Journal of Materials Processing Technology 237 (2016) 19–30

Contents lists available at ScienceDirect

Journal of Materials Processing Technology

journal homepage: www.elsevier.com/locate/jmatprotec

Effects of process parameters on friction self-piercing riveting of dissimilar materials

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ARTICLE INFO

Article history:
Received 14 November 2015
Received in revised form 17 May 2016
Accepted 21 May 2016
Available online 24 May 2016

Keywords:
Friction self-piercing riveting
Dissimilar materials
Process parameters

ABSTRACT

In the present work, a recently developed solid state joining technique, Friction self-piercing riveting (F-SPR), has been applied for joining high strength aluminum alloy AA7075-T6 to magnesium alloy AZ31B. The process was performed on a specially designed machine where the spindle can achieve the motion of sudden stop. Effects of rivet rotating rate and punch speed on axial plunge force, torque, joint microstructure and quality have been analyzed systematically. During F-SPR, higher rotating rate and slower punch speed can reduce axial force and torque, which correspondingly results in a slightly smaller interlock between rivet leg and joined materials. Improved local flowability of both aluminum and magnesium alloys under a higher rotating speed results in a thicker aluminum layer surrounding the rivet leg, where formation of Al-Mg intermetallics was observed. Equivalent joint strength obtained in this study are higher than the yield strength of the AZ31 Mg alloy. One of the tensile failure modes is the rivet fracture, which is due to local softening of rivet leg from frictional heat. Other two failure modes include rivet pullout and shear through of bottom sheet.

1. Introduction

Lightweight vehicles are receiving growing attention in recent years for energy and environmental concerns. High specific strength materials, including ultra-high strength steel, aluminum and magnesium alloys are gradually applied into vehicle bodies, which raises the demand of multi-material vehicle structures. Accordingly, development of reliable and economical dissimilar material joining process is required. Considering the incompatible physical properties of different materials and formation of brittle intermetallic compounds, extensive researches on solid state welding and mechanical joining techniques have been conducted and showed superiorities over traditional fusion welding process. Friction stir welding (FSW) is a promising solid state process for welding dissimilar materials. Somasekharan and Murr (2004) employed this technique to join aluminum alloy 6061 to magnesium alloy and the weld zone shows an intercalated microstructure with recrystallized shear bands rich in either Mg or Al element. Liu et al. (2014) investigated FSW of aluminum alloy to advanced high strength steel and the highest joint strength could reach 85% of the base aluminum alloy. Besides solid state welding, there are several newly developed mechanical joining techniques. Gao et al. (2009) developed the friction stir blind riveting process, which improves traditional riveting by rotating the rivet while penetrating it into the workpiece. This eliminates the requirement of pre-drilled holes. Robustness of the process is shown under a wide range of operating parameters and a higher static and fatigue strength can be obtained compared with that obtained from resistance spot welding. Min et al. (2015) further studied the process with an optimized blind rivet geometry, especially at the rivet tip, which is machined to a sharp profile and can penetrate the workpiece with a cutting action. This significantly reduces the riveting force. Another mechanical joining process is the flow drill screwdriving process, which was first developed by Skovron et al. (2014). The technique combines friction hole drilling, thread forming and screw fastening into one single process and reduces weld cycle time to a large extent. During the process, a rotating screw is driven to pierce and extrude the material with the assistance of friction heating. Threads are formed in this created extrusion. The two workpiece sheets can finally be securely clamped together by screwdriving of the fastener into these formed threads. Skovron et al. (2015) also investigated the effects of workpiece temperature on this joining process. A reduced process time and installation torque for the final fastening of screw can be observed by preheating the workpiece to

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http://dx.doi.org/10.1016/j.jmatprotec.2016.05.022
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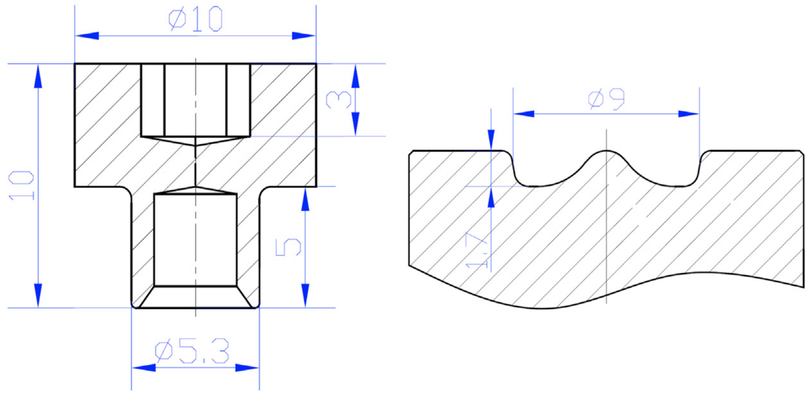

Fig. 1. Detailed rivet and die geometry (Unit: mm).

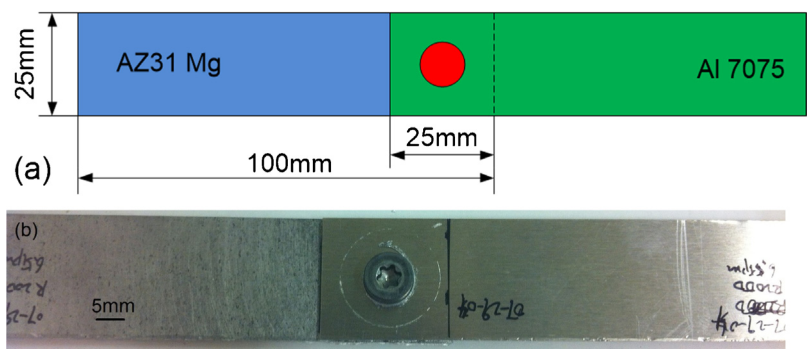

Fig. 2. Tensile shear specimen geometry: (a) schematic illustration; (b) actual joint.

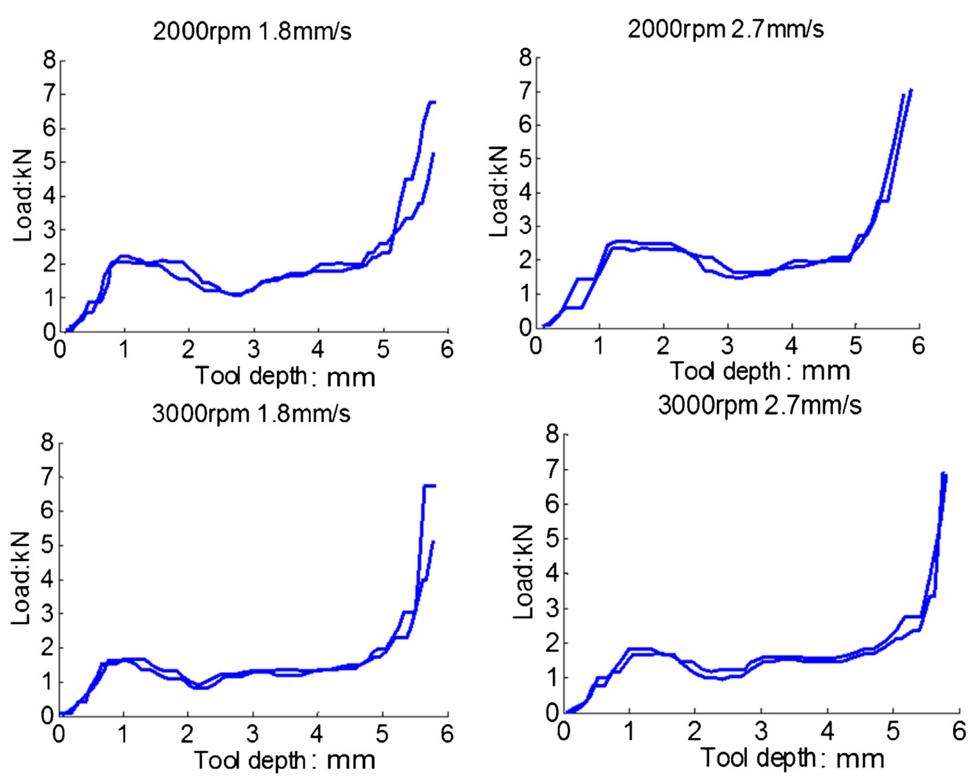

Fig. 3. Relationship of axial punching load with regard to tool depth under different process conditions.

a higher temperature. The third innovative mechanical joining process is called friction bit joining, which was first developed by Miles et al. (2010). During the process, the joining bit first cuts through top workpiece sheet. The bit and surrounding material are heated by friction and finally the bit is left on the workpiece as a filler material. Squires et al. (2015) applied this process to spot weld alu-