Improving Component Life and Performance

LAMBDA TECHNOLOGIES

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FATIGUE STRENGTH RESTORATION USING COMPRESSIVE RESIDUAL STRESS ON HIGH STRENGTH STAINLESS STEELS

INTRODUCTION

Martensitic precipitation hardening (PH) stainless steels are used in applications requiring high strength and resistance to general corrosion and stress corrosion cracking. This group of alloys is commonly used for critical components in the aerospace, nuclear and petrochemical industries.

Surface damage from exposure to corrosive environments can dramatically reduce the fatigue strength of high strength PH alloys. Maintenance and repair of PH stainless steel components, resulting from corrosion damage, can significantly increase operational costs. Compressive residual stresses can have a dramatic impact on the corrosion fatigue strength and damage tolerance of high strength PH stainless steels.

A study was conducted at Lambda Research to evaluate the effects of compressive residual stress on the corrosion fatigue properties of PH 13-8 Mo (13-8) stainless steel. Lambda provides a comprehensive selection of testing services and engineering expertise to provide optimal component performance through residual stress design. Lambda has developed similar results for 17-4 PH and 450 stainless steel. Links to those test results are listed below.

Link to 17-4 PH results:
http://www.lambdatechs.com/html/resources/245.pdf
http://www.lambdatechs.com/html/resources/247.pdf

Link to 450 SS results:
http://www.lambdatechs.com/html/resources/246.pdf

News Updates from Lambda Research

UPCOMING CONFERENCES

NACE Corrosion Conference – March 14-18, 2010 at the Henry B. Gonzalez Convention Center in San Antonio, TX

Jeremy Scheel, Senior Research Engineer, will be presenting two papers:

Monday March 15, 2010

"Sulfide and Chloride Stress Corrosion Cracking Mitigation Using Low Plasticity Burnishing", a joint effort between Lambda Research and U.S. Steel.

Tuesday, March 16, 2010

"The Effect of Surface Enhancement on the Corrosion Properties, Fatigue Strength, and Degradation of Aircraft Aluminum".

P-SAR Conference - March 16-18, 2010, at the Sawgrass Marriott Hotel in Jacksonville, FL.

Dr. Jayaraman, Director of Materials Research, will be presenting:

"Low Plasticity Burnishing (LPB) as an MRO Technology to Improve Component Life, Damage Tolerance, Performance, and Safety".

Please make a note on your calendar to attend these conferences and see these informative presentations.

For more information about our testing capabilities, accreditations, or other publications, visit our website at www.lambdatechs.com

In this program 13-8 fatigue samples were shot peened (SP) or low plasticity burnished (LPB) following exposure to NaCl solution to study the restorative effects of residual compression.

SURFACE TREATMENT AND SALT WATER EXPOSURE

Trapezoidal cross section fatigue samples were machined from 13-8 round bar stock in a modified H1100 heat treat condition. Lambda has a full-service machine shop to provide machining of test specimens for characterizing surface enhancement methods and optimizing manufacturing processes to improve component performance.

Test samples were either SP or LPB treated to introduce residual compression. The SP parameters are as follows: 6 to 8A Almen Intensity, CCW14 steel shot, and 200% coverage. LPB parameters were chosen to produce a nominal compressive depth of 0.03 in. with minimal cold working.

In order to study the restorative effects of each surface treatment, a portion of the fatigue samples were exposed to a NaCl solution while under an applied stress, prior to surface treatment. The active gage region was loaded in tension to 90% of the yield strength in custom built 4-point bend fixtures in an alternate immersion bath of 3.5% weight NaCl solution for 100 hrs.

During fatigue testing, some of the samples were subjected to an active corrosion environment with 3.5% weight NaCl solution. In this manner, specimens were exposed to a corrosive environment for the duration of the test. To establish the baseline fatigue strength, a separate set of SP and LPB samples were tested with no prior corrosion or active corrosion.

RESIDUAL STRESS MEASUREMENT

X-ray diffraction (XRD) residual stress measurements were made at Lambda's premiere commercial XRD laboratory facility. Measurements were made on test samples in an as-machined, as-machined + SP, and as-machined + LPB condition.

Figure 1 shows the residual stress distributions for the three conditions. Machining produced a shallow layer of compression. SP produced a depth of compression on the order of 0.005 in., with maximum compression just below the surface on the order of –175 ksi. LPB produced a relatively deep layer of compression, on the order of 0.03 in., with maximum compression of nominally –190 ksi.

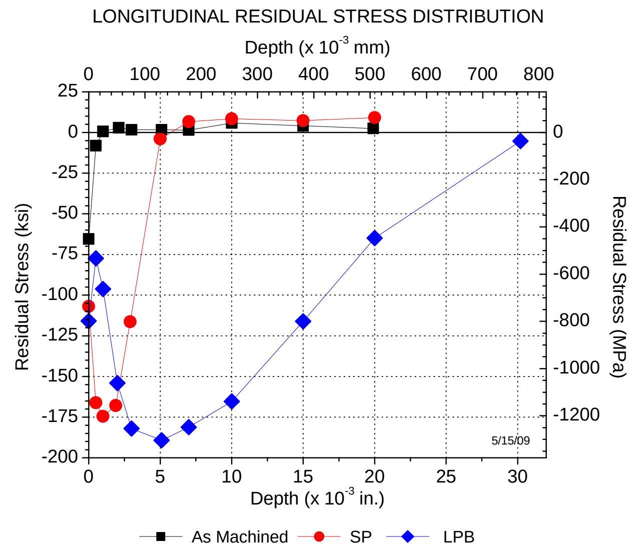

Figure 1: XRD residual stress distributions as a function of depth showing relatively deep compression from LPB.

HIGH CYCLE FATIGUE TESTING

All tests were performed at room temperature under constant amplitude loading at Lambda's Surface Integrity & Process Optimization facility. Lambda has several high cycle fatigue systems and supporting metallographic analysis capabilities, providing a complete set of tools for accurately evaluating the influence of residual stress on fatigue.

The stress vs. life (S-N) results for the fatigue tests are shown in Figure 2. Data are shown in a semi-log plot of maximum stress vs. cycles to failure. SP and LPB baseline tests show comparable fatigue strengths. Corrosion damage from both the pre-fatigue corrosion and active corrosion produced a debit for both the SP and LPB repaired samples. For the repair samples, the LPB treatment produced a fatigue life improvement of over 10X compared to SP at an applied stress of 120 ksi. The fatigue strength was nominally 25% higher for LPB compared to SP.

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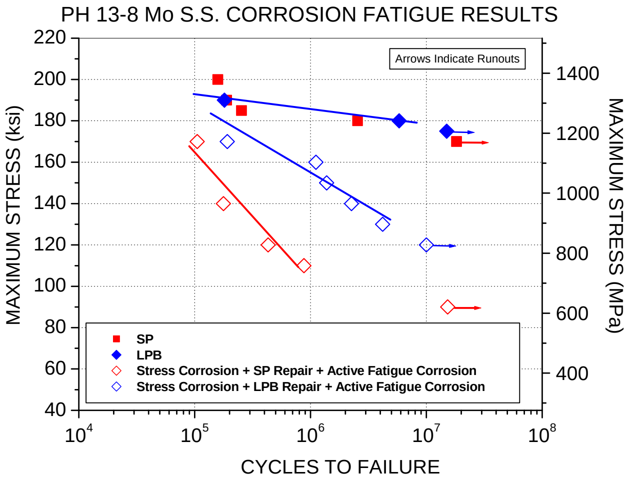

Figure 2 – Fatigue test results for baseline and repaired test samples. LPB processing provided greater than an order of magnitude increase in life compared to SP

SUMMARY

- XRD results indicate a nominal 6X greater depth of compression for LPB compared to SP.
- Fatigue strength of 13-8 was reduced as a result of NaCl solution exposure.
- Deeper compression imparted by the LPB process provided over a 10X fatigue life improvement compared to SP, and a nominal 25% improvement in fatigue strength.
- Surface enhancement methods can be used on 13-8 components to improve the fatigue performance and improve damage tolerance ultimately reducing operational costs associated with maintenance and repair.