LAMBDA Technologies Group

Diffraction Notes

www.lambdatechs.com

Issue No. 45 Improving Component Life and Performance Winter 2018

USING LPB TO INHIBIT STRESS CORROSION CRACKING OF WELDED STAINLESS STEEL COMPONENTS

INTRODUCTION

SCC has been observed for decades in low carbon austenitic alloy weldments such as types 304L and 316L stainless steel and continues to be a primary maintenance concern for many components. Despite the fact that these alloys generally exhibit excellent corrosion resistance, studies have revealed that all grades and conditions of austenitic stainless steels are susceptible to SCC given the right conditions, namely a corrosive environment and applied or residual tensile stress above a certain threshold[1]. The threat of SCC damage directly impacts inspection, repair, and replacement costs. It is a particularly dangerous and potentially catastrophic mechanism that initiates slowly and can progress undetected at stresses well within engineering design limits and typical operating conditions. A cost effective means of mitigating SCC would greatly reduce operational and maintenance costs.

Lambda Research, part of the Lambda Technologies Group, conducted a DOE SBIR funded study to determine the effects of beneficial compressive residual stress on the prevention of SCC in welded stainless steel components. It was shown that post-weld surface enhancement processing via Low Plasticity Burnishing (LPB)[2-4] can be used to introduce deep compression into tensile weld zones thereby mitigating SCC.

MATERIAL PROCESSING

Type 304L and 316L stainless steel was chosen for the study due to its widespread application. Plate material conforming to ASME SA240 was machined and welded into test plates of approximately 1 x 6 x 12 in. Welding was performed by a certified nuclear repair facility using a shielded metal arc welding (SMAW) process and weld filler metal E308 and 152 for the 304L and 316L plates, respectively.

One half of the weld was LPB processed to impart a depth and magnitude of compression necessary for SCC mitigation. A close up picture of the weld region showing LPB treated and untreated material can be seen in Figure 1. As can be seen in the figure LPB processing improves the surface finish and reduces surface irregularities.

RESIDUAL STRESS AND SCC TESTS

X-ray diffraction residual stress measurements were performed on the 304L and 316L welded test plates. Measurements were made at locations adjacent to the weld and at distances of 0.2, 0.5, and 1 in. from the weld fusion line on both the LPB treated and untreated halves of the specimens. Figure 2 shows the residual stress distributions plotted as a function of depth for each of the various distances from the weld fusion line. Peak tension of over +100 ksi was measured in the untreated side of both specimens. LPB treatment produced compression approaching -100 ksi.

SCC tests were performed using hot magnesium chloride ($MgCl_2$) solution exposure. The use of $MgCl_2$ solution exposure is a generally accepted method for determining the susceptibility of materials to SCC and is described in ASTM G36[5]. The test consisted of a 32 hour exposure at a temperature of 120°C. Figure 3 contains post-exposure pictures of a test sample. Fluorescent dye penetrant was used to aid in the visual inspection of cracks. Both the 304L and 316L alloy samples showed similar results. The LPB treated sides of the plates were completely free of any SCC. Significant SCC was observed along the untreated side of the weld fusion line and along the edge of the plate on the untreated side. The cross section images illustrate the depth of the SCC. Crack depths on the untreated side of the plate approach the weld depth.

SUMMARY

- Heat affected zones of welded 304L and 316L stainless steel exhibited tensile residual stress of over +100 ksi.
- LPB processing successfully imparted deep residual compression approaching -100 ksi.
- SCC tests reveal severe cracking in the untreated material with depths approaching that of the entire weld.
- No SCC occurred on the LPB treated side of any of the welded specimens.
- LPB was shown to effectively eliminate stress corrosion cracking in welded 304L and 316L stainless steel.

REFERENCES

[1] P. L. Andresen and M. M. Morra (2008) Stress Corrosion Cracking of Stainless Steels and Nickel Alloys in High-Temperature Water. Corrosion: January 2008, Vol. 64, No. 1, pp. 15-29.

[2] Navy Phase II SBIR (2002) Contract N68335-02-C-0384, “Affordable Compressor Blade Fatigue Life Extension Technology”

[3] Air Force Phase II SBIR (2003), Contract F33615-03-C-5207, “Component Surface Treatments for Engine Fatigue Enhancement”

[4] NASA Phase II SBIR (1999) Contract NAS3-99116, “Low Cost Surface Enhancements Method for Improved Fatigue Life of Superalloys at Engine Temperatures”

[5] ASTM Standard G36, 1994 (2013), “Standard Practice for Evaluating Stress-Corrosion-Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution,” ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/G0036, www.astm.org.

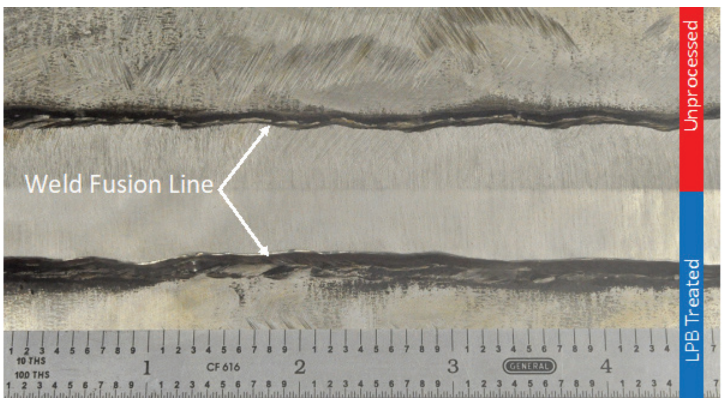

Figure 1: 304L Test Plate Close-Up

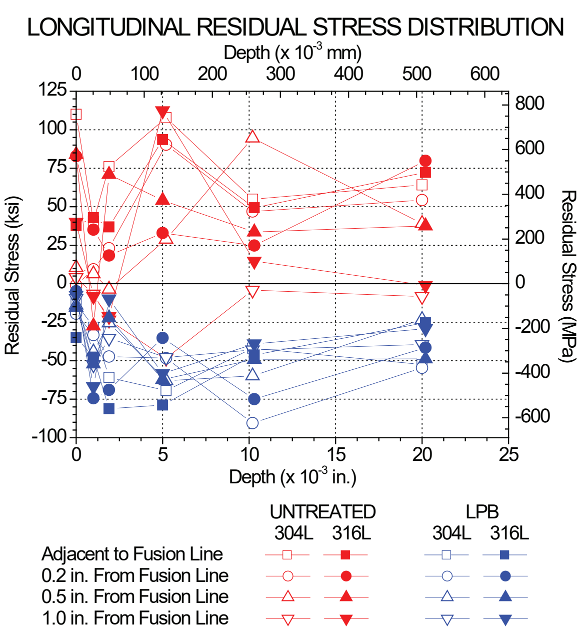

Figure 2: RS Profiles of 304L and 316L Stainless Steels

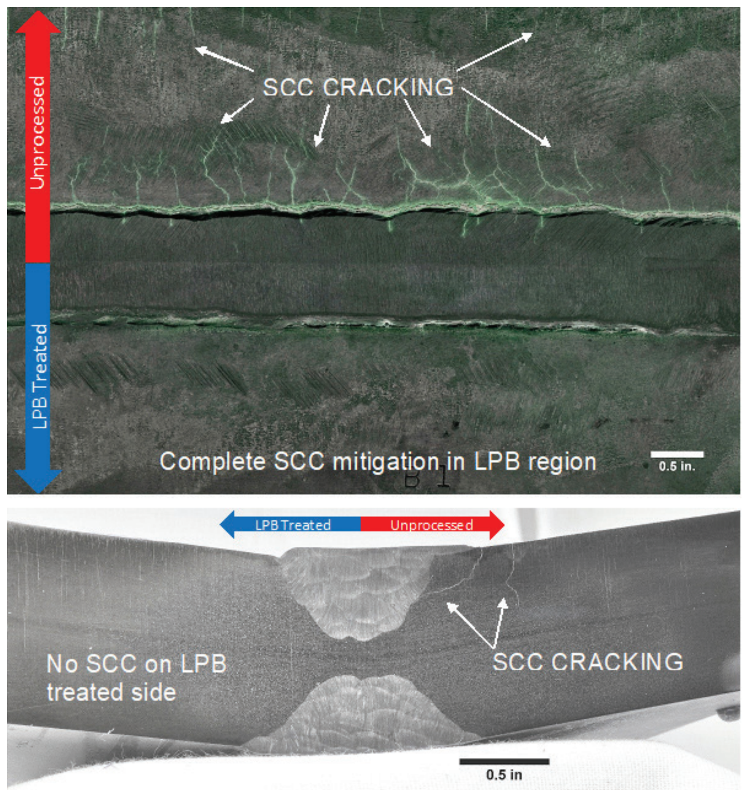

Figure 3: Full 304L Specimen with Dye Penetrant and Cross Section Images Showing Deep SCC in Heat Affected Zone on Untreated Portion and Complete Absence of SCC on LPB Treated Portion