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Plasticine Modeling of Material Mixing in Friction Stir Welding

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Abstract

Plasticine of primary colours was utilized and the hue attribute of generated secondary colour was tracked. The degree of mixing was indicated by the intensity of secondary colour. Hue component was obtained from digital images of joined plasticine cross-section by converting RGB colour-maps to HSV colour-maps. Effect of tool pin profile that included circular, hexagonal, square and triangular was examined in this context. As the number of faces on the tool pin reduces, up-till pin with four faces (square) the pin induced mixing increases and results in the elimination of joint line remnant. Material adjacent to the face was transported in lumps and experienced spinning/whirling movement. During mixing phenomenon flow velocities of constituents undergoing it tends to fluctuate. The fluctuation is significantly large for higher levels of mixing and the same was noticed for a square profile from the results of finite element simulations. The results obtained from plasticine and finite element simulations are validated using aluminium weld.

Keywords: Plasticine, Flow visualization, Material intermixing, JLR (Join Line Remnant), Tool pin profile, FE (Finite Element) simulations

1. Introduction

Friction Stir Welding (FSW) is a growing solid-state welding process. Its growth is marked by its potential to join high strength aluminium alloys, which are not recommended with conventional fusion welding. Considering its potential, its application is extended for casting modification, powder processing, achieving superplasticity, surfacing, micro-forming and channelling. In FSW, adequately stirred material at initial butting interface is expected to give sound joints and subsequent superior mechanical properties. Stirring entails large deformation and mixing of material and it occurs in weld nugget at high temperatures (below the melting point) and strain rates. Failure to accomplish this results in JLR (Joint Line Remnant) defect in the weld. JLR originates from oxide /contaminant layer at the butting surfaces, which inhibit metal-to-metal contact, and consequently, the initial interface is left unwelded. The presence of unwelded surfaces and edges impairs the static and dynamic strength of friction stir welds. The problem aggravates while friction stir welding materials with tenacious contaminant layer. Vugrin Tamara, (2005) through their electron microscopy studies on friction stir butt welded 6013-T4 alloy demonstrated that these oxide and hydroxide layers lead to flaws in weld nugget. The presence of JLR is found to have an adverse effect on fatigue properties of the FSW welds. Zhou et al., (2006) reported JLR reduced the fatigue life of FS welds by 21-43 times in AA5083. Le Jolu et al., (2015) and Chen et al., (2015) in separate studies have reported of JLR having a detrimental effect even on the tensile strength of AA2198 and AA2219 FSW welds. In