SAND2014-15467D

Comparison of microstructures before and after welding to predict reliability

Class 1 – Light Microscopy

Problem

To assure the reliability of a system which must contain hydrogen gas, data were needed to predict and model the microstructure and strength of the heat affected zone (HAZ) in a welded 304L stainless steel forged container. The microstructure of the as-forged 304L is resistant to damage from hydrogen gas, but the microstructural changes within the weld HAZ due to welding increase the susceptibility to hydrogen damage. The recrystallized grains which form within the weld HAZ and which lack the dislocation structure imparted by forging, are of primary concern.

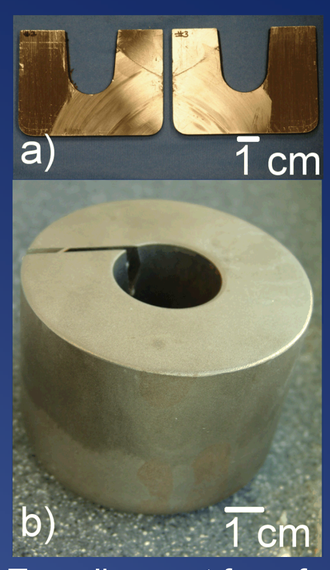

Figure 1. a) Two slices cut from forging. b) Forging with first cut visible.

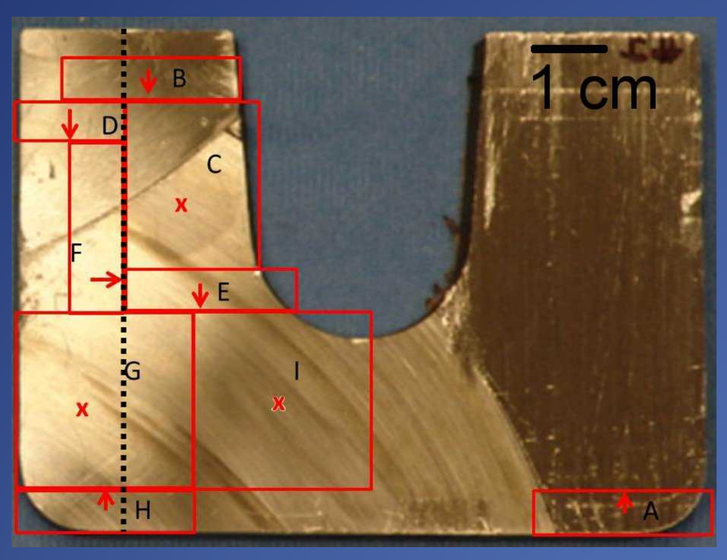

Figure 2. Map of sectioning for both the as-forged slice and the welded slice.

Analysis

Two slices (Fig. 1a) were cut from the center section of a 304L stainless steel cup-shaped forging (Fig. 1b). A single pass autogenous gas tungsten arc weld was performed on one slice, indicated by the dotted line in Fig. 2. Both slices (pre- and post-welded) were sectioned into samples A-I (boxes in Fig. 2). The arrows point to the face which was mounted and Xs indicate planar sections. Routine metallographic preparation for stainless steel, including 0.04um SiO_2 vibratory polishing, was used to produce samples for microhardness mapping and microstructural imaging. Samples were etched with 60% HNO_3, 40% DI H_20 electrolytic at 1.5 volts for 20-60 seconds (ASTM E407-219) to reveal microstructure. Hundreds of images were taken of the microstructure in the as-forged condition and the post-weld condition and analyzed (e.g. highlighted recrystallized grains in Fig. 3) to determine recrystallization and hardness in the weld HAZ.

Results

Fig. 3 is from the right side of sample E near the curved inside wall in the as-forged condition. Forty-eight percent of the grains are recrystallized and the hardness is relatively high due to the fine grain size and work imparted from forging. In Fig. 4, center of sample E, also in the as-forged condition, the grains are un-recrystallized, equiaxed, and faceted, often containing twin boundaries. The hardness is lower than the area in Fig. 3 because there is less work hardening away from the inside wall. In the same area of the forging, in the post-welded condition (Fig. 5), the structure is completely recrystallized, as evidenced by smaller, less faceted grains, and lower hardness. Precipitates (arrows) decorating the original grain boundaries are also visible. Figs. 6-9 show the final maps of recrystallization and hardness before and after welding. This information about the increase in recrystallization and decrease in hardness will be used to initialize a model of HAZ softening.

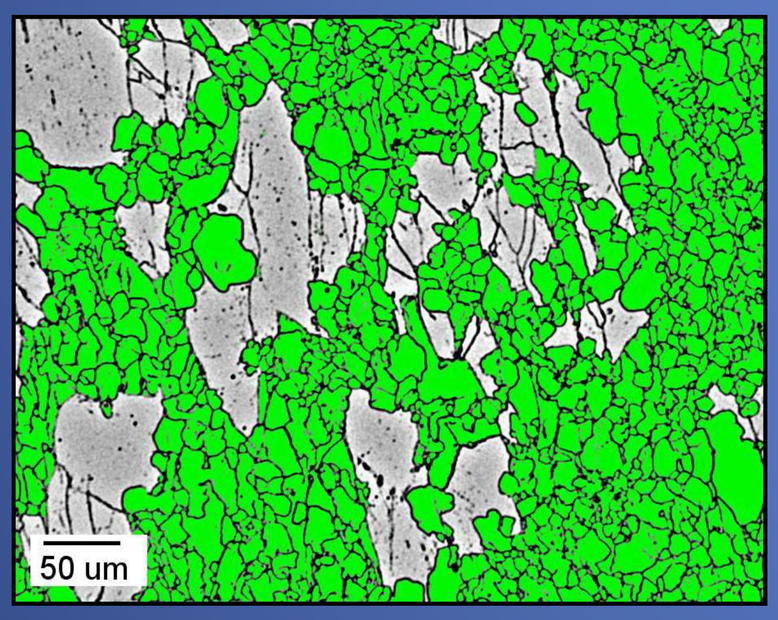

Figure 3. As-forged condition (E, right side)
100X original magnification
48% recrystallization
233 Vickers hardness.

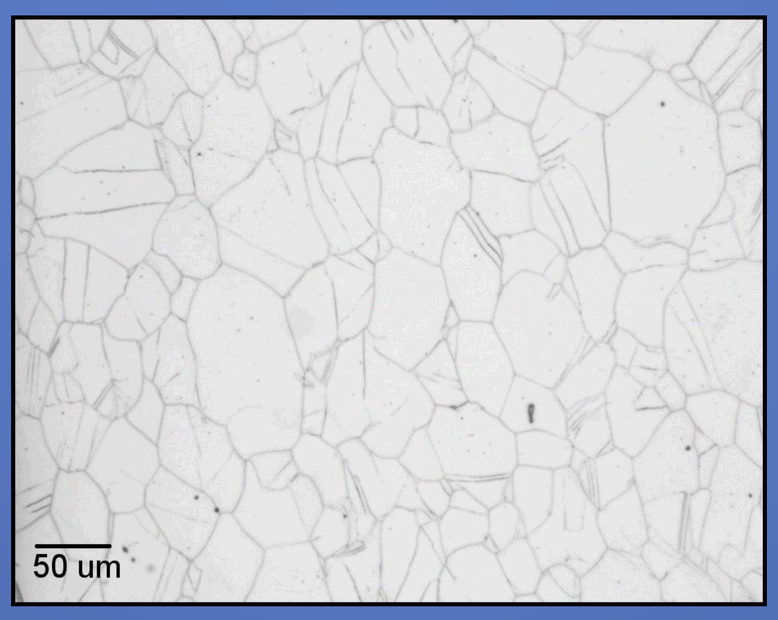

Figure 4. As-forged condition (center of E)
100X original magnification
0% recrystallization
226 Vickers hardness

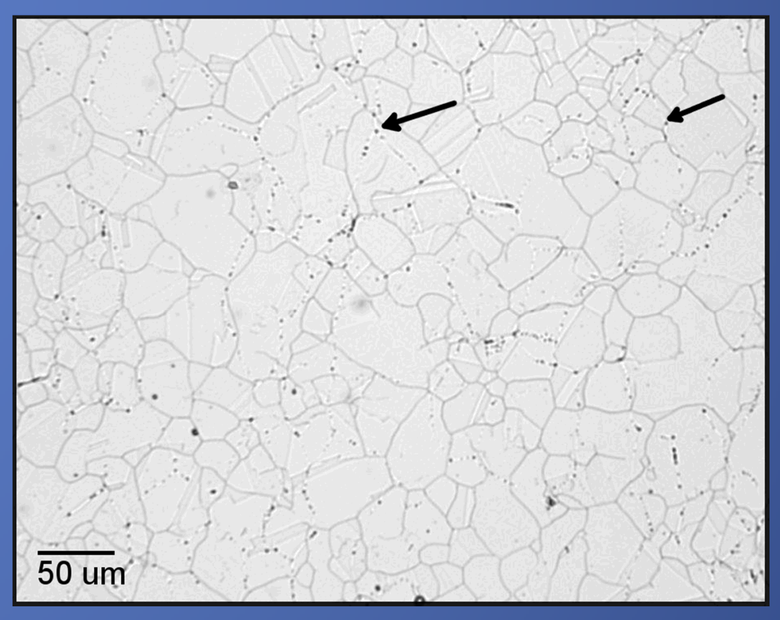

Figure 5. Post-weld condition (center of E)
100X original magnification
100% recrystallization
151 Vickers hardness

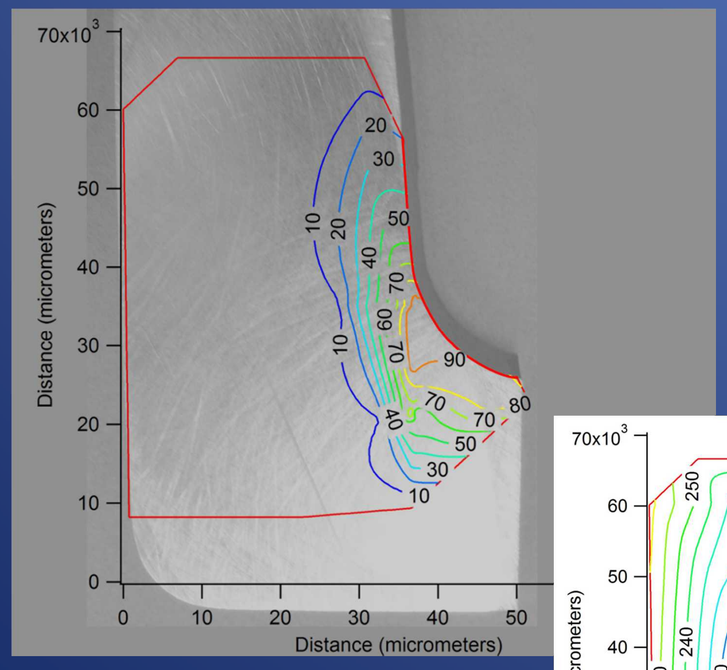

Figure 6. Pre-weld recrystallization (% recrystallization)

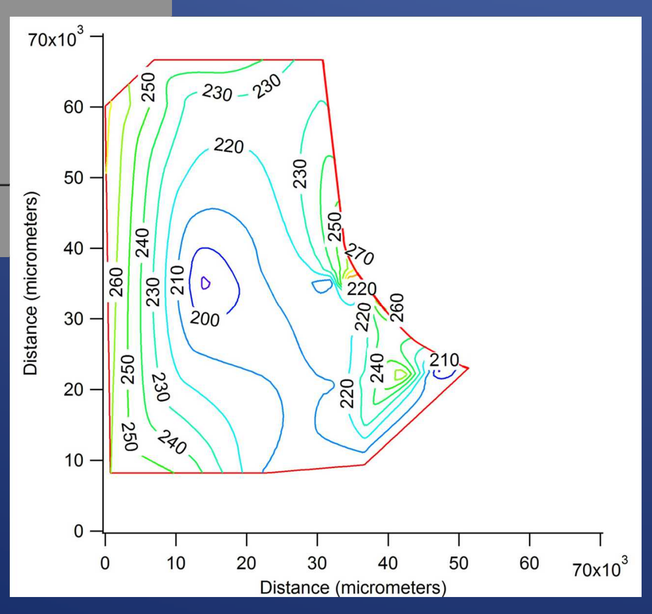

Figure 7. Pre-weld Vickers hardness

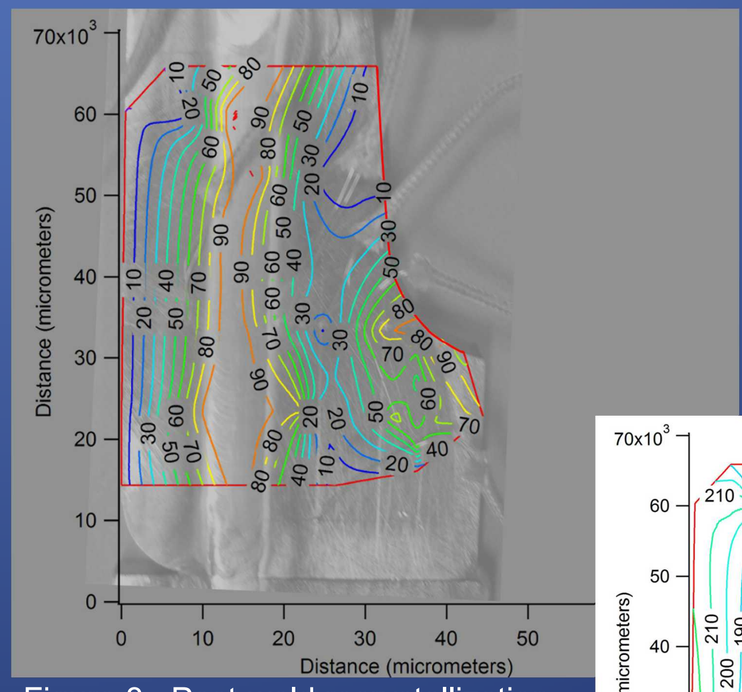

Figure 8. Post-weld recrystallization (% recrystallization)

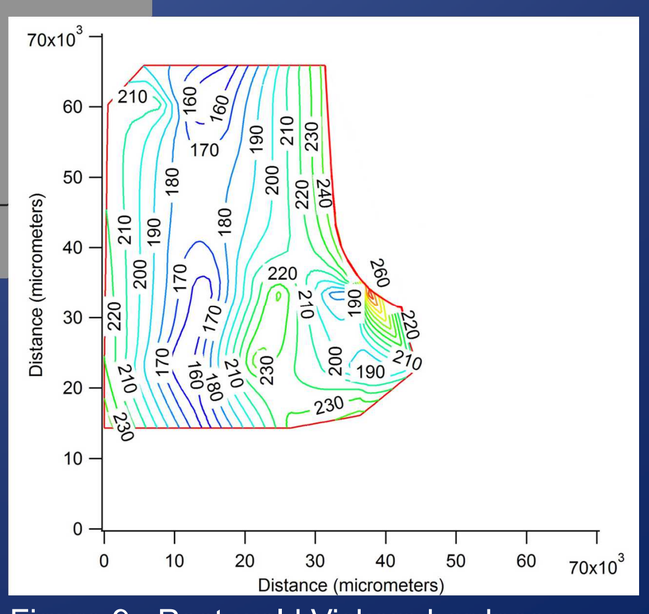

Figure 9. Post-weld Vickers hardness

These images have not been previously published or significantly altered from their original appearance by application of image-enhancement algorithms and convolution kernels, unless the purpose of the entry is to show how those are used to illustrate specific effects.

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