Improving Component Life and Performance

LAMBDA
TECHNOLOGIES

DIFFRACTION NOTES 5521 Fair Lane, Cincinnati, OH 45227 (513) 561-0883 No. 36 Summer 2009

RESIDUAL STRESS AND CORROSION FATIGUE TESTING OF 7076-T6 PROPELLER BLADES

INTRODUCTION

The propeller blade assembly for the P-3 and C-130 aircraft consists of a bronze bushing inserted into the taper-bore end of a forged 7076-T6 aluminum propeller blade via an interference fit. The dissimilar metals in the assembly create a galvanic couple between the propeller and the bushing. Over time with environmental exposure, pitting corrosion from the galvanic couple occurs on the taper bore surface. Pits often serve as initiation sites for intergranular stress corrosion cracking (SCC), which can lead to fatigue crack growth and subsequent failure. This creates the need to rework the bushing and taper bore area within the propeller blade.

During rework of the P-3 propeller blade, high intensity shot peening is used on the internal taper bore to impart sufficient depth of compression to prevent SCC. The taper bore must then be reamed to remove the extremely rough surface left by high intensity shot peening. The end-face of the blade must then be machined to produce the proper interference fit for a bronze bushing. The entire process is time consuming, labor intensive, and costly. Furthermore, the successive reaming and machining performed at required maintenance intervals ultimately limits the service life of the blade.

Low plasticity burnishing (LPB) of the internal taper bore of the P-3 propeller blade has been applied to replace the current shot peen and reaming rework process. LPB processing of the P-3 propeller blade internal taper bore was performed with a 6-axis Fanuc robot. A photo of the blade, fixture and robot are shown in

ANNOUNCEMENTS

MILESTONE

Lambda recently completed its 15,000th project! We are proud of the experience and expertise our staff has to offer, while providing the highest quality data in the industry and offering complete solutions to solve critical issues for our customers.

UPCOMING CONFERENCES

Mr. Jeremy Scheel will be presenting his technical paper, “Safe Life Conversion of Aircraft Aluminum Structures via Low Plasticity Burnishing for Mitigation of Corrosion Related Failures” at the DoD Corrosion 2009 Conference held in Washington D.C. at the Gaylord National. He will be presenting at the Corrosion Prevention and Control Strategies Session scheduled for Tuesday, August 11, 2009 from 8:00 – 5:00 pm. For more information about the DoD Corrosion 2009 Conference, go to our website at www.lambdatechs.com/news/events.html.

SBIR AWARDED

Lambda is pleased to announce that we have been awarded a Phase I SBIR contract with the Department of Energy for “Stress Corrosion Cracking Mitigation and Fatigue Strength Improvement of Light Water Reactor Components Using Low Plasticity Burnishing”.

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

Figure 1. LPB produced a smooth surface finish, eliminating the need for reaming and further machining for proper contact between the bronze bushing and the internal taper bore. An extensive investigation was performed at Lambda's laboratory facility to compare the corrosion fatigue, general pitting corrosion characteristics, and the residual stress of the current shot peening and the LPB processes. Corrosion fatigue and residual stress testing were conducted on baseline (as-machined), shot peened and LPB treated samples.

Figure 1 – Robotic LPB processing of full propeller blade

CORROSION FATIGUE TESTING

A fatigue sample with a trapezoidal gage cross section was used for the high cycle fatigue (HCF) testing. All HCF test samples were machined from the airfoil portion of a P-3 propeller blade. The fatigue specimens were milled on the active surface of the gage prior to any surface enhancement process. Lambda has a full-service machine shop allowing for the machining of fatigue test specimens for purposes of characterizing the effects of residual stress and cold working.

All fatigue tests were performed under constant amplitude loading on a Sonntag SF-1U fatigue machine. Lambda has several high cycle fatigue systems and supporting metallographic analysis capabilities, providing a comprehensive set of tools required to accurately assess the influence of residual stress on fatigue. A photo of the fatigue test setup is shown in Figure 2. Fatigue testing was conducted at room temperature in four-point bending mode. The cyclic frequency and load ratio, R, were 30 Hz and 0.1 respectively. Tests were conducted to the event of specimen fracture or until a "runout" life of 1 x 10^7 cycles was attained. The fatigue tests were conducted in an active corrosion environment with the specimens exposed to a 3.5 wt% NaCl, solution throughout the duration of the fatigue tests, simulating a marine environment.

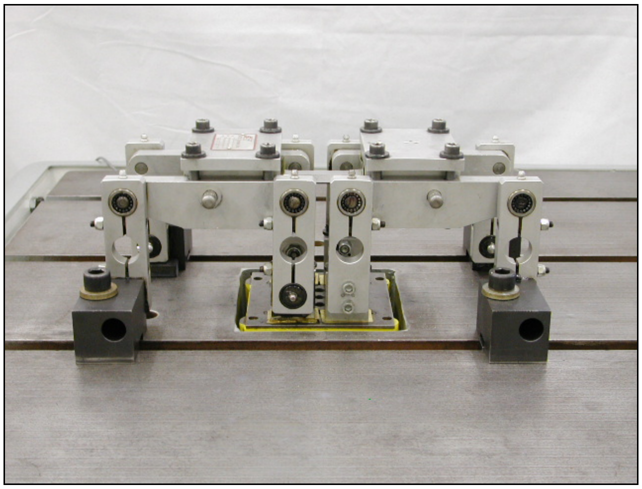

Figure 2 – 7076-T6 Fatigue specimen in 4-point bend fixture

The stress vs. life (S-N) results for the fatigue tests are shown in Figure 3. Data are shown in a semi-log plot of maximum stress vs. cycles to failure. The LPB treatment provided higher fatigue strength than the shot peen treatment for all conditions tested. LPB treated samples had an endurance limit of approximately 50 ksi compared to 42.5 ksi and 35 ksi endurance limits for the shot peened and baseline samples, respectively. The fatigue life of all samples was considerably affected by the introduction of an actively corrosive NaCl salt environment during testing. Furthermore, there does not appear to be an endurance limit for any samples when exposed to the actively corrosive environment. The LPB treated samples were most resistant to the active corrosion and exhibited an approximate 15 ksi improvement in strength over the other surface treatments.

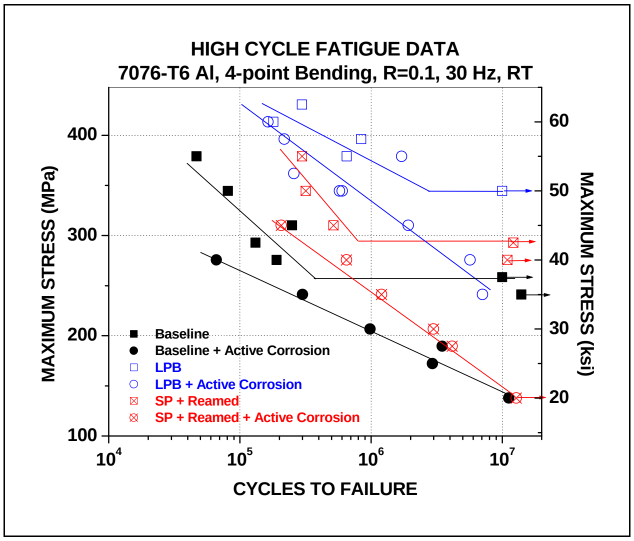

Figure 3 – S-N results for 7076-T6 specimens

RESIDUAL STRESS MEASUREMENTS

X-ray diffraction residual stress measurements were made at Lambda's premier x-ray diffraction laboratory with diffractometers specifically built to accurately measure the residual stresses vs. depth. Measurements were made at mid-gage of the fatigue specimens for the baseline, shot peened and LPB conditions. Measurements were made as a function of depth in the treated gage region. Results are shown in Figure 4. Machining alone produced nominally 0.006 in. depth of compression. Shot peening produced compression to a nominal depth of 0.025 in. LPB produced a depth of compression on the order of 0.035 in. LPB produced peak compression nominally 40% greater than shot peening.

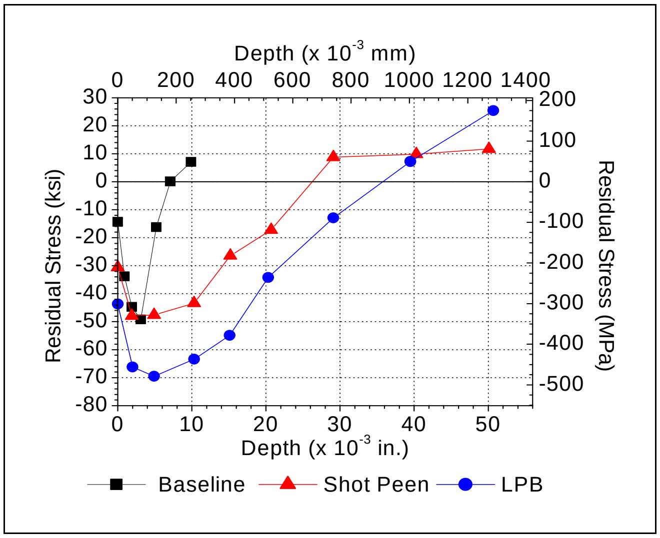

Figure 4 – Residual stress distributions in high cycle fatigue specimens

SUMMARY

Lambda conducted both high cycle fatigue and residual stress tests to characterize the influence of LPB on the corrosion fatigue properties of 7076-T6 aluminum P-3 propellers. Fatigue and residual stress results on shot peened, as-machined and LPB treated samples demonstrated that the LPB process is superior to the current shot peening process in terms of fatigue strength and residual stress. LPB has been selected to replace heavy shot peening and re-machining during blade overhaul, reducing maintenance costs and extending the existing blade life indefinitely.