Static Strength of aluminium-to-steel thin welded joints: preliminary results

I. Al Zamzami[a], J. B. Davison and L.Susmel
Department of Civil and Structural Engineering, the University of Sheffield, Mappin Street, Sheffield S1 3JD, United Kingdom
[a]ialzamzami1@sheffield.ac.uk

Abstract.
The aim of this paper is to report an investigation of the static strength of aluminium-to-steel thin welded joints manufactured by using welding technology EWM coldArc. Butt-welded, lap-welded and cruciform-welded connections were tested under tensile static loading. The direct inspection of the fracture surfaces revealed that, regardless of the geometry of the joint being tested, breakage always took place, on the aluminium side in the heat-affected zone (HAZ). This suggests that Eurocode9 which is used to design aluminium alloys welded joints can be used also to design aluminium-to-steel welded joints.

Introduction

The necessity of welding aluminium-to-steel has recently increased in the metalworking sector. However, using the conventional fusion welding technology to weld aluminium-to-steel was seen to cause many problems as aluminium and steel have different physical properties (e.g. thermal expansion, conductivity and melting temperature). Further, their different metallurgical characteristics result in the formation of hard and brittle intermetallic phases (Fe-Al) at the interface between the two materials. These intermetallic phases markedly deteriorate the mechanical properties of aluminium-to-steel hybrid welded joints [1, 2].
Since the early 2000s, much research work in the field of dissimilar material welding has been done with the aim of not only achieving stronger and more flexible hybrid joint solutions, but also of increasing the manufacturing productivity [3- 5]. As a result, low-energy-input welding technologies were developed (e.g. Cold-Arc Welding technology) to specifically join aluminium-to-steel, with the coldArc method representing the most advanced technological solution being available to date in the marked (www.ewm-group.com).

Welding technology

Welding machine EWM alpha Q 551 puls (www.ewm-group.com) was used to manufacture the welded specimens being tested. This machine uses the pulsed metal inert gas (MIG) welding technology along with the coldArc system. The MIG welding process has been widely used in the automotive industry to join a variety of thin metallic sheets. It is an advanced form of welding that allows an excellent control over the rate of heat input and the metal transfer. Its lower heat input allows thin metal sheets to be welded without causing any burn through.

Technology EWM coldArc makes it possible for very thin sheets of metal (starting from a thickness of 0.3mm) to be welded without spattering. It is a modified short-arc process for root welding of pipes or thin materials. It has excellent gap bridging capabilities and causes no damage to the zinc coating and less warping due to the lower process heat. Therefore, it is ideal to weld aluminium to steel, provided that the steel being used is coated with a zinc layer that minimises the formation of hard and brittle intermetallic phases.

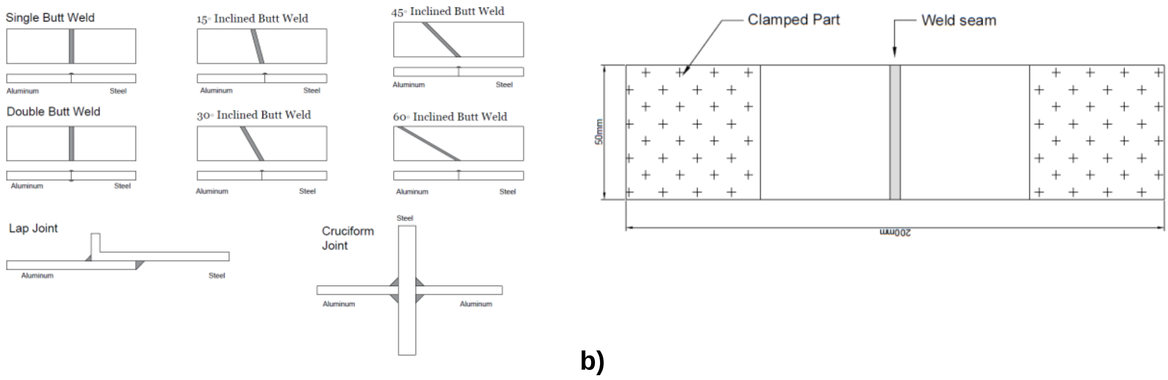
Experimental procedure

The test specimens used in the present investigation were made of 1mm thick aluminium alloy AA1050 and cold rolled low carbon steel EN10130:199. Table.1 summarises the chemical compositions of the materials used. For 1mm thickness, the welding parameters were set as follows: arc voltage equal to 15.3V, current to 54 Amps and wire feed to 5m/min. The shielding gas used in the coldArc torch was 100% argon.

Table 1 Mass chemical composition of the used materials by weight percentage.

Alloy	Chemical composition [wt%]							
AA1050	Cu	Mg	Si	Fe	Mn	Zn	Ti	Al
	0-0.05	0-0.05	0.25	0-0.4	0.05	0.07	0-0.05	Balanced
EN10130:1991	C	P	S	Mn	Fe			
	0.12	0.045	0.045	0.60	Balanced			
Filler wire AA7013	Cu	Mg	Si	Fe	Mn	Zn	Ti	Al
	0.01	0.01	5.02	0.09	0.02	0.01	0.002	Balanced

Fig.1a shows the different welded specimens that were tested under tensile static loading in order to investigate the static strength of aluminium-to-steel welded joints manufactured using the EMW coldArc welding technology. The tensile tests were run using a 100 kN MAYSE dynamic and static machine. The specimens were prepared as shown in Fig.1b and tested at room temperature under a nominal displacement rate of 2 mm/min.



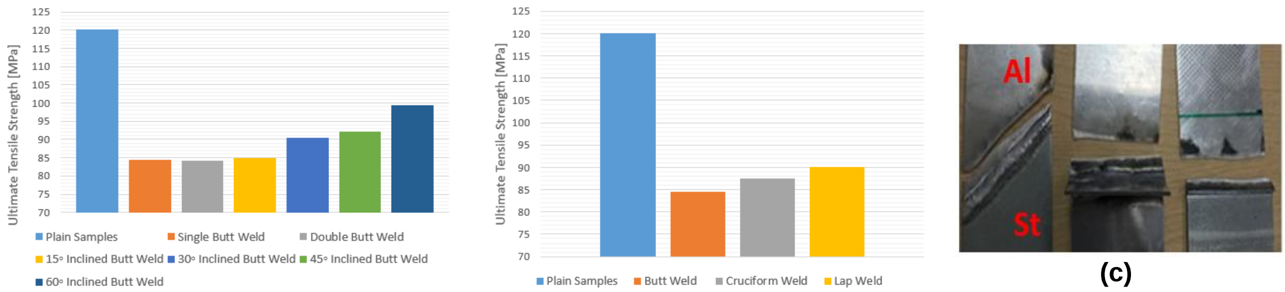
a) b)

Figure 1 a) Geometry of investigated aluminium-to-steel welded components b) Schematisation of the tensile specimens

Results and discussion

The hybrid welded joints shown in Fig. 1 were tested in the as-welded condition. For each welded geometry being considered, ten specimens having length equal to 200mm and width to 50mm were tested. Figures 2a and 2b summarise the average ultimate tensile strength (UTS) being determined experimentally. Irrespective of geometry or weld inclination, static breakage was seen to take place always on the aluminium side in the HAZ (i.e., away from the weld interface region – see Fig. 2c). As shown in Fig. 2a, both the single- and double-butt welded joints were characterised by the same static strength. This further confirms that, for the combination of materials being investigated, the welds manufactured using the coldArc technology were stronger than the heat-affected aluminium. In particular, the UTS of the aluminium HAZ (i.e., 84 MPa) was seen to be larger than 70% of the parent aluminium UTS (i.e., 120 MPa), thus proving that the aluminium-to-steel welded joints being tested were characterised by remarkable mechanical performance.

According to the above experimental findings, Eurocode9 (EC9) was then used to estimate the static strength of the aluminium-to-steel welded joints being tested. According to EC9, the static strength of butt welded joints made of aluminium 1050 is equal to 55 MPa. The fact that the strength estimated according to EC9 is much lower than the UTS value of 84 MPa that was obtained by testing the aluminium-to-steel but welded specimens shown in Fig. 1 strongly supports the idea that EC9 is suitable also for designing steel-to-aluminium welded joints against static loading. Finally, turning to inclined welds, as expected, the strength of the aluminium-to-steel welded joints was seen to increase as the weld angle increased (Fig. 2a).



(a) (b)

Figure 2 a) The average tensile strength results of Al-St butt, lap and crucifrom Welded Joints b) The averagr tensile strength results of inclined angles c) tensile static failure of hybrid welded joints

Conclusions

The results generated by testing the specimens of Fig. 1a suggest that aluminium-to-steel welded joints can be designed against static loading by focussing attention solely on the aluminium part, i.e., on the weakest link in the structural chain of the joint.

Acknowledgements

EWM (www.ewm-group.com) is acknowledged for supporting the present research investigation.

References

[1] *Kittipong Kimapong and Takehiko Watanabe, “Lap Joint of A5083 Aluminium Alloy and SS400 Steel by Friction Welding,” Materials Transactions, vol. 46, no. 4, pp. 835-841, 2005.*

[2] *Guo-liang QIN, Yu-hu SU, Shu-jun WANG, “Microstructures and properties of welded joint of aluminium alloy to galvanized steel by Nd: YAG laser + MIG arc hybrid brazing-fusion welding,” Trans. of Nonferrous Metals Society of China, vol. 24, pp. 989-995, 2004.*

[3] *H Okamura & K Aota, “Joining of dissimilar materials with friction stir welding,” Welding International, vol. 18, no. 11, pp. 852-860, 2004.*

[4] *S Katayama, “Laser welding of aluminium alloys and dissimilar metals,” Welding International, vol. 18, no. 8, pp. 618-625, 2004.*

[5] *K Kato & H Tokisue, “Dissimilar friction welding of aluminium alloys to other materials,” Welding International, vol. 18, no. 11, pp. 861-867, 2004*