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Parametric optimization of friction stir welding of AA 6101 T-64 and pure Cu using response surface methodology

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Abstract
The friction stir welding (FSW) process was used to join electrical grade aluminium alloy 6101 T-64 and pure Cu plates and optimized using the Box–Behkan approach of response surface methodology. The tool rotational speed, traverse speed, tool offset, and tool tilt angle were deemed to be relevant parameters since they have a considerable significance on the weld joint properties. By using mathematical models, the relationship between welding parameters and responses (tensile strength σ_s and electrical resistivity ρ) is examined. The responses are maximized or minimized in these models. Response plots produced from mathematical models are used to analyze the interaction effects of the FSW parameters on the output responses. Through the use of the analysis of variance (ANOVA) method, the constructed models are validated. The results of the experimental research demonstrated that a wide range of FSW settings can be used to construct sound weld joints without defects. The findings from the tensile strength ANOVA table showed that the tool rotational speed and tool offset were significant parameters, however the traverse speed and tool tilt angle were not significant parameters for tensile strength. From ANOVA table of electrical resistivity all parameters were found significant for electrical resistivity. The experimental results and predicted models showed good agreement. The microhardness study at optimized welding parameters revealed the variations in microhardness distribution in different regions. It is found that the microhardness distribution was higher in the bottom region followed by top region and middle region.

Keywords Friction stir welding (FSW) · Box–Behkan design method · Response surface methodology (RSM) · Tensile strength · Electrical resistivity · Microhardness

1 Introduction

The Welding Institute (TWI) invented the friction stir welding (FSW) process in 1991 as a "green technology" [1, 2, 6, 8, 10]. It's a solid state joining technique carried at the recrystallization temperature. A rotating tool pin with an unique feature is inserted between the base materials' adjacent edges. Frictional heating between the material surface and the tool shoulder leads the material to soften. A solid state weld joint is formed when the softened material is stirred by the tool pin [24, 27, 31, 32]. The process reduces defects like solidification cracking and intermetallic compounds (IMCs) formation since it works below the material's melting point [24]. FSW joints shows low distortion and greater weld strength [23, 27]. The process is used to join materials that are similar and dissimilar. In the nuclear, aerospace, electrical, and electronics industries, joints made of different materials are used for weight & cost reduction and improvement in productivity [1, 5, 6, 9, 13, 14]. Copper and aluminum has good corrosion resistance, mechanical properties, heat and electrical conductivities [17, 27]. The common industrial applications of Al–Cu joint are in busbars, electrical connectors, bimetals, heat exchanger tubes, heat sink, and refrigeration tubes [1, 5, 6, 9, 14]. Cost, mass and weight reduction is required in present days engineering applications [20]. Both materials are having different physical, chemical, flow stress, and mechanical properties. The IMCs affects the mechanical and electrical properties [7, 9, 30]. Incorrect parameter selection results in poor stirring, and

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