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Mechanical and microstructural investigation of friction spot welded AA6181-T4 aluminium alloy

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ABSTRACT

Friction spot welding (FSpW) is a solid state welding process suitable for spot joining lightweight low melting point materials like aluminium and magnesium alloys. The process is performed by plunging a rotating three-piece tool (clamping ring, sleeve and pin) that creates a connection between sheets in overlap configuration by means of frictional heat and mechanical work. The result is a spot welded lap connection with minimal material loss and a flat surface with no keyhole. FSpW has been performed in a 1.7 mm-thick AA6181-T4 aluminium alloy using different welding parameters (rotation speed and joining time) aiming to produce high quality connections in terms of microstructure and mechanical performance. Microstructural features of the FSpW connections were analysed by optical microscopy; while mechanical performance was investigated in terms of hardness and tensile testing. Connections with shear strength close to 7 kN were obtained with high reproducibility. The results also showed that geometric features of the connection play an important role on the fracture mechanism and hence on the mechanical performance of the connections.

1. Introduction

Friction spot welding (FSpW) is a solid-state joining method that produces spot-like connections by plunging a rotating tool into the workpiece generating frictional heat and plastic deformation resulting in softening of the material to be welded [1–8]. Contrary to the friction stir spot welding process, there is no keyhole left at the end of the joining operation [9–11]. FSpW has received considerable attention from the automotive and aircraft industries since such processes offer an alternative to overcome the disadvantages presented by other spot joining technologies [12–15].

Spot-like joints for structural components are produced either by mechanical fastening technologies (clinching, riveting, self-piercing riveting) or by fusion spot welding techniques (resistance and laser spot welding) [16–21]. Mechanical fastening suffers from a weight penalty, difficulty of automation, requirement for sealants and corrosion problems. Fusion spot welding processes have problems associated to material melting and low weldability issues presented by some high strength lightweight alloys. Another important disadvantage is that in resistance welding, the operating costs are higher due to high energy consumption and associated infrastructure [2,22–24]. Furthermore, the need for frequent electrode dressing and reduced electrode tip life results in poor surface quality [20].

FSpW comes as an alternative to overcome these issues, being capable of replacing mechanical fastening and fusion spot welding processes in some applications. It can be also an alternative for long friction stir welds or rivets in stiffeners to skin–skin stiffened aluminium panels [25]. Furthermore, FSpW can also be used for repair, e.g. for filling the keyhole resulting from friction stir welding [26].

The FSpW is performed using a tool assembly comprised of three parts: clamping ring, sleeve and pin. Pin and sleeve are operated by separate actuators in such a way that they can be moved up and down independently. The clamping prior to welding is performed by a third actuator moving the entire welding head against the work pieces. The clamping ring has two functions: (a) to keep the sheets to be welded tightly secured during the process and (b) work as a barrier to avoid plasticised material to be lost in the form of flash. Both pin and sleeve are connected to one motor (responsible for the rotation speed) and to independent actuators (responsible for the axial displacement).

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