenue. In the category of dissimilar alloys, researchers are paying attention to structural materials, especially aluminum alloys, and steel. Aluminum and its alloys excel in strength-to-weight ratios, heat transfer, and formability, making them ideal for automotive, aerospace, and marine applications. Stainless steel, in contrast, offers enhanced toughness, corrosion resistance, wear resistance, and strong tensile and creep strength, making it promising for similar industries [8]. Incorporating these materials into the automotive, aerospace and shipbuilding industries provides a cost-effective means to enhance efficiency and reduce the overall weight of structures. This, in turn, results in reduced fuel consumption, leading to lower exhaust emissions and significant progress in pollution control, fuel efficiency, and operational range [7,9,10,8,11].

However, joining such dissimilar materials poses challenges due to differences in their mechanical and thermal properties, resulting in various solidification defects, including porosity, residual stresses, and suboptimal surface properties in conventional fusion welding [12–14]. Additionally, in the marine industry, the exposure of joints to severe conditions such as saline water increases their vulnerability to corrosion attack [15–21]. Furthermore, the contact motion causes high wear rates even at low loads, limiting industrial applications. Addressing wear issues alone could save $100 million in the US and 1.6% of the GNP in developing countries like India [22]. Hence, the imperative task is to create flawless dissimilar Al-SS joints with improved surface characteristics to maximize their industrial utility. Various new joining techniques were employed by researchers for joining difficult to join and dissimilar materials [23–25]. Friction stir welding (FSW) pioneered and patented by "The Welding Institute (TWI) UK" in 1991, stands as a promising solution, surpassing traditional fusion welding methods due to its advantages, including reduced heat input, thinner intermetallic compounds (IMCs), and enhanced surface properties [26].

Liu et.al [27] examined the friction stir welding (FSW) of AA6061 and TRIP 800/830 steel and found that tool rotation significantly impacts the structural integrity of the interfacial region of the joint. They

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