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PII: S0924-0136(17)30267-4
DOI: http://dx.doi.org/doi:10.1016/j.jmatprotec.2017.06.039
Reference: PROTEC 15292

To appear in: *Journal of Materials Processing Technology*

Received date: 16-3-2017
Revised date: 1-6-2017
Accepted date: 21-6-2017

Please cite this article as: Chen, Kai, Liu, Xun, Ni, Jun, Keyhole Refilled Friction Stir Spot Welding of Aluminum Alloy to Advanced High Strength Steel.Journal of Materials Processing Technology http://dx.doi.org/10.1016/j.jmatprotec.2017.06.039

Keyhole Refilled Friction Stir Spot Welding of Aluminum Alloy to Advanced High Strength Steel

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Abstract

A keyhole refilled Friction Stir Spot Welding (FSSW) process is developed, which consists of two steps. Regular FSSW is performed in the first step. After that, the tool travels along a circular path to refill the original keyhole. The process is applied for joining aluminum alloy 6061 to Transformation Induced Plasticity (TRIP) steel. It increases the joint strength by 56.33% compared with that of conventional FSSW joints. A ductile failure mode is observed. The process can be implemented in any universal CNC machine and needs only one simple FSSW tool. An additional pure circular path welding process shows the enhanced performance of the keyhole refilled FSSW joints relies on three bonding mechanisms: the refilled original keyhole, the increased bonding area between steel and aluminum as well as the hook structure generated from the regular FSSW process. Three distinct layers of grain structures can be observed on the hook, which reveal the material flow pattern during the process.

Keywords

Friction stir spot welding, Keyhole refill, dissimilar material joining, joint strength, fracture, bonding mechanism

1. Introduction

Multi-material vehicle structure is a promising solution for weight reduction in the automotive industry, which requires reliable and economical dissimilar material joining process. As a solid state welding technique, Friction Stir Spot Welding (FSSW) shows several advantages over traditional fusion welding process in joining dissimilar materials, as studied by Mehta et al. (2016). However, one critical issue is that a keyhole is left at the weld center after retraction of the FSSW tool, which causes stress concentration and reduction of the effective connection area of the spot weld. Moreover, since the body paint can hardly reach the bottom of the keyhole, corrosion preferentially occurs in this place. In order to remove this inherent defect, some approaches have been proposed in literature. Zhao et al. (2014) applied a refilled friction stir spot welding (RFSSW) process to weld 7B04-T74 aluminum alloy with the thickness of 1.9mm. Their welding tool was composed of three independent movable parts: a clamping ring, a sleeve and a pin. The process is illustrated in Figure