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Effects of tool design on the microstructure and mechanical properties of refill friction stir spot welding of dissimilar Al alloys

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Abstract

Al6022-T4/Al7075-T6 welds were fabricated by refill friction stir spot welding using different tool designs with identical welding parameters. Cracks and voids were formed in the welds manufactured using a standard tool. When tool penetration depth is low, metallurgical bonding was not formed completely through the weld center despite the presence of mechanical inter-locking. When tool penetration was increased to 1.5 mm, more intermixing and metallurgical bonding was formed in the weld center with some voids at the weld boundary. Defect-free welds were fabricated using a modified tool with three grooves or notches in the tool sleeve, which improved metallurgy bonding, material intermixing and mechanical inter-locking at the weld interface. The intermixed structure resulted from incorporation of the top and bottom sheet materials promoted by the grooves on the bottom of the tool sleeve, and this suppressed formation of cracks. Thus, the welds exhibit higher overlap shear strength with less sensitivity to welding parameters.

Keywords: refill friction stir spot welding, dissimilar Al alloys, tool design, microstructure, mechanical properties.

1. Introduction

Conventional friction stir spot welding (FSSW) was developed to replace resistance spot welding (RSW) and self-pierce riveting in the automotive industry. The principle of conventional FSSW is similar to that of linear friction stir welding (FSW), however the joining mechanism of conventional FSSW is rather complicated since the actual welding time itself is shorter. This constrains all the process dynamics to the transient stages of the tool plunge, dwell period (when intermixing occurs), and tool retraction. Sakano (2001) first reported conventional FSSW, which has been used for aluminum door panels since 2003, and to join an aluminum to steel bolt retainers in a trunk lid. Badarinarayan et al. (2007) found that the use of conventional FSSW resulted in ~90% energy savings and ~40% capital investment reduction compared to the RSW of Al alloys. Uematsu et al. (2008) claimed that one of the biggest disadvantages of conventional FSSW is the keyhole left after the welding process. The keyhole results in a reduction of the effective bonded area and weld strength, and thus provides a stress concentration and potential corrosion initiation point since body paint may not fully coat the keyhole. According to Tozaki et al. (2007) and Shen et al. (2013a), a tool shoulder penetration of 0.1~0.3 mm was commonly applied to guarantee axial force for the weld formation, but such a penetration could cause thinning of the top sheet. Furthermore, Shen et al. (2013a) reported that penetration of the tool pin into the bottom sheet can lead to hooking at the interface, which diminishes the effective bonded region