National Defense Industrial Association

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Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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

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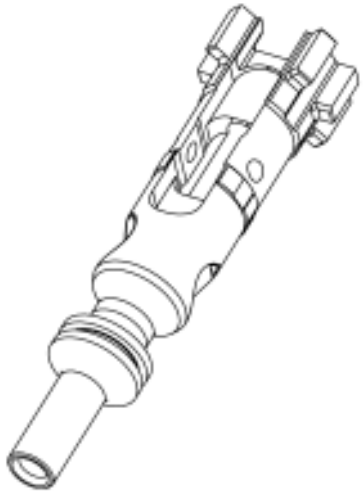
# The Problem

- 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



# The Approach

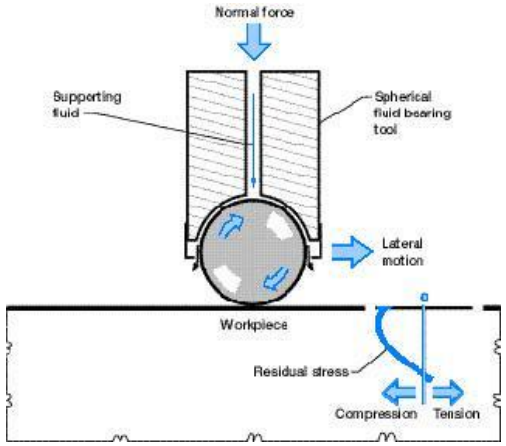
- Approach
  - Investigate potential alternatives to increase bolt fatigue life
  - Develop lab scale evaluation methods to characterize fatigue life improvements
  - Conduct Live Fire testing of modified bolts to determine increased life expectancy

# The Objective

- 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

# 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

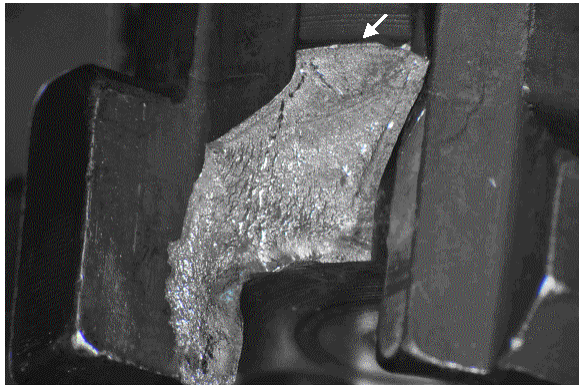


Figure 1: M4 Bolt failure

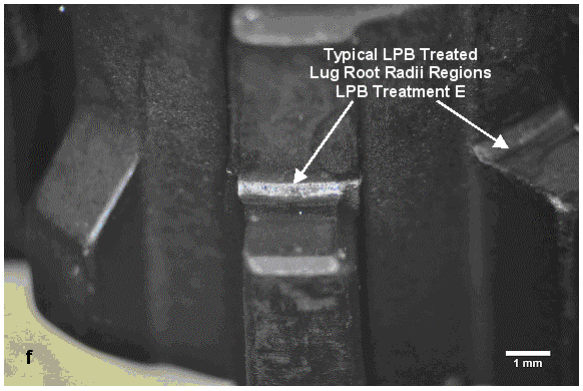



Figure 2: LPB conditioned bolt fillet

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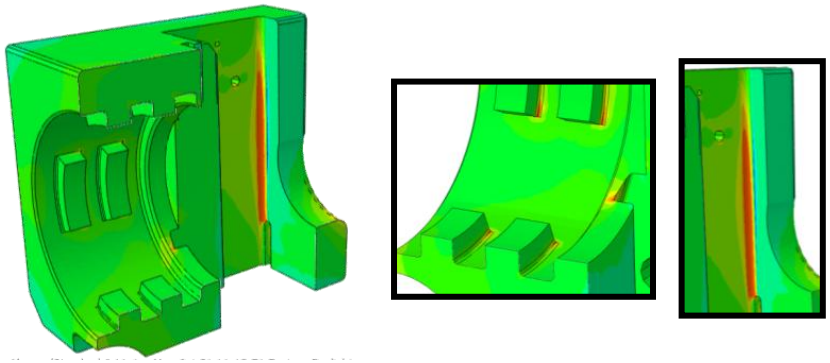
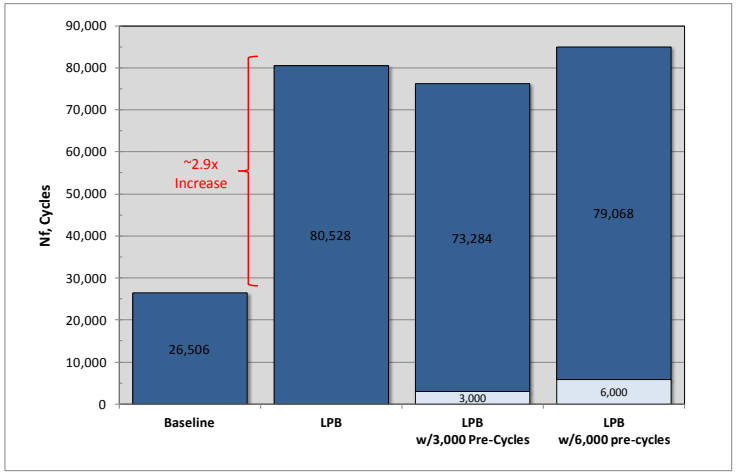
# Previous Use of LPB

- ***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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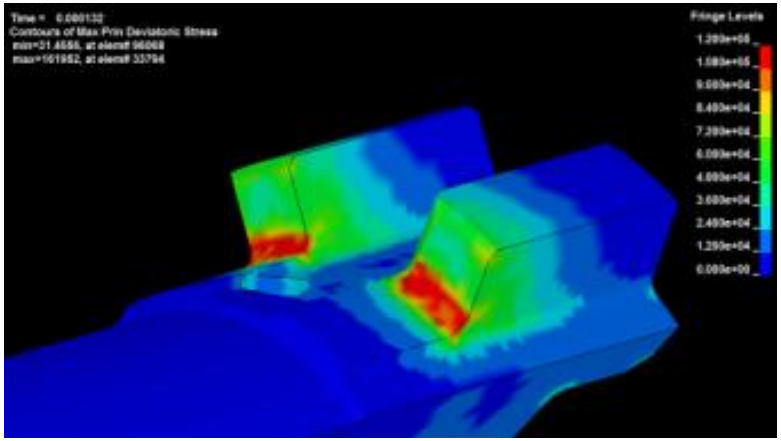
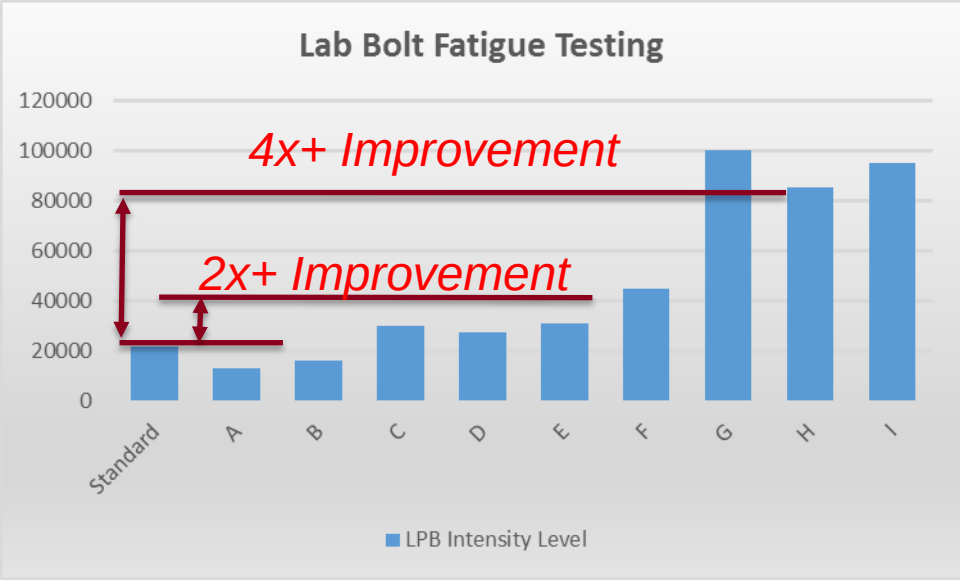
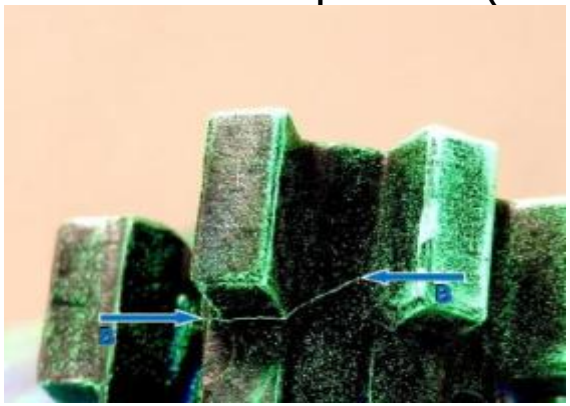
# Testing

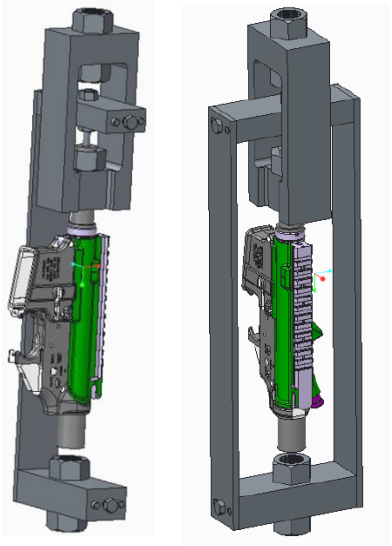
- 3D FINITE ELEMENT ANALYSIS






- Magnetic Particle Inspection (MPI)





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# Testing

- 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

# Path Forward

- **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

# Summary

- 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

# QUESTIONS

# Thank You

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

- 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**

LAMBDA Technologies Group.
*Improving Component Life and Performance*

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# BACKUP SLIDES

# BLUF

- 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 planed