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

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UNCLASSIFIED
• 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.
• 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
• 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 (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).
• 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.
• 3D FINITE ELEMENT ANALYSIS

• Magnetic Particle Inspection (MPI)
• 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
• **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
QUESTIONS
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

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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