



U.S. Army Research, Development and Engineering Command



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Low Plasticity Burnishing for Fatigue Life Extension of the M4A1 Carbine Bolt

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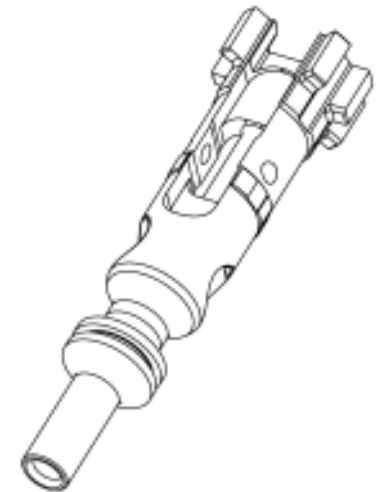
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The Problem



- The M4/M16 Bolt is a critical component of the operating group and has significant impact on the functional performance of the weapon system.
- The bolt is continually one of the top replacement part cost drivers for TACOM, with an average monthly demand of ~1800.
- The historical part life for the bolt in an M4 carbine averages approximately ~12,000 rounds
- The primary failure is cracked lugs resulting from high cyclic loading.
- Limited fatigue life of the bolt results in decreased mission readiness, safety, and weapon system reliability



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- Approach
 - Investigate potential alternatives to increase bolt fatigue life
 - Develop lab scale evaluation methods to characterize fatigue life improvements
 - Conduct Live Fire testing of modified bolts to determine increased life expectancy



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- Objectives

- Increased the fatigue life of the M4/M16 bolt, within the area of the bolt lugs, to extend life expectancy
- Reduced life cycle costs
- Increased warfighters mission readiness, safety, and reliability



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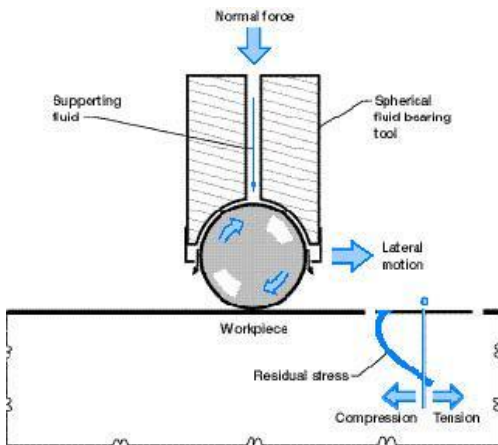
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Low Plasticity Burnishing



- Low Plasticity Burnishing (LPB[®]) is a surface enhancement process developed by Lambda Technologies, Cincinnati, OH. The process imparts deep, stable compressive residual stresses into critical engineering components in order to increase performance.
- LPB produces residual stresses that are ~5-10x deeper than with shot peening.
- LPB is CNC controlled for repeatability.
- LPB can be developed into portable applications (reduced logistics burden).



Source: <http://www.lambdatechs.com/surface-enhancement/LowPlasticityBurnishing.html>

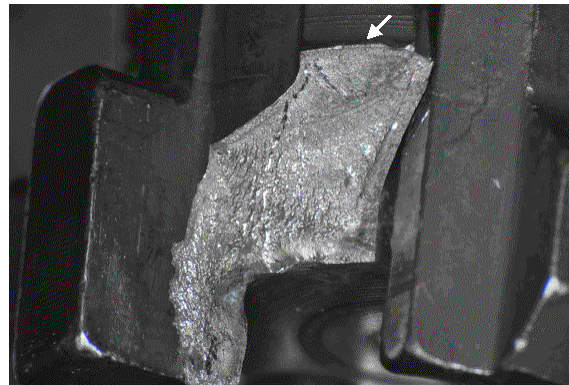


Figure 1: M4 Bolt failure

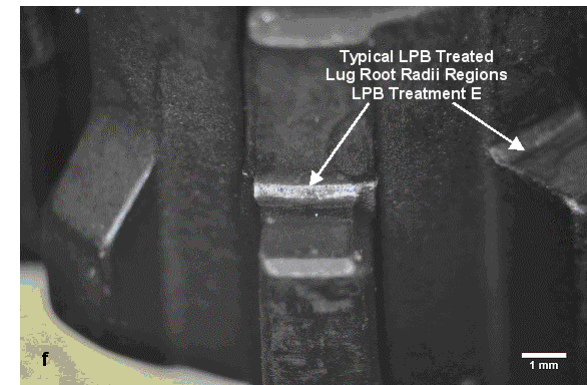


Figure 2: LPB conditioned bolt fillet



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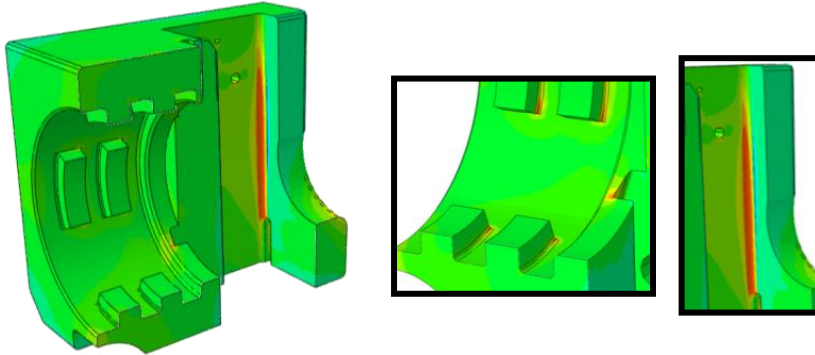


Previous Use of LPB



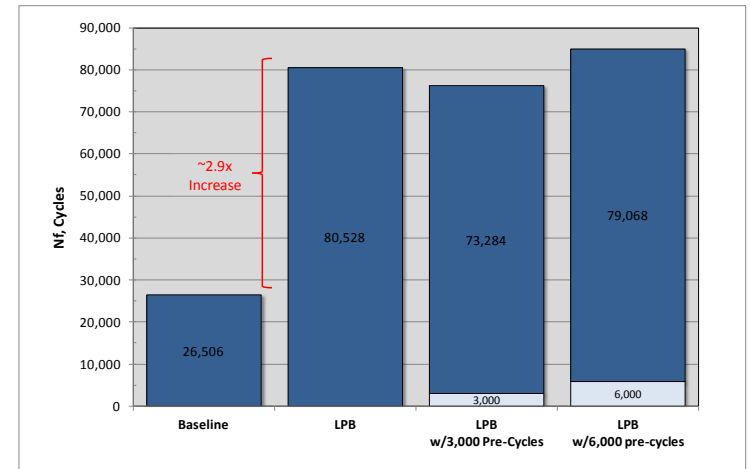
• Demonstration of LPB on the 105mm M20 Breech Ring

+ Maximum Principal Stress Field



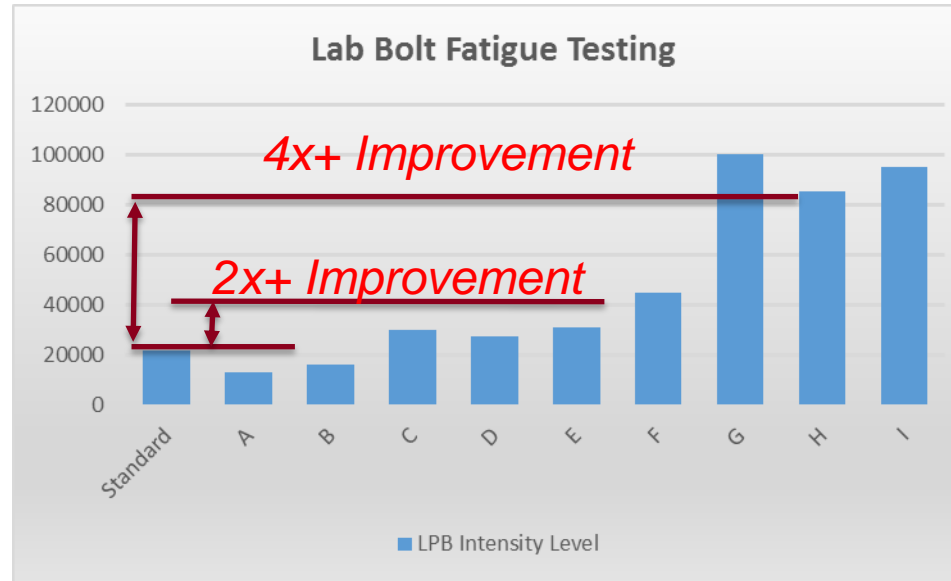
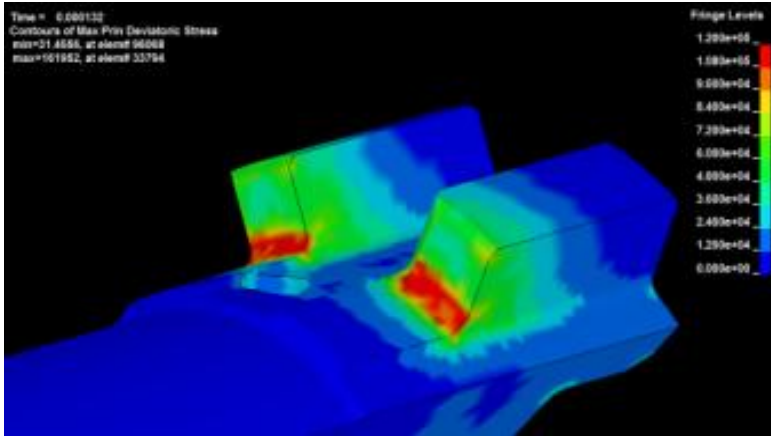
FEA demonstrates that highest principal stress is in the rear fillet (where previous components have failed during fatigue testing)

• LPB lab specimens experienced a ~2.9x increase in fatigue life.

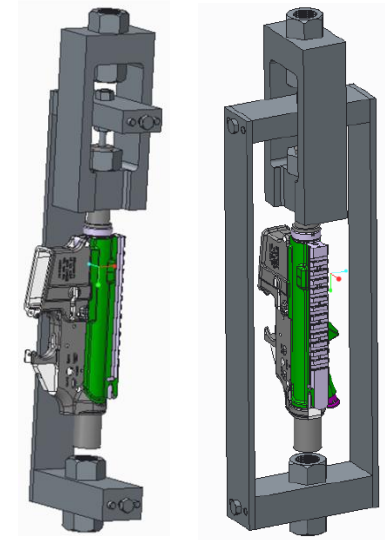
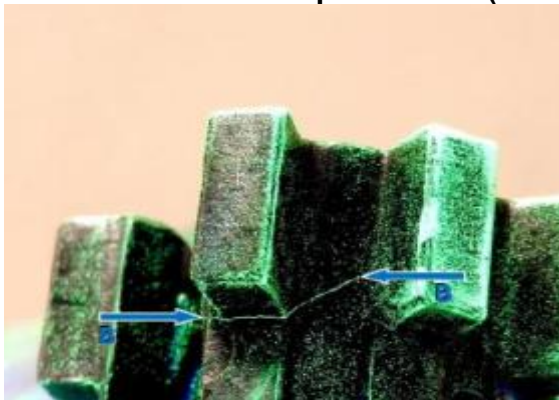


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- 3D FINITE ELEMENT ANALYSIS



- Magnetic Particle Inspection (MPI)



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- Live Fire Testing
 - Single Weapon Test (M855)
 - LPB Bolt ~ 26,000 rds fired before failure
 - Standard Bolt ~ 13,000 rds fired before failure
 - Multiple Weapon Test: Ongoing (ATC)
 - 6 LPB treated bolts
 - 6 standard bolts



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- **Future Testing:**
 - Increased LPB intensity
 - Laboratory Testing
 - Live Fire Testing
 - LPB application prior to shot peen and phosphate application
 - Laboratory Testing
 - Live Fire Testing
- **Future Research:**
 - Cavitation peening





- Low Plasticity Burnishing has the potential to increase the fatigue life of the M4 bolt by 2x its expected life
- Live fire testing of multiple test samples is ongoing in order to determine the average life expectancy of LPB treated bolts
- Additional research is planned for various other treatment methods to reduce residual stress within the bolt's lugs in addition to LPB
- Surface enhancement process like LPB have the potential to be applied to additional weapon system's bolts and fatigue critical parts



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QUESTIONS



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Special thanks to
Lambda Technologies
and
Greg Vigilante (RDECOM ARDEC)



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- Lambda Technologies Group is dedicated to the development and optimization of novel surface treatments to improve component performance
- Lambda Technologies Group encompasses many organizations, including
 - Surface Enhancement Technologies, LLC
 - Lambda Research, Inc
- Lambda’s low plasticity burnishing (LPB[®]) is a patented, proven surface treatment used to improve component performance, damage tolerance, fatigue life, and resistance to Stress Corrosion Cracking (SCC)
- LPB[®] can be performed during initial manufacture or during maintenance and repair operations
- LPB[®] is a practical, cost-effective, machine shop compatible and a logistically convenient process that provides reliable performance improvement without altering either the material or design.
- LPB[®] has been applied to a broad range of materials and industries, including:
 - high-strength steels
 - stainless steels
 - titanium alloys
 - nickel-based alloys
 - aluminum alloys
 - magnesium alloys
 - aerospace structures
 - aero engines
 - oil and gas
 - power generation
 - medical implants
 - military hardware



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BACKUP SLIDES



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- The current M4/M16 bolts life is limited due to the high cyclic fatigue exerted on the bolt lugs
- Processes exist to reduce the residual stress within the bolt lugs increasing the bolts fatigue life
- Low Plasticity Burnishing has been shown to increase the bolts fatigue life in a laboratory setting and is currently being assessed through firing of ammunition
- Additional methods of reducing residual stress in the bolt is planned

