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Effect of welding parameters on microstructure and mechanical properties of friction stir spot welded 5052 aluminum alloy

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ABSTRACT

Friction stir spot welding (FSSW) is a newly-developed solid state joining technology. In this study, two types of FSSW, normal FSSW and walking FSSW, are applied to join the 5052-H112 aluminum alloy sheets with 1 mm thickness and then the effect of the rotational speed and dwell time on microstructure and mechanical properties is discussed. The lower sheet material underneath the hook didn't flow into the upper sheet due to the concave surface in the shoulder and groove in the anvil. The hardness profile of the welds exhibited a W-shaped appearance and the minimum hardness was measured in the HAZ. The results of tensile/shear tests and cross-tension tests indicate that the joint strength decreases with increasing rotational speed, while it's not affected significantly by dwell time. At the rotational speed of 1541 rpm, the tensile/shear strength and cross-tension strength reached the maximum of 2847.7 N and 902.1 N corresponding to the dwell time of 5 s and 15 s. Two different fracture modes were observed under both tensile/shear and cross-tension loadings: shear fracture and tensile/shear mixed fracture under tensile/shear loadings, and nugget debonding and pull-out under cross-tension loadings. The performance of the welds plays a predominant role in determining the type of fracture modes. In addition, the adoption of walking FSSW brings unremarkable improvements in weld strength.

1. Introduction

With the global resource and environment problems tending to be more and more serious, more attention is paid on the weight reduction of aerospace structures, automotive bodies and high-speed passenger cars and so on. The application of lightweight materials is the most effective measure. Aluminum alloy has been one of the most promising lightweight materials due to a series of fine characteristics such as light weight, corrosion resistance, specific strength, impact resistance and high recycle.

Traditional technologies for spot joining aluminum alloys are resistance spot welding and riveting. There exist a lot of disadvantages such as high energy consumption, large current and large deformation for resistance spot welding, and low production efficiency and bad working environment for riveting. In spite of many improvements in resistance spot welding and riveting, no breakthrough has been made in the aspect of joining mechanism and properties. In 1993, on the basis of "linear" friction stir welding (FSW), Mazada corporation of Japan proposed the fixed friction stir spot welding (FSSW), which can be seen in Fig. 1 [1] and has been successfully applied to the production of hood and rear door of the sport vehicle Mazada RX-8 [2]. In 1999 Germany GKSS research center proposed the refill friction stir spot welding [3]. Many researchers show great interest in friction stir spot welding because of its advantages such as excellent mechanical properties, low distortion, ease of handling, low cost and clean working environment.

During FSSW, tool penetration and the dwell period essentially determine the heat generation, material plasticization around the pin, weld geometry and therefore mechanical properties of the welded joint [4]. When tool geometry keeps constant, the tool rotational speed and dwell time are the most important parameters. Lathabai et al. indicated that the shear strength increased and then decreased with increasing tool rotational speed in the AA6061-T5 friction stir spot welded joints, while Tozaki, Freeney and Merzoug et al. found the tensile and shear strength decreased with increasing tool rotational speed [5–8]. Tran et al. pointed out that the strength increased with increasing tool dwell time in AA5754 and AA7075 friction stir spot welds [9]. Lathabai and Arul et al. stated that the shear strength increased and then decreased with increasing tool dwell time, leaving a maximum [5,10]. But Tozaki and Addison et al. found the properties of joints decreased with increasing tool dwell time [11,12].

In view of the aforementioned, the overall objective of the work, that will be discussed here, was to improve our current understanding of the effect of welding parameters on microstructure and mechanical properties of friction stir spot welds. Fixed FSSW was performed to join 5052 aluminum alloy sheets with 1 mm

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