LAMBDA
Technologies Group

Improving **Component Life** *and* **Performance.**

DIFFRACTION NOTES 5521 Fair Lane, Cincinnati, OH 45227 (513) 561-0883 No. 39 Summer 2013

THE INFLUENCE OF COMPRESSIVE RESIDUAL STRESS ON THE CORROSION FATIGUE PERFORMANCE OF STAINLESS STEELS

The development of 12% chromium stainless steels is reported to have originated in the early 1900's for steam turbine blade applications. Since that time there have been many advancements to stainless steel alloys. Type AISI 410 stainless steel (410 SS) is a hardenable 12%Cr stainless steel that combines the superior wear resistance of high carbon alloys with the corrosion resistance of chromium stainless steels. 410 SS is used considerably in low pressure (LP) turbine blade applications but is also widely used elsewhere in the aerospace, petrochemical and power generation industries. 410 SS components are, however, susceptible to stress corrosion cracking (SCC) and corrosion fatigue problems.

Significant costs are incurred in the prevention of fatigue and SCC failures. Costs associated with downtime and replacement can skyrocket in the event of a component failure. Introduction of compressive residual stress can dramatically reduce these costs by increasing fatigue strength and mitigating SCC. Laboratory tests were conducted at Lambda's laboratory facility to characterize the influence of residual compressive stress on the corrosion fatigue properties and damage tolerance of 410 SS. Both shallow and deep layers of compression were introduced and the subsequent fatigue benefit compared.

ANNOUNCEMENTS

New Portable Mechanical Residual Stress System

Lambda has recently introduced a new CNC based mechanical residual stress measurement instrument capable of measuring the principal residual stress vs. depth using either the center-hole drill (ASTM E837) or the ring core methods. The system allows for precision CNC machining using a high speed drill for hole drill measurement. The system can also machine annular grooves around a monitoring strain gage for ring core residual stress measurement. The system is portable allowing for measurements on large samples either at our laboratory facility or at our customer's site. Please contact Doug Hornbach (dhornbach@lambdatechs.com) or Tom Lachtrupp (tlachtrupp@lambdatechs.com) for more information.

Website

Please visit Lambda's updated website: www.lambdatechs.com to see the many laboratory services offered, as well as our large library of Technical Papers, Diffraction Notes, and Application Notes.

Other Services Provided

In addition to residual stress measurement services, Lambda provides testing services including retained austenite, texture analysis, surface treatment optimization and much more. Go to our website to see all of our services.

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410 SS fatigue test samples were treated with either shot peening (SP) or low plasticity burnishing (LPB®). SP imparts relatively shallow compression with high cold working and LPB conversely imparts deep compression with low cold working. Samples were also tested in an as-machined condition for a baseline reference.

Fatigue samples were subjected to mechanical or corrosion damage, prior to testing, to simulate typical in-service damage. Mechanical damage was accomplished by introduction of a 0.010 in. deep notch via electrical discharge machining (EDM) in the active gage region. An EDM notch depth of 0.020 in. was also used on a group of LPB treated samples. Corrosion damage was simulated by exposing the specimens to 3.5% weight NaCl solution in alternate immersion, per ASTM G44, for 100 hrs, while loaded at 90% of the yield strength. Pre-corroded samples were then fatigue tested in an actively corrosive environment by application of a pad saturated with 3.5% weight NaCl solution on the sample gage region. All fatigue tests were performed at room temperature in four-point bending at R=0.1 with a run out condition of 10^7 cycles.

Residual stress results measured by x-ray diffraction are shown in Figure 1. All three surface conditions have compression at and near the surface. The as-machined residual stresses are relatively shallow. SP and LPB treatments produce a depth of compression on the order of 0.010 in. and 0.030 in., respectively. LPB has the highest magnitude compression of the group.

High cycle fatigue results are shown in Figures 2 and 3. Figure 2 shows the results for the mechanically pre-damaged samples and Figure 3 shows the results for the samples pre-damaged by corrosion. Pre-damaging

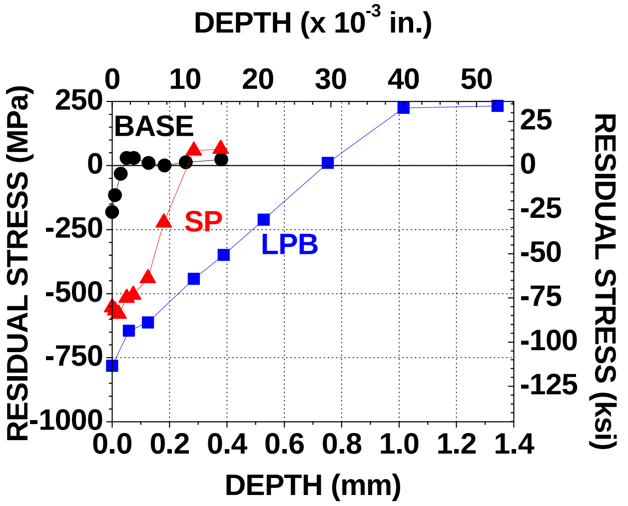

Figure 1: Residual Stress vs. Depth Profiles

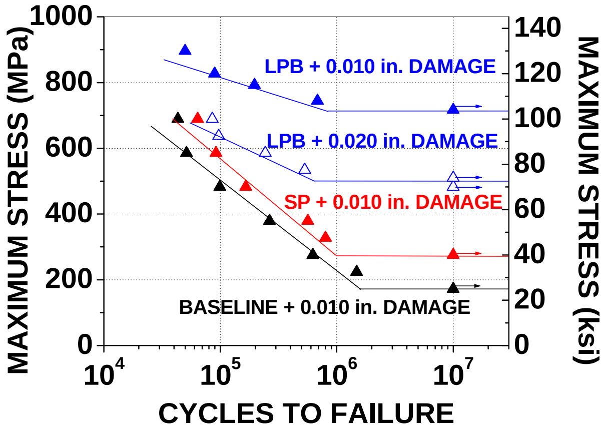

Figure 2: Fatigue Results for Mechanically Pre-Damaged Material.

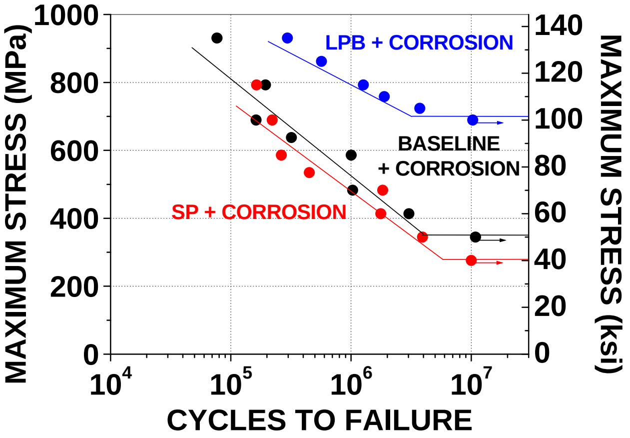

Figure 3: Fatigue Results for Corrosion Pre-Damaged Material.

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dramatically reduced the fatigue strength of both the as-machined and the SP condition relative to the LPB condition. Deeper compression from LPB produced a nominal 2X increase in fatigue strength and nearly a 100X improvement in life over the SP condition for the 0.010 in. EDM damage and pre-corroded conditions. As shown in Figure 2, the LPB treated samples containing the deeper 0.020 in. notch provided superior fatigue properties over the SP samples containing the shallower 0.010 in. deep notch.

Deep compression generated via LPB dramatically increases the fatigue strength and damage tolerance of 410 SS through the introduction of deep compression penetrating well below any conceivable in-service damage, providing protection that typical surface treatments such as SP cannot offer.

Summary:

- LPB produced 3X the depth of compression of SP.
- Deeper compression provided by LPB produced a 2X benefit in fatigue strength and nearly a 100X improvement in life over SP.
- LPB provided superior fatigue strength over SP even with twice the depth of damage.
- Significant improvement in component performance can be achieved with the appropriate depth and magnitude of residual compression.

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