WELDING OF SIMILAR STAINLESS STEEL WITH DIFFERENT SULPHUR CONTENT

- A CASE STUDY*

A fabrication unit welds machined type 304L stainless end plugs to type 304L stainless steel tubing approximately 10 mm in diameter and 0.5 mm wall thickness, using pure argon in a chamber and orbital autogenous Gas Tungsten Arc Welding (GTAW). There is a machined shoulder on the end plug, so it fits both inside the tube and against its end, with matching outer diameter measurements. When the sulfur contents of the two parts are different, the arc pulls strongly toward the low-S component, making it difficult to meet penetration requirements. It was not possible to increase heat input enough to make the difference without violating qualification limits. What's causing this, and is there anything besides increasing heats that will help?

The problem of arc pulling is correctly identified as related to sulfur content and is due to surface tension gradients, the Marangoni Effect. It says that, when the sulfur content is "normal" *i.e.*, greater than 0.005%, the surface tension of the weld pool increases with increasing temperature. This causes the hottest metal along the surface of the weld pool to be drawn toward the pool center, where it has nowhere to go but downward. This downward flow of hottest metal in the pool center causes deep, narrow penetration patterns. When the sulfur content is lower, there is a reversal, *i.e*, the surface tension decreases with increasing temperature, causing the hottest metal along the weld pool surface to be drawn outward toward the cooler pool edges. Then the result is a wide but shallow penetration pattern.

The work by Tinkler and coworkers in 1983 ("Welding 304L stainless steel tubing having variable penetration characteristics", Paper 29, International Conference - The Effects of Residual, Impurity and Micro-Alloying Elements on Weldability and Weld Properties, London, England, November 15-17, 1983, The Welding Institute) showed that when a high-sulfur stainless steel is welded to a low-sulfur stainless steel the surface tension gradient on the high-sulfur side starts a flow of the hottest metal toward the pool center. But there is no offsetting flow toward the center from the low-sulfur side. As a result, the hottest metal overshoots the pool center before it starts a downward flow. This causes eccentric penetration, with the deepest penetration on the low-sulfur side. This effect is what was observed when the arc pulls strongly toward the low-S component.

Tinkler, *et al.*, found a solution to eccentric penetration in the form of copper heat sinks very close to the weld to constrict the pool. This approach would probably require establishing a new welding procedure because use of heat sinks is likely to require higher current for complete penetration. They also found that GTA welding over the original weld a second time improved the penetration pattern because the sulfur was then more homogeneously distributed. A third possible solution to the problem would be the application of newly developed fluxes for enhancing penetration in, GTAW. These were described by Paskell, *et al.*, in 1997, (GTAW Flux Increases Weld Joint Penetration, Welding Journal 76 (4) pp 57 to 62).

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* Based on the reply by Damian J. Kotecki, published in Welding Journal, Vol. 80, No. 7, July 2001.