Joining of Steel to Titanium with Interlayers

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EWI has been engaged in a new class of technologies for joining titanium alloys to steels. Implicit in applying thermal joining processes to this material combination is the formation of low-melting eutectics as well as a range of intermetallic compounds. The technologies described here combine the use of refractory metal interlayers with established forge welding processes. Two variants of these technologies are described below.

Recently, EWI has been studying resistance mash seam welding (RMSeW) for creating sheet-metal-based titanium-to-steel joints. RMSeW technology is related to resistance seam welding (RSeW). For RMSeW, sheet-metal parts are configured with a small overlap (typically one to three times the metal thickness) in a resistance seam welding machine. Current is passed between the wheels as they roll along the bond line. The combination of resistance heating and a compressive force applied via the weld wheels creates a continuous forge joint. As shown in Figure 1, RMSeW was used to weld 304 stainless steel (SS) to titanium with a 63-μm thick niobium (Nb) foil interlayer. Here it can be seen that the titanium forges over the surface of the steel while the Nb interlayer remains uninterrupted and continuous across the bond surface. It is also evident that both the titanium and the steel have effectively bonded to the foil over the majority of the interface.

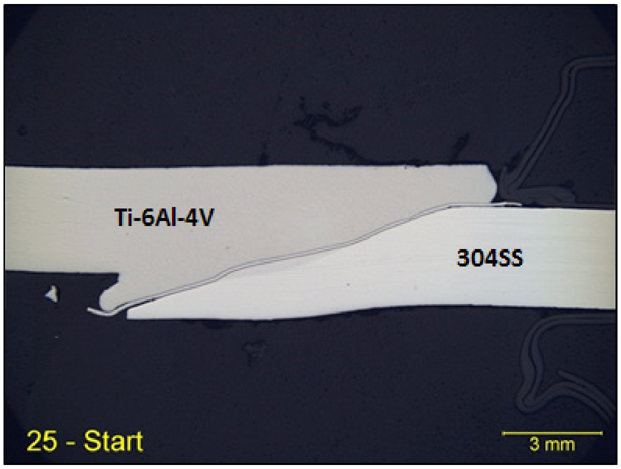

Figure 1: Cross section of a RMSeW joint between Ti-6Al-4V and 304SS. Note the residual Nb interlayer across the bond line.

Upset welding (UW) is a resistance-based forge-welding process that produces butt joints on either sheet or bar-type workpieces. In this process, the workpieces are configured in a press-type frame and brought together under force. As current is applied, the workpieces are resistively heated, and upon reaching the upsetting temperature are forged together. Titanium-to-steel UW joints were made using a Nb interlayer nominally 60-μm thick. The macrostructure of the resulting joint is shown in Figure 2. As evident from this macrograph, the forging is decidedly biased toward the titanium. However, there is also clear evidence of deformation on the 304SS side of the joint. Further, the thin Nb foil can also be seen, extending from the top and bottom surfaces at the bond location. The combination of heat and surface strain on both sides of the Nb foil allowed two solid-state joints to form, similar to those seen in the RMSeW welds discussed above.

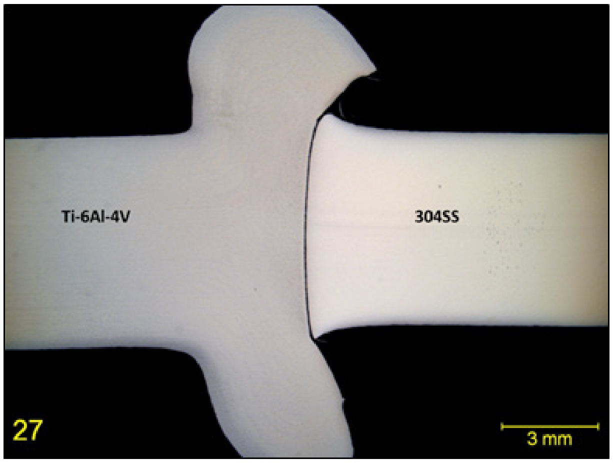

Figure 2: Cross section of an upset weld made between Ti-6Al-4V and 304SS employing a Nb foil at the interface.

Joint strengths for both processes range from 200 to 300 MPa. Continued process optimization will be required to achieve strengths comparable to the titanium and steel base materials.

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