Joining of aluminium/steel sheets with dissimilar thicknesses by FSW: Joint design and mechanism of welding

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Introduction

This research introduces a straightforward design for joining a thin steel (St) sheet (2 mm thickness) to an aluminium (Al) sheet (5 mm thickness) in a butt configuration, resulting in a S-shaped Al/St interface due to the offset of the Friction Stir Welding (FSW) tool into the steel. The contribution of this interface to the mechanical behavior of the joint during tensile testing is analyzed. The results of the present study provide practical use of FSW for the design and application of dissimilar materials joining.

Methodology

- Two substrates, Al1050 and St37, with 5 mm and 2 mm plate thicknesses, respectively, were joined by FSW.
- Support plates were used in the top and bottom part of the manufacturing apparatus on the side of the carbon steel substrate, with 1 mm and 2 mm plate thicknesses, respectively.
- The SEM/EDS examination was carried out using a high-resolution environmental Scanning Electron Microscope.
- 5 mm wide specimens were machined by Wire Electrical discharge machining (WEDM) for tensile testing.

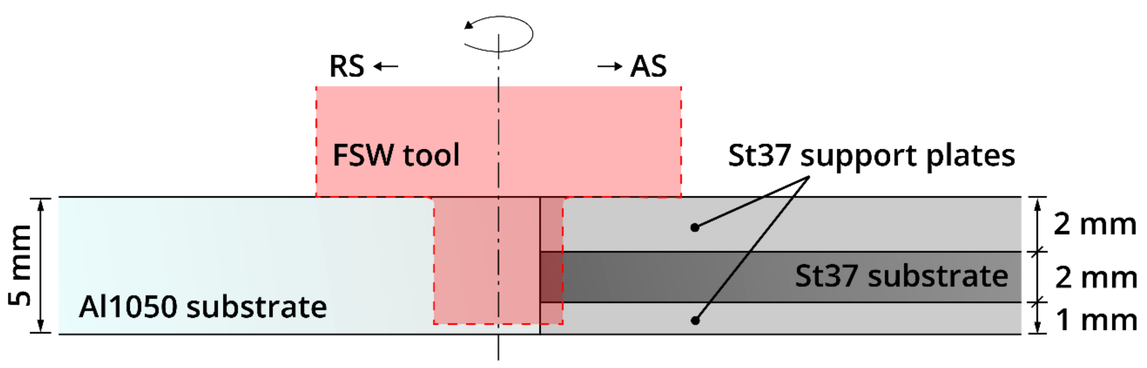

Figure 1. Schematic of the joint configuration for FSW of aluminum to steel with dissimilar thicknesses.

Results and discussion

- Figure 2 displays the cross section of the joint after removing the support plates.
- Figure 2b shows various parts of the interface marked to be examined by SEM for Intermetallic Compounds (IMCs) detection.
- A S-shape interface is observed whose curvature at the top and bottom of the joint is produced due to the material flow influenced by the shoulder and the bottom of the pin, respectively. The interface in the welds without offset is straight.

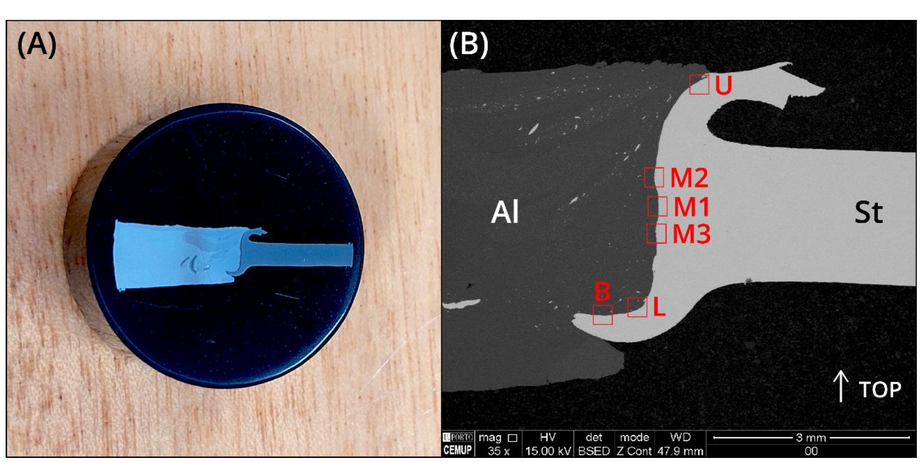

Figure 2. The image of the ross section of the joint taken by a) optical microscope and b) SEM.

Results and discussion

- Figure 3 shows the SEM images from various regions of the interface marked in Figure 2.
- The IMC layer is not uniform along the interface form the top to the bottom. Some cracks are observed perpendicular to the interface.
- The thickness of the IMC layer has a declining trend from the top to the bottom.

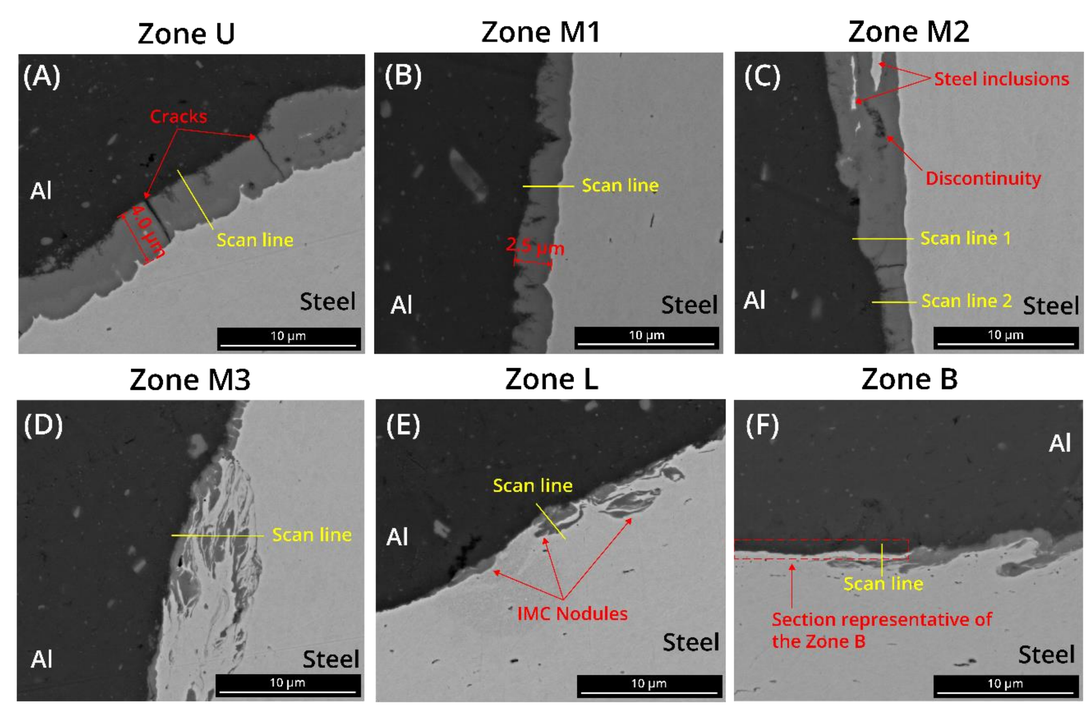

Figure 3. SEM images from various regions of the interface marked in Figure 2.

- Figure 4 shows the force-extension curves of the aluminum/steel joints made by FSW with and without a tool offset into steel.
- The fracture load of the joint with offset (2250N) is 25% higher than the one without a fool offset, indicating the role of the S-shape interface.

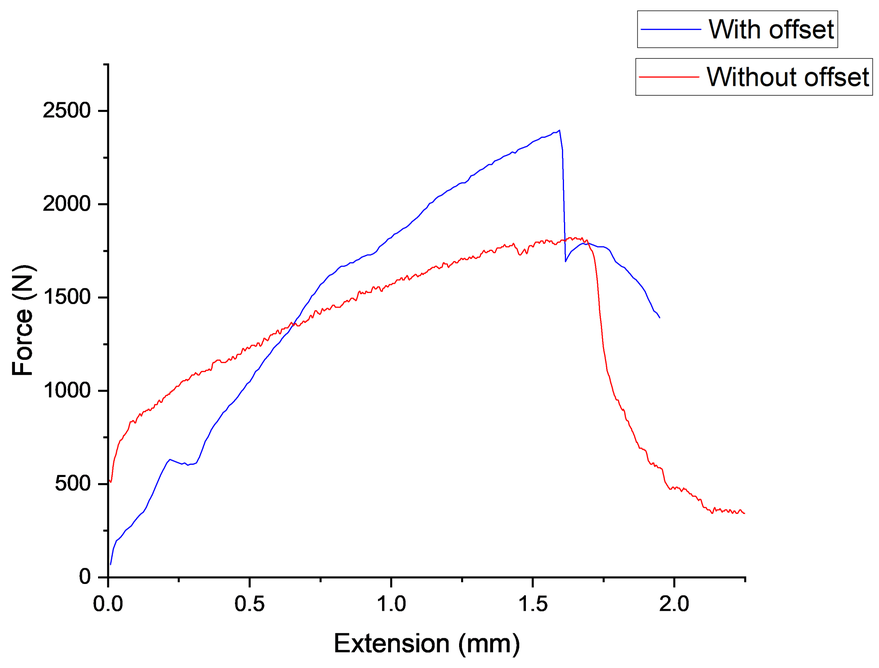

Figure 4. Force-extension curves of the welded samples under tensile loading.

Conclusions

- A simple method was used to join aluminum/steel with different thicknesses. Support plates accommodated the difference in thickness.
- A S-shape interface was obtained with a nonuniform IMC layer from the top to the bottom of the interface. The thickness of the IMC layer declined from the top to the bottom.
- The fracture load of the joint with an offset of the tool was 25% higher than the one without a tool offset, indicating the role of the S-shape interface on the joint strength.