Trends on joining of aluminium-steel in various joint geometries

R. Beygi (INEGI, Portugal), R.J.C. Carbas, E.A.S. Marques, L.F.M. da Silva

Advanced Joining Processes Unit

Introduction

Intermetallic compounds (IMCs) have always been a major challenge in joining dissimilar aluminum-steel by friction stir welding (FSW). The formation of these compounds is inevitable, since their formation is a prerequisite for the production of a metallurgical joint. This study focuses on the technical feasibility of 3 joining technologies for various joint configurations such as butt, lap, and Tee between aluminum and steel. Three joining technologies; friction stir welding (FSW), friction stir bonding (FSB), and weld-brazing (WB) have been chosen and studied for this purpose. Technically, the best joining methods for butt joining and lap joining are FSW and FSB, respectively. For Tee joining, depending on the position of two metals, FSW and WB are most feasible when aluminum is placed as skin and stringer, respectively. Among these processes, WB is more likely to produce brittle IMCs at the interface. The IMC formation during FSW is more controllable than WB..

Methodology

Sheets of carbon steel and Al1050 were joined by FSW in butt and Tee configurations (Al as skin).
Sheets of galvanized carbon steel and Al1050 were joined by FSB in lap configuration.
Sheets of galvanized carbon steel and Al1050 were joined by WB in lap and Tee configurations (Al as stringer).
Tensile testing was used to measure the static joint strength.
Scanning electron microscopy (SEM) was used to evaluate the IMCs at the interface.
Figure 1 shows the joint configurations and the technique used to make those joints.
Figure 2 shows how Tee-joints were evaluated.

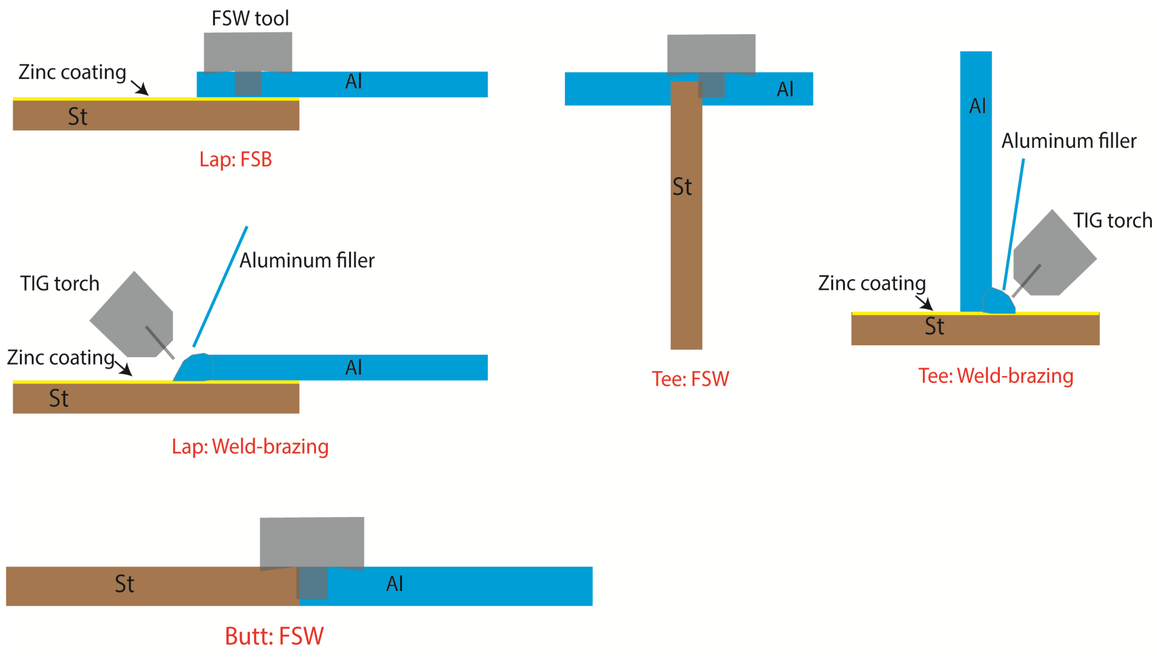

Figure 1. Various joint configurations between Aluminum and steel by various techniques

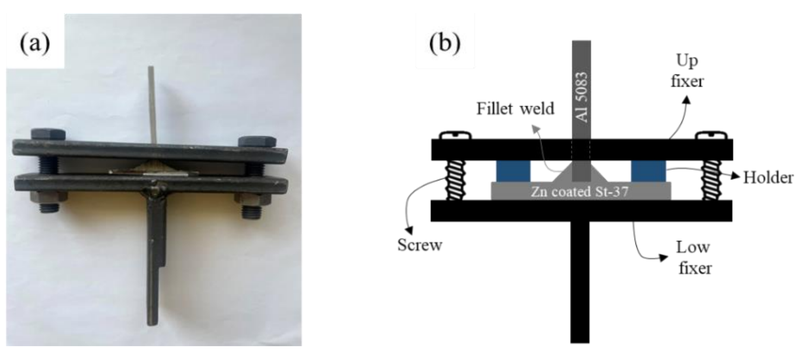

Figure 2. a) The fixture used to evaluate the strength of Tee-joints. b) Schematic of the tensile testing of Tee-joints.

Results and Discussion

Figure 3 shows the SEM images taken from the interfaces.
The SEM images from WB joints, both in lap and Tee joints, show the presence of pores due to evaporation of Zn coating. A thick IMC layer was observed at the interface.
The SEM image of FSB joint showed a thick transition layer which was found to be a solid solution compound of Al-Zn-Fe. Zinc coating did not evaporate and thus no pore was formed.
The SEM images from the FSW joints showed a thin IMC layer at the interface.

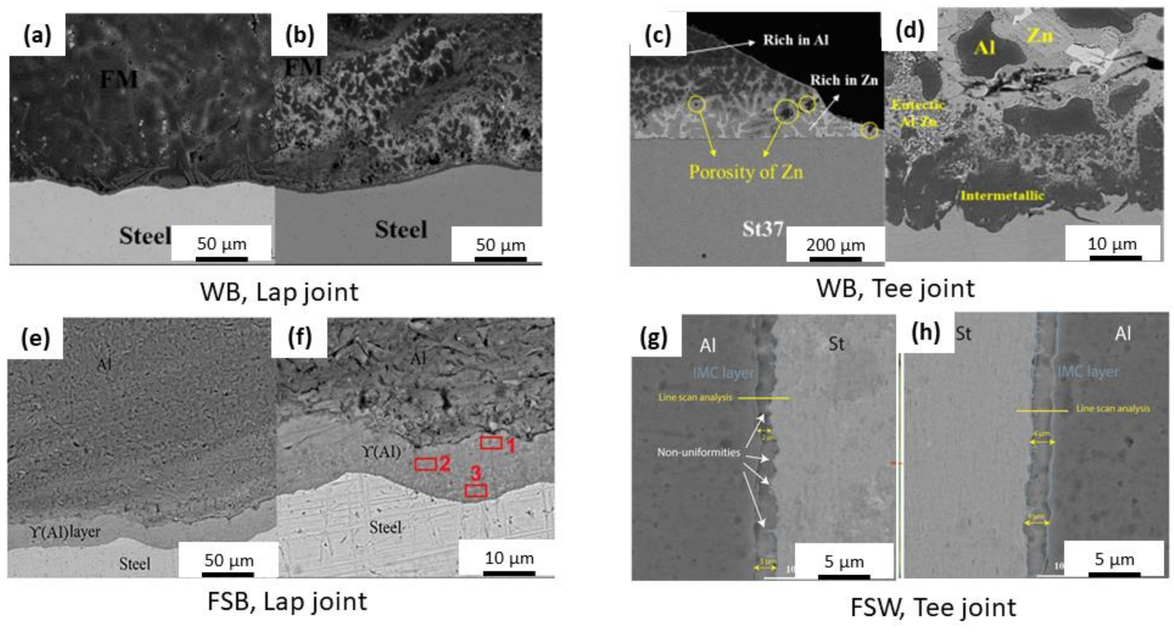

Figure 3. SEM images of cross-sectional interface of various joints.

During tensile testing, the lap joints failed from the base material, showing a good resistance of the joint interface regardless of the joining technique. The minimum shear strength was calculated to be 80 MPa for FSB joints and 35 MPa for WB joints.
WB joints in Tee-configuration showed a brittle fracture from the interface with a very low joint strength (lower than 30 MPa)
The but joints made by FSW had strength of 90 MPa. The fracture occurred through the IMCs at the interface.

Conclusions

- WB technique needs a coating of zinc on steel. While the joint strength is acceptable in shear mode (lap joints), it is very low in tensile mode (Tee joints). Pore formation due to zinc evaporation, eutectic microstructure, and a thick layer of IMC are the main characteristics of WB joints.
- FSB technique also needs a zinc coating on steel. It is used in lap configuration. As a solid-state welding technique and preserve of zinc, no pore is formed at the joint. A thick transition layer forms at the interface which has a high fracture toughness.
- FSW joints show the highest tensile strength (90 MPa). This is due to the low thickness of IMC. Their shear strength is even higher such that no failure occurs through the IMC layer.

References

Effect of Mg and Si on intermetallic formation and fracture behavior of pure aluminum-galvanized carbon-steel joints made by weld-brazingA Alikhani, R Beygi, MZ Mehrizi, F Nematzadeh, I Galvão, Journal of Central South Univedrsity 28 (11), 3626-3638