LAMBDA Technologies Group

Diffraction Notes

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Issue No. 48 **Improving Component Life and Performance** 2021

IMPROVING THE FATIGUE LIFE OF THREADED FASTENERS VIA SURFACE ENHANCEMENT

INTRODUCTION

Threaded fasteners are used extensively for a multitude of applications. It is estimated that approximately 85% of threaded fastener failures are a result of fatigue. Fastener failures lead to billions of dollars in repair and maintenance costs as well as equipment downtime. Their widespread use in critical engineered components makes them an important focus of improvement as performance requirements are continually increasing. Threaded fasteners play such a critical role in the American economy that the Fastener Quality Act (FQA) was signed into law in 1990, and amended several times since then, to ensure their quality.

Fasteners can experience both mean and cyclic loading during use that can lead to premature failure due to fatigue. Fastener fatigue failure commonly occurs in the thread fillet or the fillet to thread interface on the first engaged thread. Higher strength threads are often formed by rolling which provides a smoother finish and improves fatigue strength compared to threads that are machined via cutting or grinding. Rolling can also produce a layer of compressive residual stress in the fillet region providing further fatigue benefit.

In pursuit of improving the fatigue performance of threaded fasteners, the Lambda Technologies research laboratory conducted a study to characterize the effects of compressive residual stress introduced via Low Plasticity Burnishing (LPB®) on the fatigue performance of B7 steel threads. By selectively imparting a highly compressive layer of residual stress that extends well below the surface in the area of the maximum applied stress, LPB technology has been able to significantly improve the fatigue performance of many different materials and components.

MATERIAL PROCESSING

A threaded rod manufactured from B7 steel (AISI 4140, ASTM A193) was chosen for this study due to the availability and widespread applications of the material. The threaded rod was 3/8 in. with 16 threads per inch. The threads were roll formed following heat treatment. The heat treatment was performed per the ASTM A193 specification to obtain a minimum tensile strength of 125 ksi and a maximum hardness of 35 HRC. The rod was cut into fatigue specimens of approximately 4 in. in length as shown in Figure 1.

HIGH CYCLE FATIGUE TESTING

A group of threaded samples were LPB treated in order to compare the fatigue properties to the baseline (untreated) condition. LPB tooling was designed to introduce high compressive residual stress into the threaded root. The rod samples were treated along the entire 4 in. length.

All fatigue testing was performed under constant amplitude loading on a Sonntag SF-10U fatigue machine using a specially designed axial loading fixture, as shown in Figure 2. The cyclic frequency and load ratio, R, were 30 Hz and 0.7, respectively. The load ratio of R=0.7 was chosen to simulate a bolted joint with enough preload to prevent gapping within the joint under an applied load. All specimens were tested until failure at a maximum applied load of 5000 lbs.

RESULTS AND SUMMARY

The fatigue results were analyzed using a Weibull probability distribution and are shown in Figure 3. The L10, L50, and L90 lives are shown in Figure 4. Results indicate that the LPB treatment improved the fatigue life significantly. The L10 life (life at which 10% of specimens will fail) for the LPB processed samples is nominally 7X greater than that of the baseline condition. At L50 (life at which 50% of specimens will fail) the fatigue life for the LPB condition is approximately 11X greater than the baseline condition. At L90 (life at which 90% of specimens will fail) the LPB samples have a life of nominally 15X that of the baseline condition.

Another useful measure of the Weibull analysis is reliability. Reliability is the complement of the Percent Failed scale.

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Reliability provides a statistical measure of how many samples or components will survive for a given life. The Percent Reliability scale is shown on the right hand axis of the graph in Figure 3. For a reliability of 90% (Sample Survival Rate of 90%) the baseline samples have a life expectancy of 680,000 cycles while the LPB treated samples have a life expectancy of 4.4 million cycles, a nominal 7X increase.

It has been shown that the life of steel threaded fasteners can be increased significantly through the use of engineered compressive residual stress. By placing compression in the thread root region, the life of the B7 steel threaded fasteners was improved by more than 15X. Given that most of the threaded fastener failures result from fatigue, the use of compressive residual stresses can provide a substantial cost savings from reduced replacement and downtime.

Please see our website at www.lambdatechs.com for the full technical paper and complete list of references.

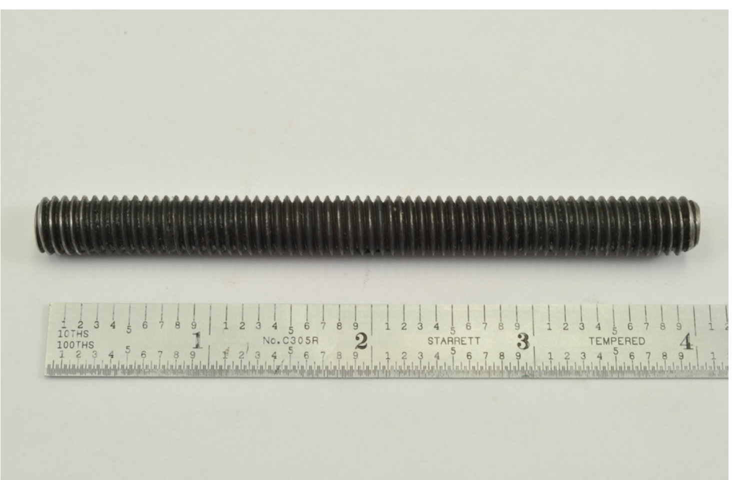

Figure 1: HCF Specimen Sectioned from Standard B7 (4140) Steel UNC 3/8 in.-16 Threaded Rod

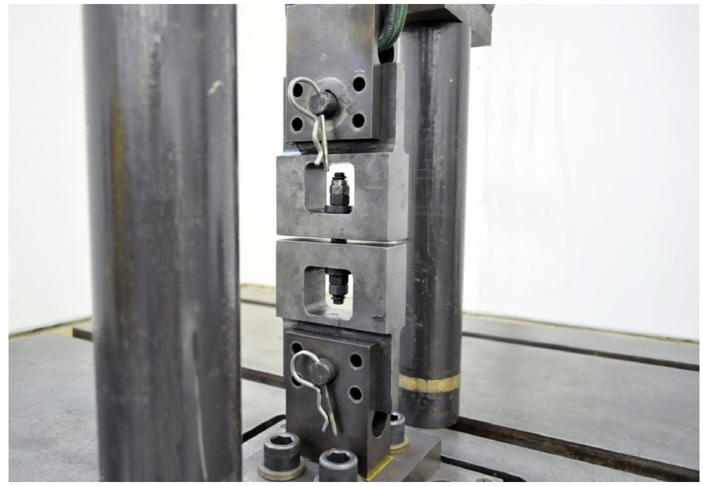

Figure 2: Specimen in Axial Loading on a Sonntag SF-10U HCF Machine

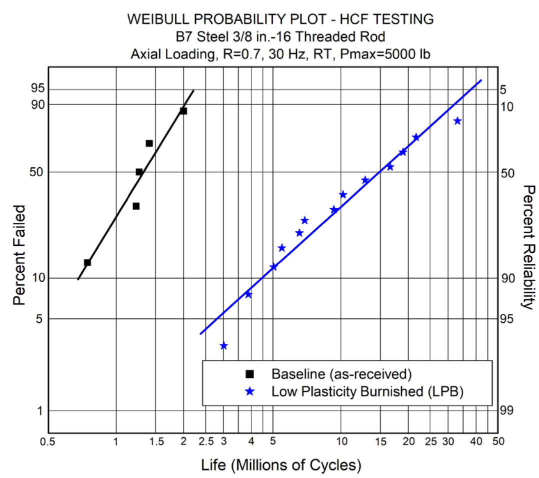

Figure 3: Weibull Failure Probability Plot

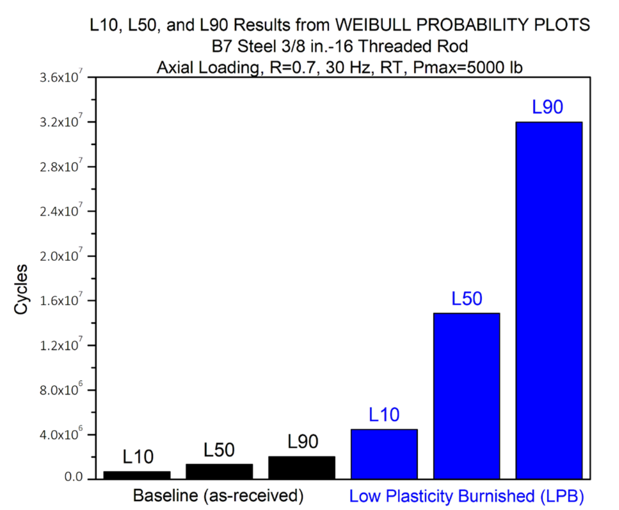

Figure 4: Results from Weibull Probability Distributions for Baseline and LPB Processed Specimens

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