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# IMPROVING FATIGUE AND CORROSION PERFORMANCE OF 17-4 PH STAINLESS STEEL USING ENGINEERED COMPRESSIVE RESIDUAL STRESS

## INTRODUCTION

17-4 precipitation-hardened (PH) stainless steel is widely used in aerospace, energy, and industrial applications for its high strength, moderate corrosion resistance, and good fatigue properties. Common components include compressor blades, turbine hardware, shafts, valves, fasteners, and structural fittings that operate under cyclic loading and often in corrosive environments.

Despite favorable bulk mechanical properties, failures in 17-4 PH components are commonly governed by surface-initiated damage mechanisms. Fatigue and stress corrosion cracking (SCC) often initiate at or near the surface where tensile stress, damage, and corrosion is most severe. As operating demands increase and inspection intervals are extended, maintaining surface integrity becomes critical to reliability.

This article presents experimental results demonstrating how engineered compressive residual stress improves fatigue life, corrosion fatigue resistance, and damage tolerance of 17-4 PH stainless steel.

## ROLE OF RESIDUAL STRESS IN FATIGUE AND CORROSION

Manufacturing processes, such as machining and grinding, can leave tensile residual stresses at the surface of 17-4 PH components, accelerating fatigue crack initiation and promoting environmentally assisted cracking. Conventional surface treatments like shot peening can introduce compressive residual stress, but often produce shallow compression, high cold work, and increased surface roughening. These factors can limit fatigue benefits and reduce residual stress stability under cyclic loading or elevated temperature.

Engineered surface treatments are designed to impart deep, high-magnitude compressive residual stresses with minimal cold work. This approach suppresses crack initiation, slows early crack growth, and improves resistance to corrosion fatigue and SCC without degrading surface finish or dimensional accuracy.

## FATIGUE PERFORMANCE AND DAMAGE TOLERANCE

Fatigue testing of 17-4 PH shows substantial improvements in fatigue strength following the introduction of deep compressive residual stress via Low Plasticity Burnishing (LPB®) treatment. In smooth specimens, treated material exhibits significantly higher endurance limits compared to untreated or conventionally processed material.

The performance gains are even more pronounced in the presence of surface damage. In tests simulating foreign object damage (FOD) using surface notches, untreated specimens experienced reductions in fatigue strength exceeding 70–80%. LPB treated components containing deep compressive residual stress retained much of their baseline fatigue performance, demonstrating a marked improvement in damage tolerance.

These findings are particularly relevant for aerospace compressor and turbine components, where minor surface damage is common during service.

## CORROSION FATIGUE AND SCC MITIGATION

Corrosion fatigue testing conducted in chloride containing environments shows that untreated 17-4 PH stainless steel can lose 40–60% of its fatigue strength relative to air. Engineered compressive residual stress largely restores this lost performance by lowering the effective tensile stress at the surface.

This same compressive effect mitigates stress corrosion cracking, as demonstrated in 17-4 PH and other turbine and compressor alloys. This supports the broader utility of designing residual compression for components exposed to corrosive operating environments.

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## SUMMARY

Experimental evidence consistently demonstrates that fatigue life, corrosion fatigue resistance, and damage tolerance of 17-4 PH stainless steel are strongly influenced by the surface residual stress state. Engineered mechanical surface treatments that introduce deep, stable compressive residual stress provide significant performance improvements without altering alloy chemistry or bulk properties.

Residual compression by design offers a practical and proven method to extend service life and improve reliability of 17-4 PH components in critical applications. For more on this topic, see the full paper on our website.

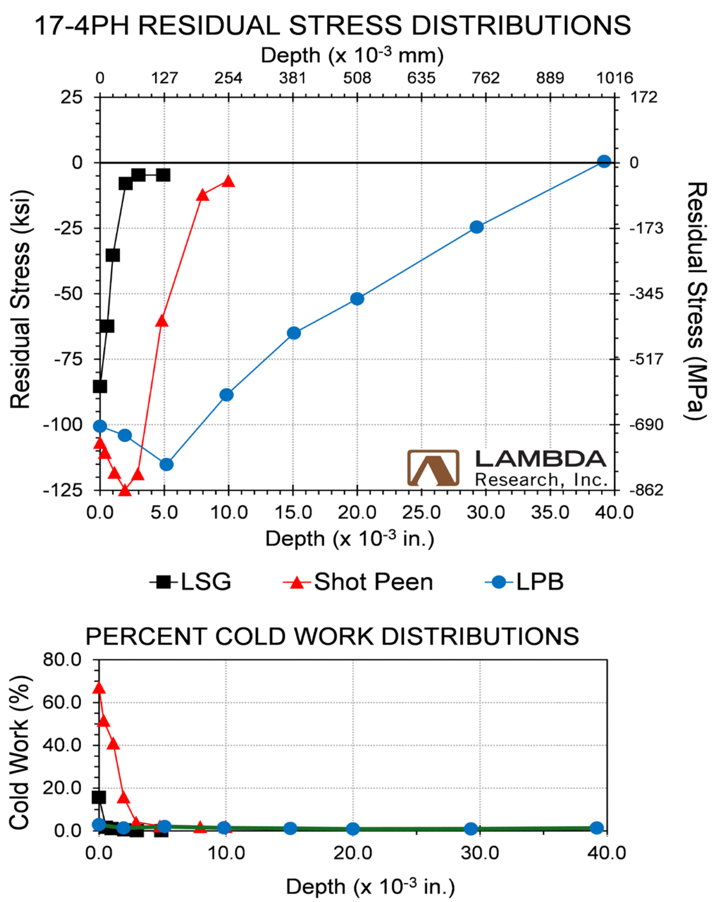


**Figure 1: Residual stress and cold work depth profiles in 17-4 PH stainless steel comparing low-stress ground, shot peened, and LPB-treated conditions.**

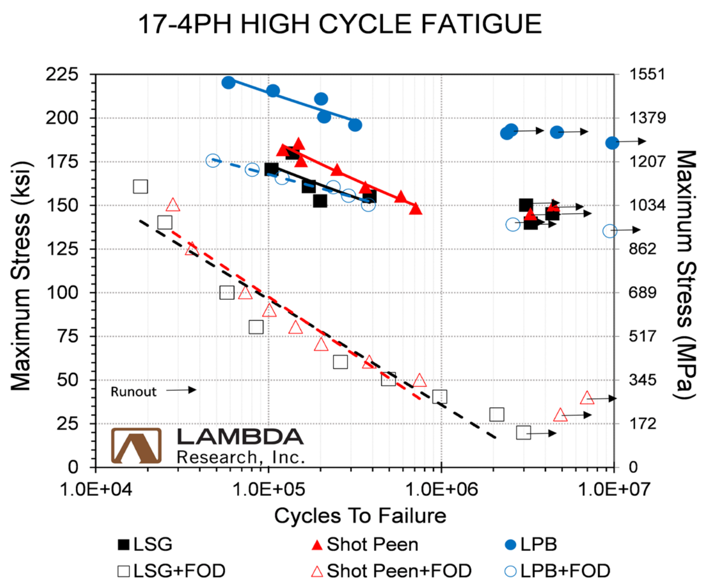


**Figure 2: Fatigue S-N performance of 17-4 PH stainless steel showing the effects of surface treatment and 0.25 mm (0.010 in.) simulated foreign object damage.**

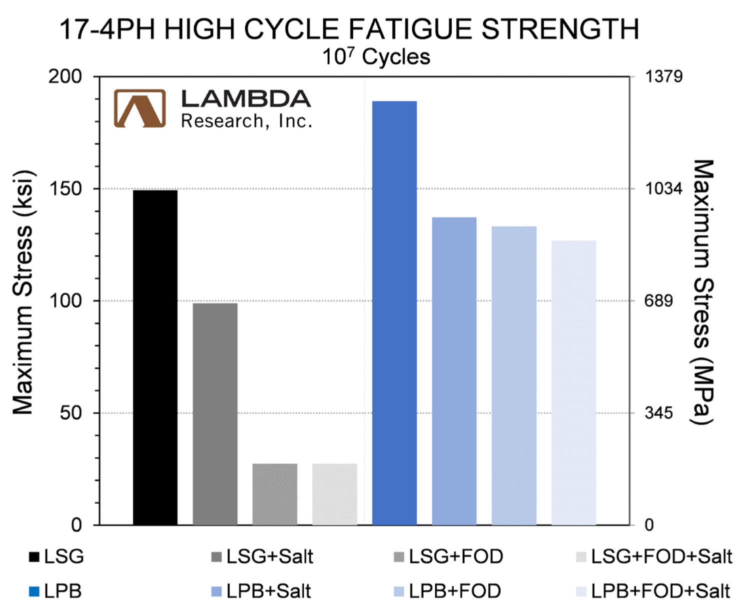


**Figure 3 Comparison of fatigue performance of 17-4 PH stainless steel in air, corrosive environments, and with 0.25 mm (0.010 in.) simulated foreign object damage illustrating restoration of fatigue strength through engineered compressive residual stress.**