Improving Component Life and Performance

LAMBDA TECHNOLOGIES

DIFFRACTION NOTES 5521 Fair Lane, Cincinnati, OH 45227 (513) 561-0883 No. 37 Fall 2009

RESIDUAL STRESS AND STRESS CORROSION CRACKING CHARACTERIZATION of LPB TREATED 316L STAINLESS STEEL WELDMENTS

INTRODUCTION

Low carbon austenitic stainless steel grade 316L is a commonly used material in many industries where corrosion resistance is critical. Grade 316L, the low carbon version of 316, is highly resistant to sensitization (grain boundary chromium carbide precipitation), due to high temperatures experienced during weld fabrication. 316L is used extensively in welded components in the nuclear, aerospace, power generation, pulp and paper processing industries where it assures optimum corrosion performance. Although 316L has excellent corrosion resistance the welding process can produce high levels of tensile residual stress making the material susceptible to stress corrosion cracking (SCC).

SCC is a unique mode of corrosive attack that is the result of a combination of susceptible material, a corrosive environment, and applied or residual tensile stresses. SCC 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.

Post-weld surface enhancement processing of the weld and parent metal can eliminate SCC. Introducing compressive residual stresses in the critical regions of the weld, eliminates one of the requirements for SCC to occur, thereby mitigating the failure mechanism.

An extensive study has been performed at Lambda's laboratory facilities to determine the benefit in SCC resistance afforded by low plasticity burnishing (LPB)

LAMBDA NEWS

SBIR AWARDED

Lambda is pleased to announce that we have been awarded a Phase I SBIR grant from the Department of Defense Army Division for "Low Plasticity Burnishing (LPB) as a Crack Initiation Resistant Surface Treatment Process for Case Hardened Steels."

PHASE III SBIR AWARDED

Lambda has been awarded a Phase III contract from the Department of Defense Naval Air Division for the "Application of Low Plasticity Burnishing (LPB) to Improve Blade Leading Edge (LE) Foreign Object Damage (FOD) Tolerance and Fatigue Life on the Pegasus F402-408 Engine LPC Components."

ASTM INTERNATIONAL WORKSHOP

Doug Hornbach, President of Lambda Research, will be presenting the topic, "Application of Low Plasticity Burnishing (LPB) to Improve the Fretting Fatigue Performance of Ti-6Al-4V Femoral Hip Stems", at the ASTM International Workshop at the Hyatt Regency Atlanta on November 10, 2009, in the morning session. If you would like more information about this workshop, click on the following link http://www.astm.org/filtrexx40.cgi?+-P+MAINCOMM+E08+-P+EVENT_ID+1623+-P+MEETING_ID+49905+/usr6/htdocs/newpilot.com/MEETINGS/symposiamainsite.frm

Please visit our website: **www.lambdatechs.com** to see any new updates and advances that Lambda has made in the field of materials testing and surface enhancement. Check out our extensive library of technical papers.

316L stainless steel circular weldments. LPB is a popular surface enhancement method used in many industries for fatigue strength improvement and resistance to SCC. Welded test samples were made and one-half of the sample LPB treated. SCC tests were conducted at Lambda to characterize the influence of compressive residual stresses. X-ray diffraction residual stress measurements were made using customized diffractometers and data collection software specifically designed to accurately map the residual stress and cold working.

TEST SAMPLES

Circular weld test samples were made to study the influence of LPB on SCC. A test sample is shown in Figure 1. In this study a circular weld bead of Alloy 52 weld filler material was applied about the center of square plates of 316L stainless steel. Specimens were nominally 3.8 X 3.8 X 0.5 in (96.5 X 96.5 X 12.7 mm). Welding was performed using a TIG welding process and consisted of a single bead of weld material. Each welded specimen was subsequently LPB treated on ½ of the welded surface leaving the other half in the as-welded condition. Figure 2 shows the LPB processing of a welded specimen.

Figure 1 – 316L circular weld specimen

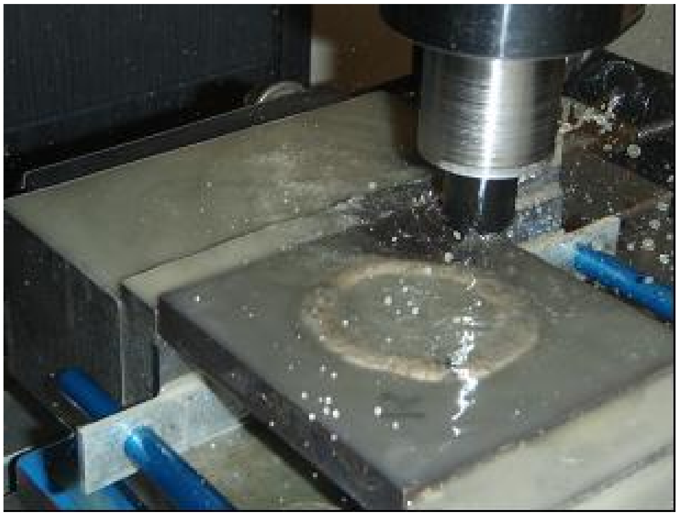

Figure 2 – LPB processing of a 316L circular weld specimen.

SCC TESTING

Following LPB all test specimens were exposed for 100 hours fully immersed in a solution of 150°C Magnesium Chloride ($MgCl_2$) per ASTM G36. Testing was performed in a borosilicate glass reaction vessel equipped with a condenser to maintain solution concentration. Thermocouples were used to gage the temperature and a laboratory heater was used to maintain a controlled temperature. Following exposure, specimens were cleaned with distilled water and a degreasing agent to prepare for dye penetrent examination. Fluorescent dye under black light was used to reveal the extent of cracking.

Photographs were taken of each specimen after testing to document the extent of SCC. Figure 3 shows macro photographs of a tested specimen. The LPB treated half of the specimen showed no signs of SCC or any other damage indicating LPB treatment completely mitigated SCC. The as-welded (untreated) half of the specimen suffered extensive through-thickness SCC damage with cracking in both the hoop and radial directions relative to the weld. It is important to note that the cracking that initiated on the as-welded side of the specimen terminated precisely at the physical boundary where the LPB treatment begins. This demonstrates the ability of the compressive stress field produced by LPB to arrest cracking.

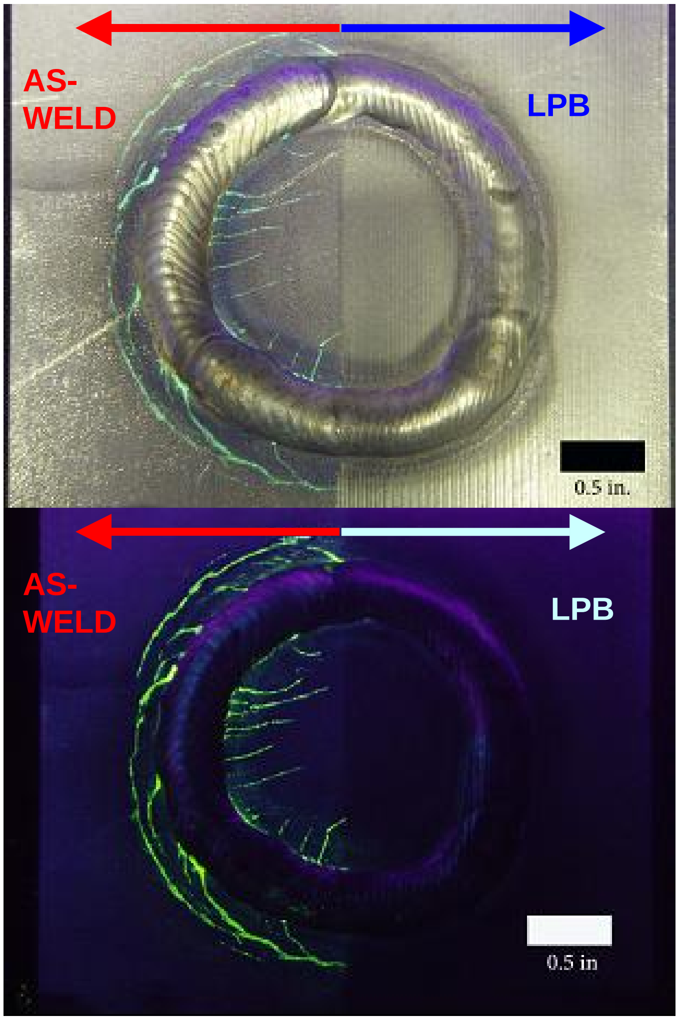

Figure 3 – Light and dark field fluorescent dye penetrant photographs of severe SCC cracking on the untreated half of a 316L specimen. LPB completely mitigated SCC.

RESIDUAL STRESS MEASUREMENT

X-ray diffraction residual stress measurements were made at Lambda's premiere x-ray diffraction laboratory facility. Measurements were made as a function of depth and distance across the welded specimens prior to testing. Figure 4 shows the residual stress distribution for a ½ LPB treated test sample. The LPB treated material is compressive with maximum compression on the order of –100 ksi. The as-welded half of the specimen contains high levels of tension, approaching +100 ksi.

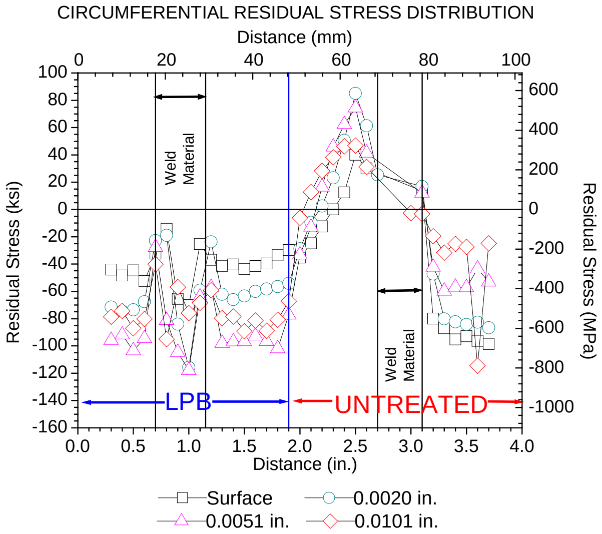

Figure 4 – Residual stress distribution as a function of depth and distance across a 316L specimen.

SUMMARY

Testing was performed at Lambda Research to characterize the effect of LPB on SCC of welded 316L stainless steel. SCC and residual stress tests were conducted at Lambda's laboratory facility using specialized instrumentation built and designed in-house. Specimens were welded and subsequently treated with LPB on one-half of the specimen leaving the other half in the as-welded (untreated) condition. The LPB treatment produced uniform, high magnitude compressive stress across the processed region that completely mitigated SCC when exposed to 150°C Magnesium Chloride. The as-welded portions of the specimens suffered extensive SCC with cracking extending completely through the thickness of the specimen. LPB treatment successfully and completely mitigated SCC in welded 316L stainless steel.