LAMBDA Technologies Group
Diffraction Notes
www.lambdatechs.com
Issue No. 43 Improving Component Life and Performance Spring 2017

LPB FOR THE IMPROVEMENT OF DAMAGE TOLERANCE, CRACK INITIATION RESISTANCE, AND FATIGUE PERFORMANCE OF CASE HARDENED STEELS

INTRODUCTION

High cycle fatigue (HCF) performance of critical drive train components, including gears and shafts, has long been improved through the introduction of a shallow surface layer of compressive residual stress. This is often accomplished by means of shot peen processing. These components are typically manufactured from high strength case carburized steels, finish ground to tolerance, then shot peened to enhance fatigue strength. Achieving greater depth and magnitude of compression through higher intensity peening may further improve the fatigue performance, but often comes at the cost of unacceptably high levels of cold work and surface roughness. High cold working can lead to relaxation of compressive stresses when exposed to elevated temperatures and overload conditions.

A residual stress and fatigue study conducted by Lambda Research studied the effects of shot peening and Low Plasticity Burnishing (LPB®) over an as-ground condition in 9310 carburized steel components. LPB processing offers the combined advantages of deep compression, smooth surface finish, and low levels of cold work.

MATERIAL PROCESSING

Test specimens were machined from 9310 steel bar stock acquired in the AMS 6265M condition. They were then carburized and heat treated. Approximately 0.005 in. of material was ground from the surface of each sample in order to eliminate the decarburized layer. The final case depth was approximately 0.050 in. deep with a surface hardness of nominally 62 HRC. Sample groups included as-ground, LPB processed, and shot peened treatments.

RESIDUAL STRESS

Figure 1 shows the X-ray diffraction residual stress distributions measured at Lambda's test facility. Data are shown as a function of depth for each sample group. The as-ground condition has a relatively shallow compressive surface layer with maximum compression of -75 ksi. Shot peening produced surface compression of -140 ksi and maximum compression of –220 ksi at a depth of approximately 0.002 in. LPB produced surface compression of -140 ksi and maximum compression of -270 ksi at a depth of 0.005 in.

HIGH CYCLE FATIGUE

High cycle fatigue tests were performed at room temperature under constant amplitude loading at Lambda's Surface Integrity & Process Optimization (SIPO) facility. Electrical discharge machining (EDM) notches of 0.010 in. deep were used to simulate contact (pitting fatigue) damage. 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. Arrows indicate a run-out condition in which the specimen did not fail.

The as-ground specimens demonstrated a nominal fatigue strength of 200 ksi, which dropped to approximately 60 ksi with the introduction of the EDM simulated damage. The shot peened specimens showed a slightly better fatigue strength of about 220 ksi in the smooth (undamaged) condition and approximately 100 ksi with the EDM notch. The LPB treated specimens clearly demonstrated superior fatigue strengths of approximately 240 ksi undamaged and about 170 ksi with the notch.

LAMBDA Technologies Group

Diffraction Notes

www.lambdatechs.com

Issue No. 43 Improving Component Life and Performance Spring 2017

SUMMARY

- LPB processing produces a depth of compression up to 3X greater than shot peening. The peak compressive residual stress for LPB is 20% greater than that of shot peening.

- In the smooth condition, LPB provides a 10% improvement in fatigue strength over shot peening.

- With the presence of a 0.010 in. deep EDM notch, LPB produces nearly a 2X improvement in fatigue strength over shot peening.

- LPB produces a much smoother surface, with a surface roughness of 5 – 10 μin, while shot peening leads to a relatively rough surface with 25 μin of Ra surface roughness.

In summary, LPB treatment improved the fatigue performance over the standard shot peening treatment in carburized and heat treated 9310 steel and increased the resistance to simulated contact pitting damage. This demonstration paves the way for developing applications of this technology by appropriate design of LPB tools and implementation of the designed residual stresses to improve the performance of carburized steel drivetrain components.

LONGITUDINAL RESIDUAL STRESS DISTRIBUTION

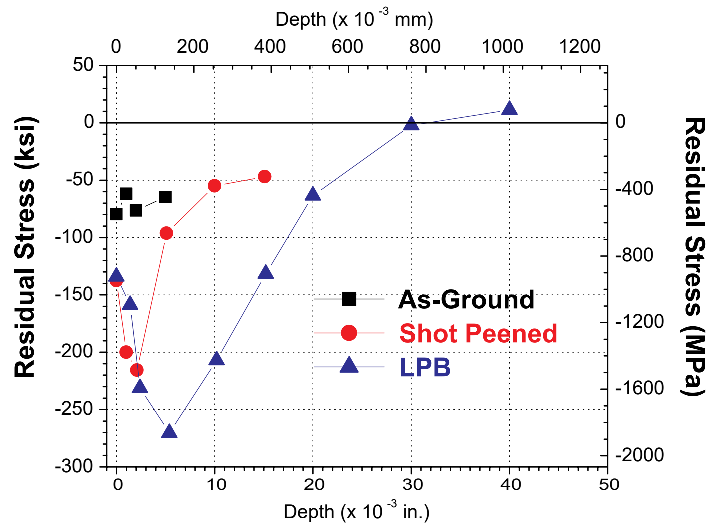

Figure 1: Plots of Residual Stress vs. Depth in As-Ground, Shot Peened, and LPB-Treated 9310 Steel

HIGH CYCLE FATIGUE DATA

9310 Case Carburized/Hardened Steel Thick Section Samples

R = 0.1, 4-point Bending, 30 Hz, RT

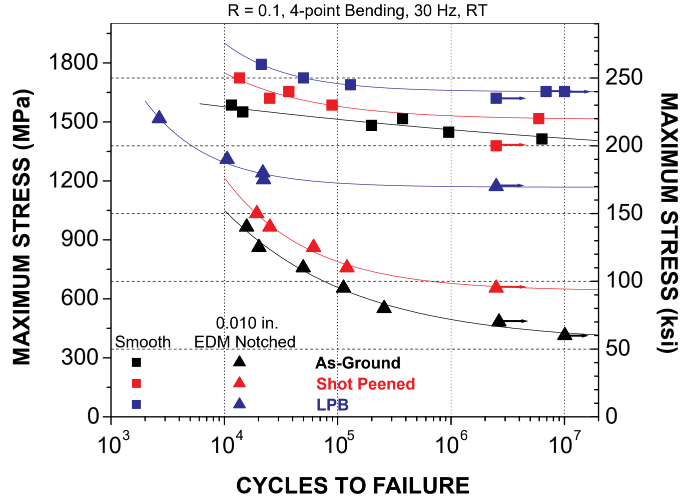

Figure 2: Maximum Stress vs. Cycles to Failure in As-Ground, Shot Peened, and LPB-Treated 9310 Gear Steel