Laser Peening for U.S. Army Helicopters

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Technology Overview
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**Laser Peening for U.S. Army Helicopters**

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**Laser Shock Peening**

*Laser Shock Peening* is an innovative process for introducing deep compressive residual stresses into the surface of metallic parts.

**Material Property Improvements Include Increased:**
- Fatigue strength and fatigue life
- Resistance to crack initiation and propagation
- Resistance to fretting fatigue and wear
- Resistance to stress corrosion cracking
Laser Peening Process

Laser peening is not a thermal treatment; it creates deep compressive residual stresses in the surface of a part with a shock wave created by high intensity laser pulses that mechanically cold-work the surface.

Before processing, an opaque overlay (typically black paint or tape) and a transparent overlay (typically flowing water) are applied to the surface to be laser peened.

The laser pulse passes through the transparent overlay and strikes the opaque overlay causing it to begin to vaporize. The vapor absorbs the remaining laser light and produces a rapidly expanding plasma plume.
Stress Wave Propagation

Material Being Treated
Direction of Stress Wave

Appearance of Stress Wave as It Propagates Into the Treated Material
Laser Shock Peening

- A pattern of laser pulses results in an area of deep compressive stress
- Results of industry and government testing shows that laser peening stops or significantly inhibits crack initiation and propagation in blades
Nd:Glass Laser System – Two Beams at up to 50 Joules Per Beam

MC Laser System (2-beam) Operates at 1.25 Hz (every 0.8 seconds)
Shot Peening

- Residual Stress depth ~0.1 mm (0.004 inches)

Laser Peening

- Residual Stress depth 1 to 1.5 mm (0.040 to 0.060 inches)
Testing Results of Fan Blades after Simulated FOD

Siren Testing Device
Heated 24 hr at 400F before testing at Room Temperature

After See, Thompson and Sampson, Air Force Research Laboratory, USAF
Laser peening increases notched fatigue strength of IBR airfoils above the fatigue strength design criteria.

Initiative established the first production-ready IBR Peening Cell.

Increased notched* fatigue strength and FOD resistance on laser peened F119 IBRs

* EDM Notch 0.050-inches deep
Fatigue Properties

7050-T351 Aluminum

4 GW/cm²

3-point bending, R=0.1, Notched: $K_t=1.68$

After P. Peyre, et.al.
Fretting Fatigue Results

- Fretting, $R=0.5$, laser peened, large spots
- Fretting, $R=0.5$, laser peened, small spots
- Fretting, $R=0.5$, not laser peened
- Fretting, $R=0.5$, laser peened, low intensity, large spots
- Fretting, $R=0.0$, laser peened, large spots
- Fretting, $R=0.0$, laser peened, small spots
- Fretting, $R=0.0$, not laser peened

Stress, MPa vs. Cycles to Failure
Evolution of Laser Peening Production Applications

B1-B Lancer, F101-GE-102 Engine

F/A-22 Raptor, F119-PW-100 Engine

F-16 Falcon, F110-GE-100,129 Engines
Laser Peening of Army Aviation Applications

Tougher Drive Systems for Higher HP Helicopter Versions Needed for High Altitude Missions such as Afghanistan

Apache

Chinook

Blackhawk
Army Helicopter Gears

- Chinook Transmissions
  - Engine - Gear tooth root
  - Forward - Planetary gears
  - Aft - Spiral bevel gear

- Apache
  - Main rotor transmission shaft – Upper and lower splines
ARL/Penn State & Gear Research Institute – Gear testing program underway to evaluate laser peening effects on gear bending fatigue.

Boeing Helicopters - Investigating effects of laser peening for CH-47 horizontal hinge pins

Rolls-Royce – Investigating laser peening to prevent fatigue failures originating at corrosion pits.
Demonstration

LaserPeen® Processing of F110-100 Turbine Engine Blade
Using the RapidCoater™ System

LSPT’s automated RapidCoater™ system reduces the processing time from ~33 minutes (with tape) to less than 6 minutes!

F-16 Falcon

F110 Engine
Laser Peening of Hidden Surfaces
New Growth Area

Issue with Current Systems

• Dovetail slots have limited line-of-sight access (hidden surfaces) due to high aspect ratio (slot length to width)

Approach

• Reduce laser beam size
• Use the similar power densities to generate deep compressive stresses
• Deliver laser beam through articulated arm to processing pen

Benefits

• Reduced laser system costs
• Smaller laser system footprint
• Provides improved fretting fatigue resistance

Demonstrated laser peening on F110-GE-400 2nd stage fan disk with prototype system
Program Goal: Develop a pre-production laser peening system based on a commercially-available, high-repetition-rate laser system using LSPT’s small spot processing approach and articulated arm beam delivery.

Additional Benefit: Small-scale system components can be integrated into a portable unit for deployment at AF repair depots in a follow-on engineering effort once high-repetition-rate laser peening is validated.
Laser Bond Inspection

*Boeing 787*

*Boeing UCAV X-45*

Acceptable Bond Integrity

Inspecting to Ensure Bond Strength
Burst Laser System for Standoff Mine Neutralization

10-kW continuous laser works, but is slow and not mobile

10-kW pulsed burst laser is much more efficient and will be mobile