

Laser Peening for U.S. Army Helicopters

Contract No. W911NF-06-2-0034

Technology Overview
Army Research Laboratory
Aberdeen Proving Ground, MD



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Report Documentation Page

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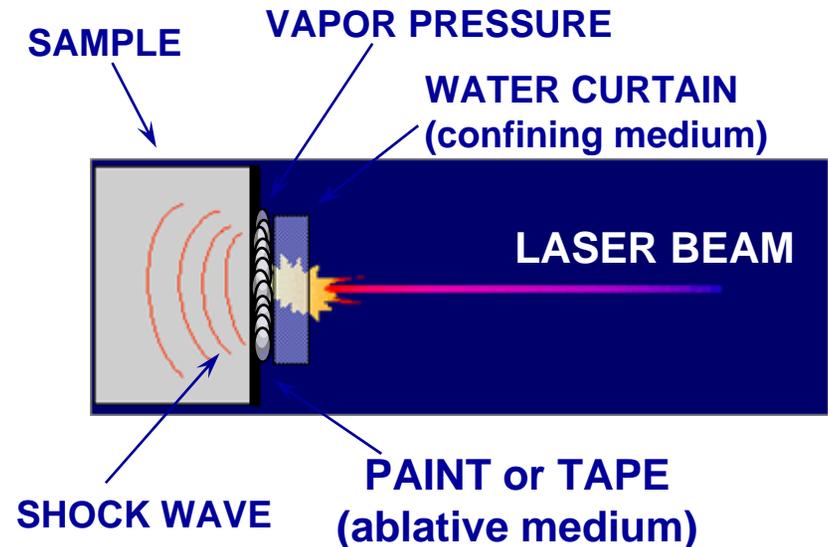
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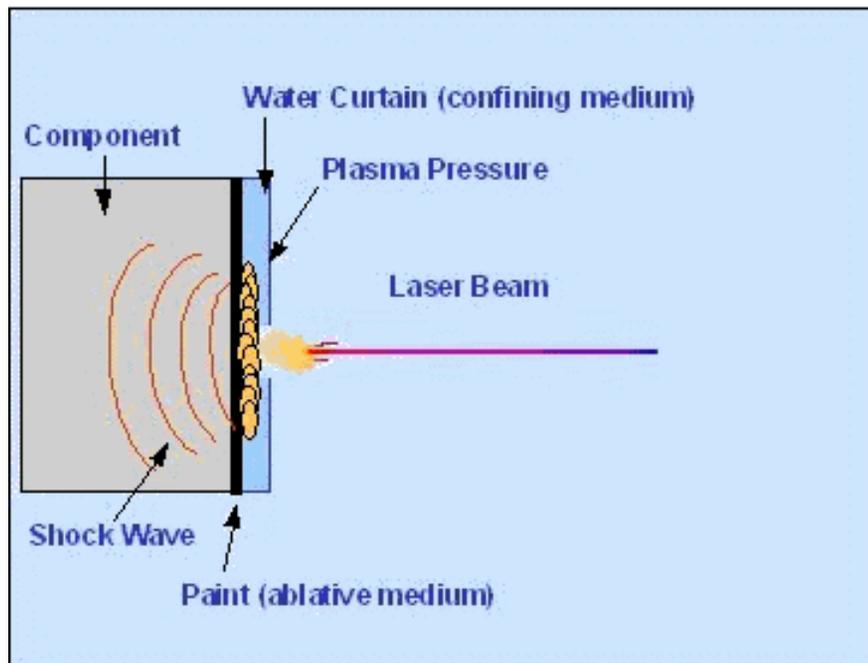
Laser Shock Peening is an innovative process for introducing deep compressive residual stresses into the surface of metallic parts

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

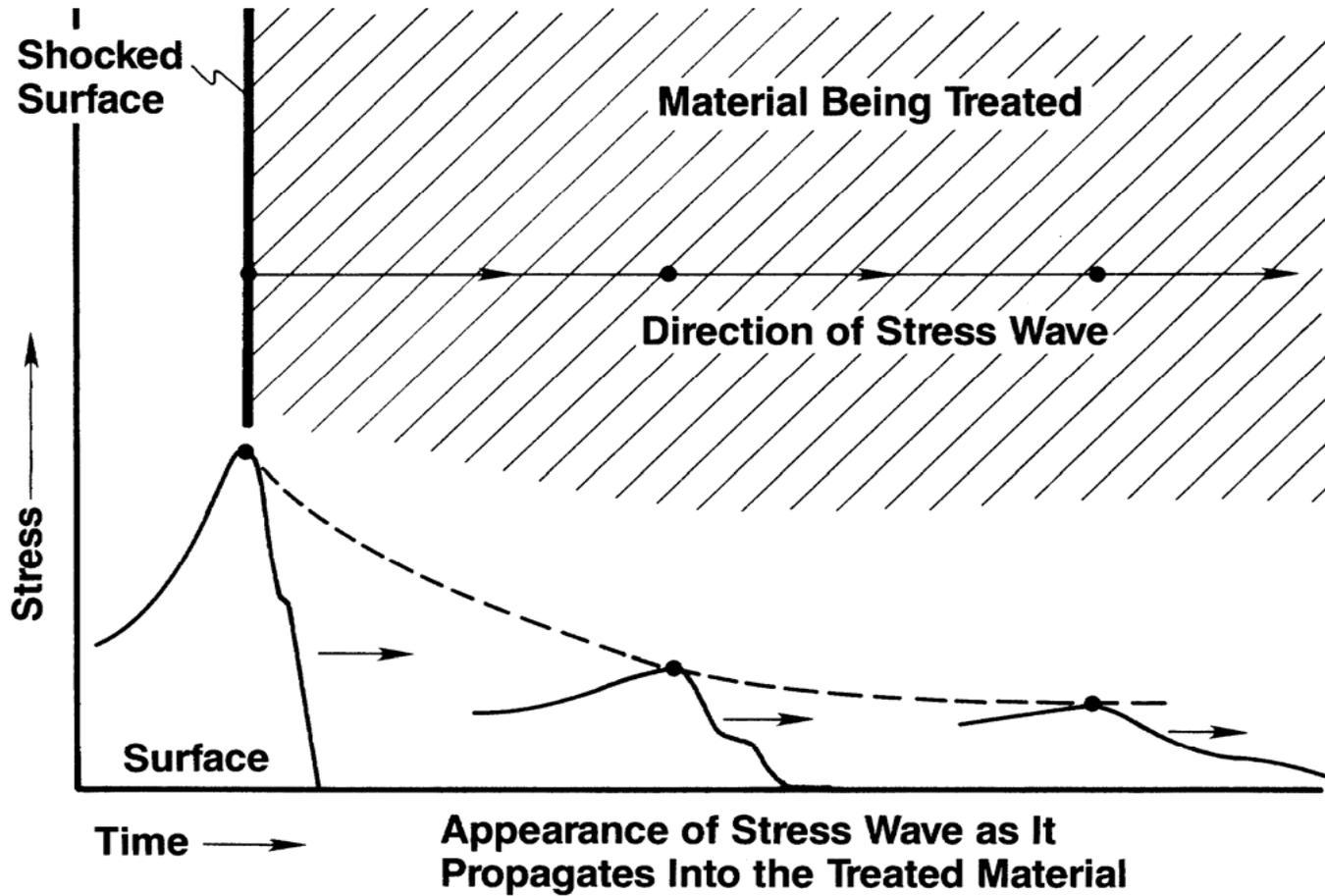


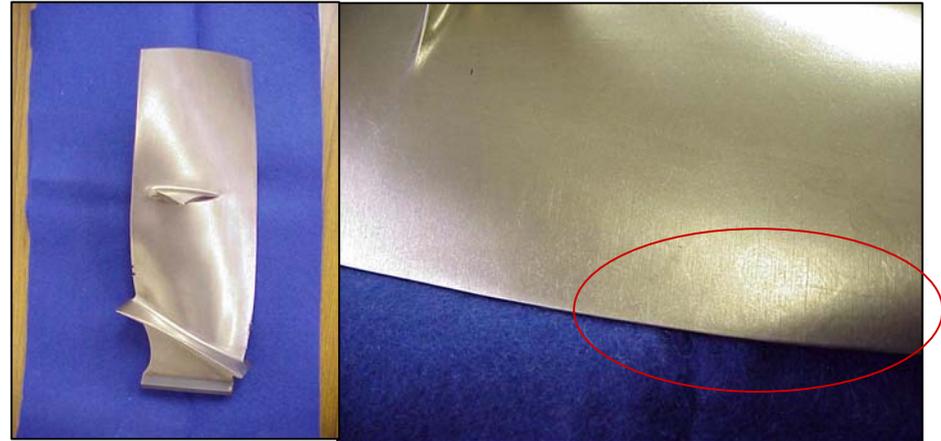
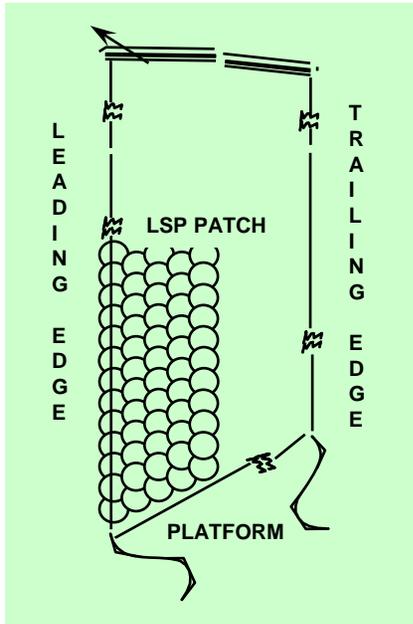
Laser peening is not a thermal treatment; it creates deep compressive residual stresses in the surface of a part with a shock wave created by high intensity laser pulses that mechanically cold-work the surface.



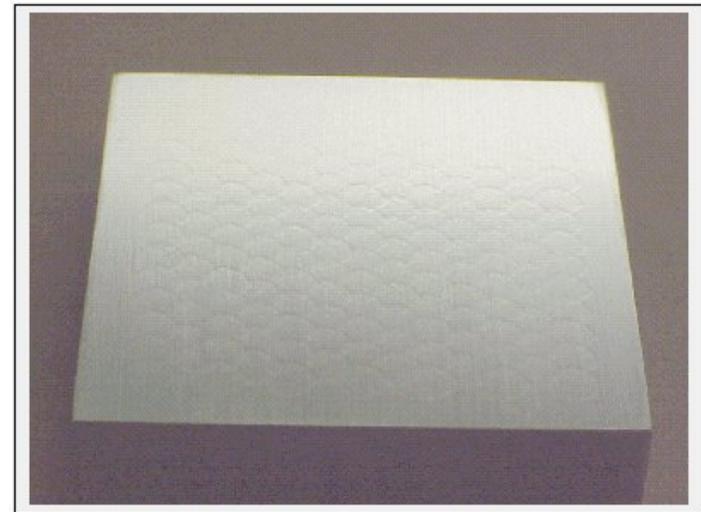
Before processing, an opaque overlay (typically black paint or tape) and a transparent overlay (typically flowing water) are applied to the surface to be laser peened.

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.





- 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





DoD ManTech Manufacturing Cell Laser System



Nd:Glass Laser System – Two Beams at up to 50 Joules Per Beam



*Small Parts Peening Cell
(Turbine Airfoils)*



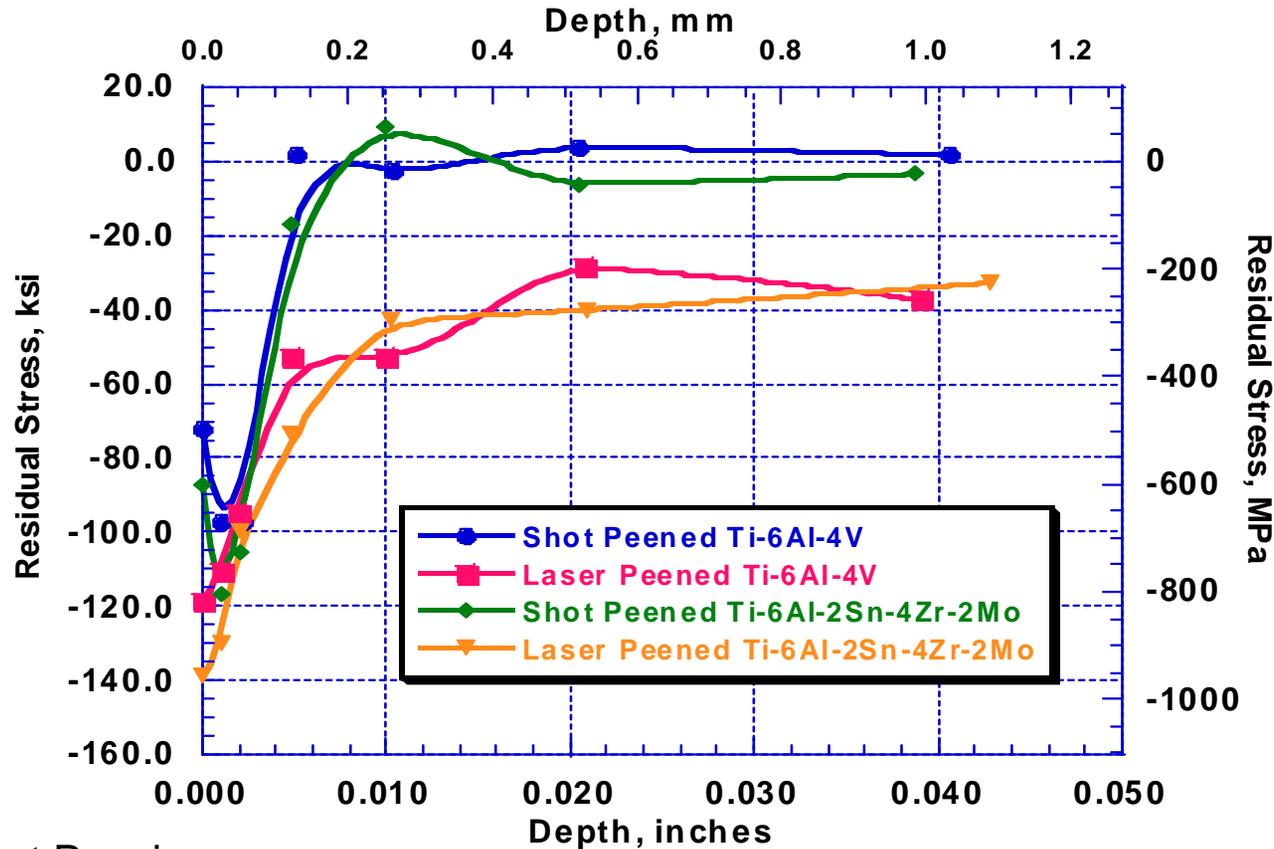
*Large Parts Peening Cell
(Integrally Bladed Rotors)*

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



Residual Stresses

Laser Peening versus Shot Peening



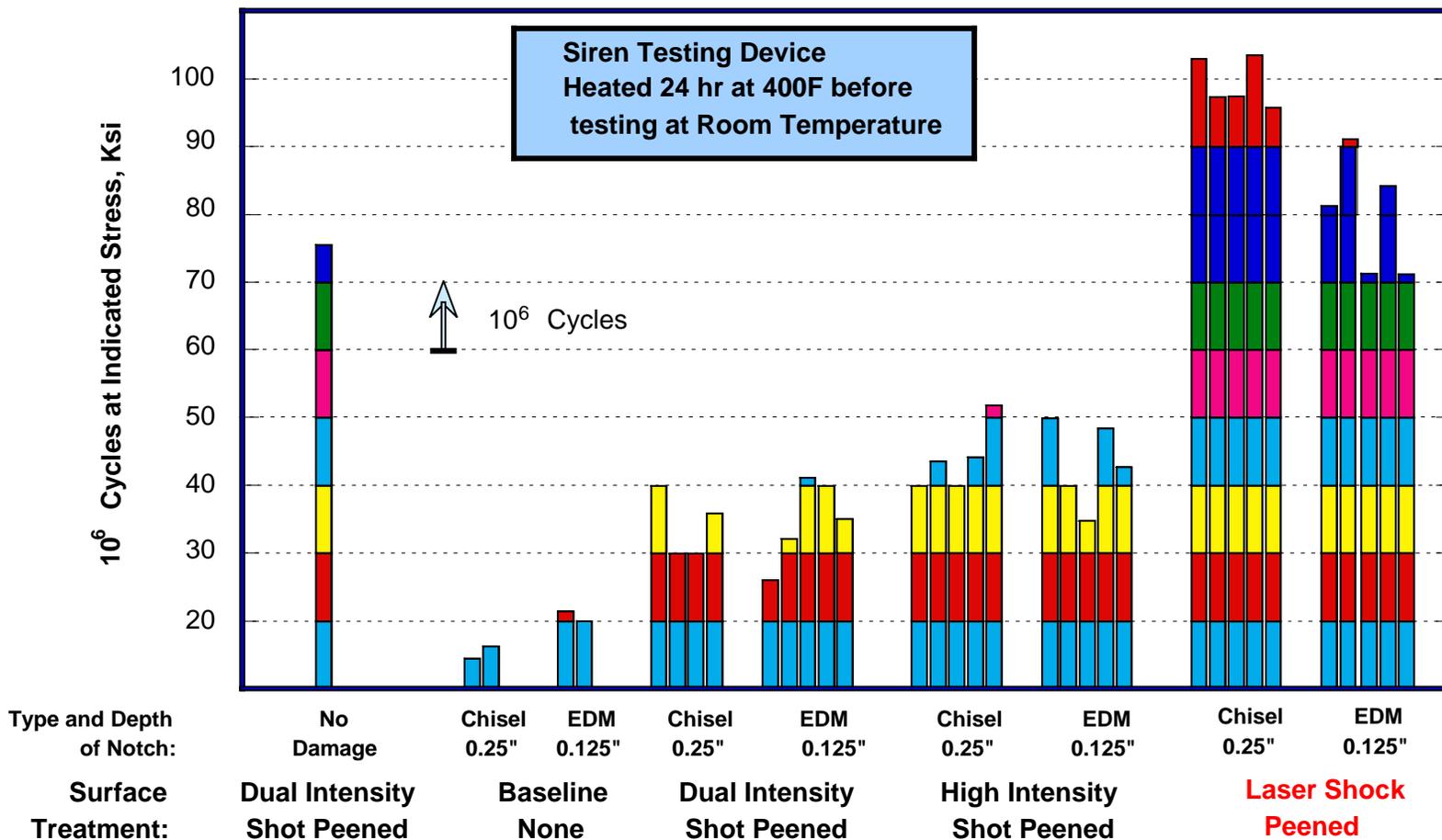
Shot Peening

—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



After See, Thompson and Sampson, Air Force Research Laboratory, USAF



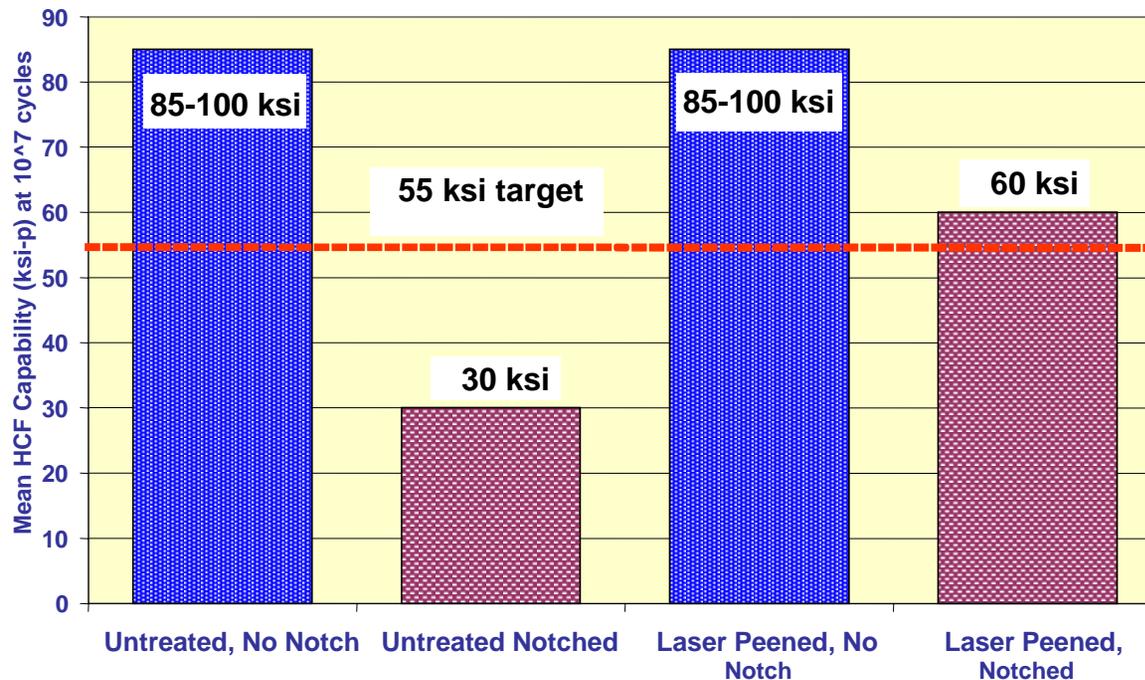
F119 IBRs

Improved Fatigue Strength and Damage Tolerance



- Laser peening increases notched fatigue strength of IBR airfoils above the fatigue strength design criteria
- Initiative established the first production-ready IBR Peening Cell

Effect of Laser Peening on F119 IBR Fatigue Life

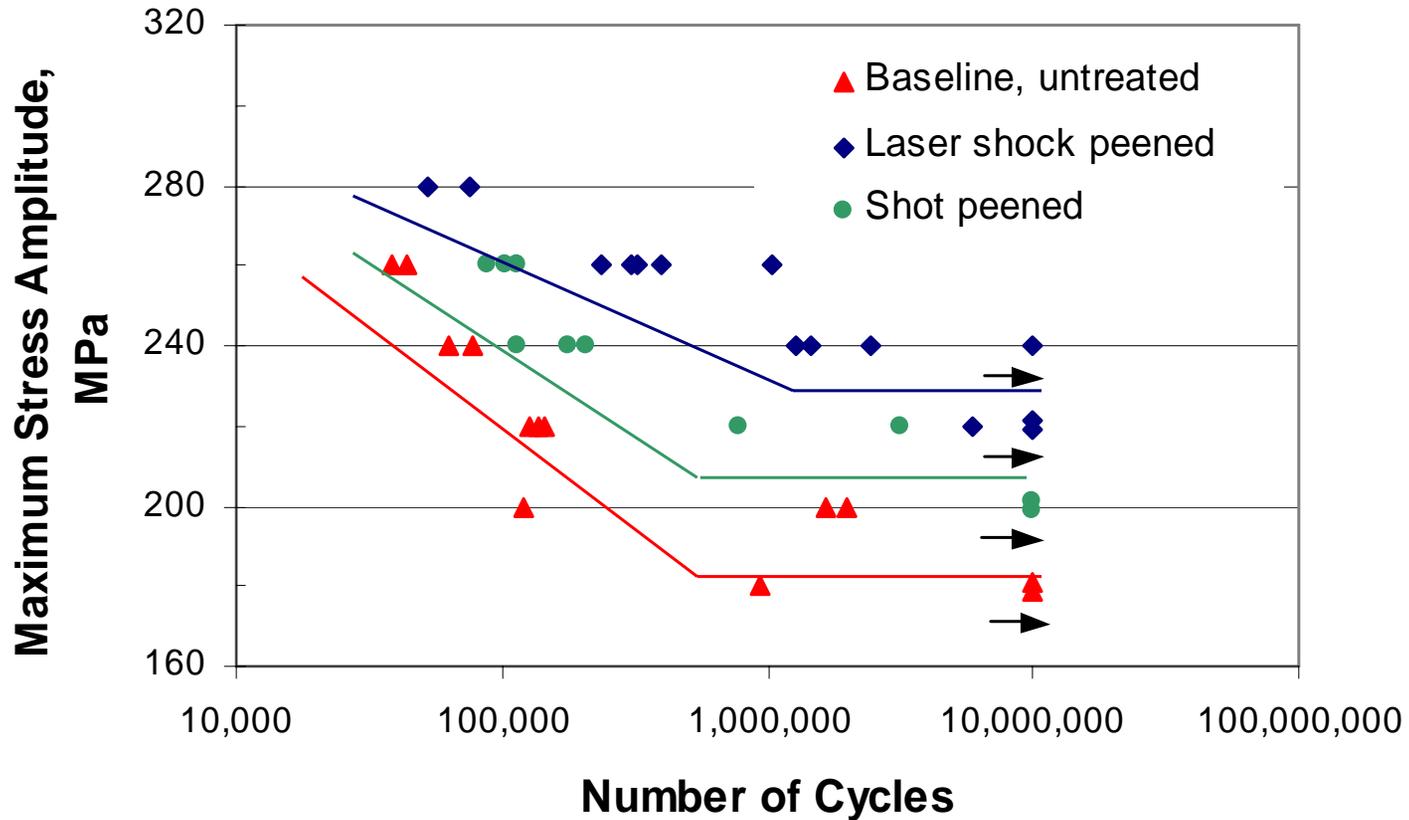


Increased notched* fatigue strength and FOD resistance on laser peened F119 IBRs

* EDM Notch 0.050-inches deep



Fatigue Properties



7050-T351 Aluminum

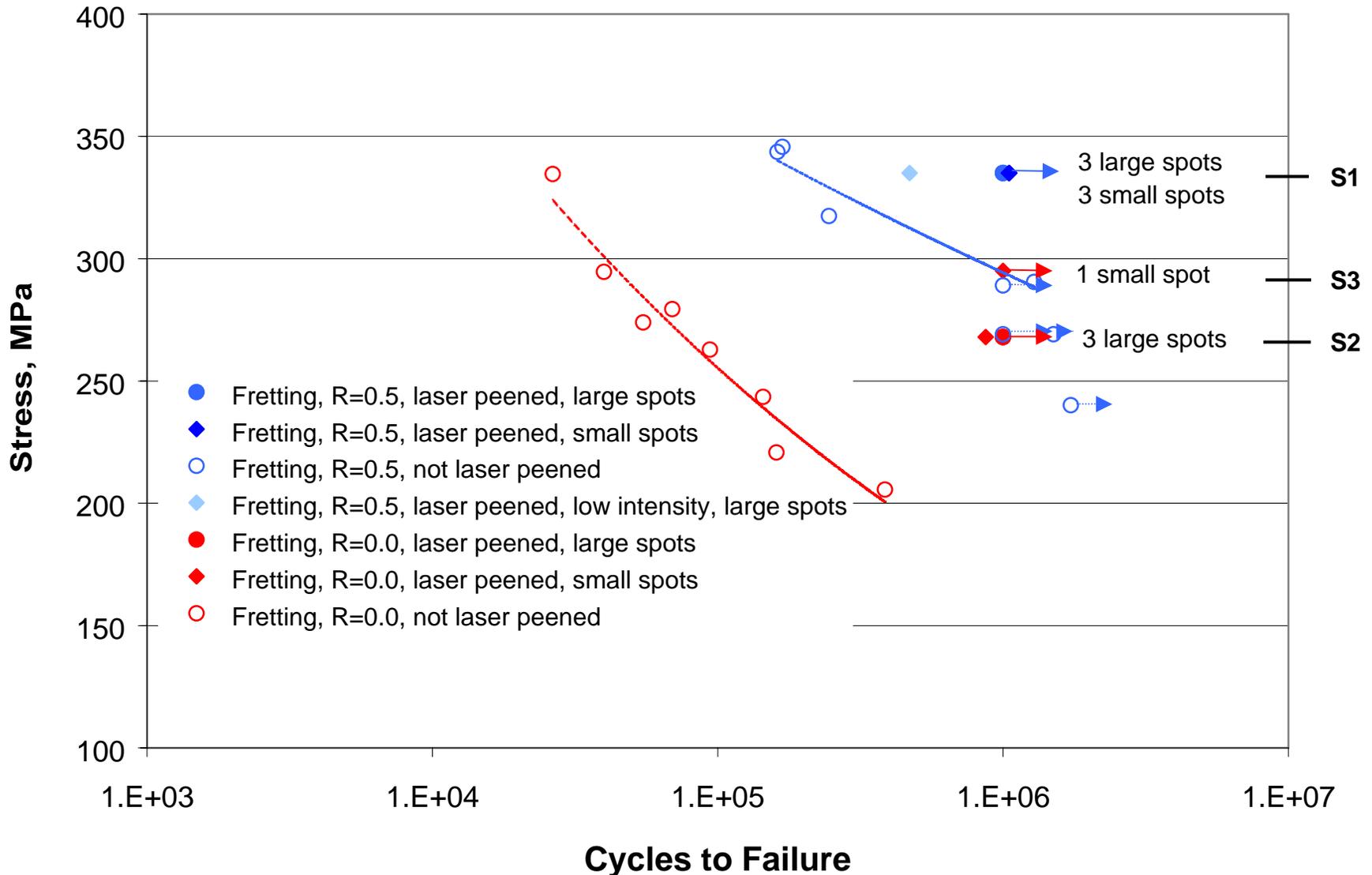
4 GW/cm²

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

After P. Peyre, et.al.



Fretting Fatigue Results



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



Apache



Chinook



Blackhawk

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



- **Chinook Transmissions**
 - Engine - Gear tooth root
 - Forward - Planetary gears
 - Aft - Spiral bevel gear
- **Apache**
 - Main rotor transmission shaft – Upper and lower splines

Application Development Projects



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



Bell 430 helicopter



2nd-3rd Stage IBR

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

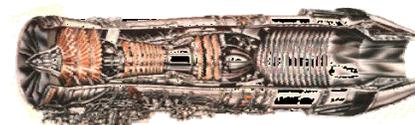
LaserPeen® Processing of F110-100 Turbine Engine Blade Using the RapidCoater™ System



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

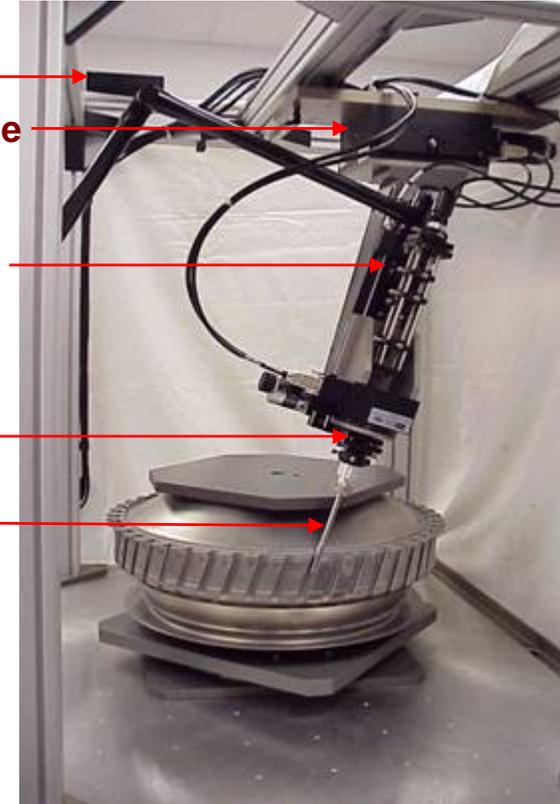
Articulated Arm

XY Translation Stage

Z Translation Stage

Rotary Stage

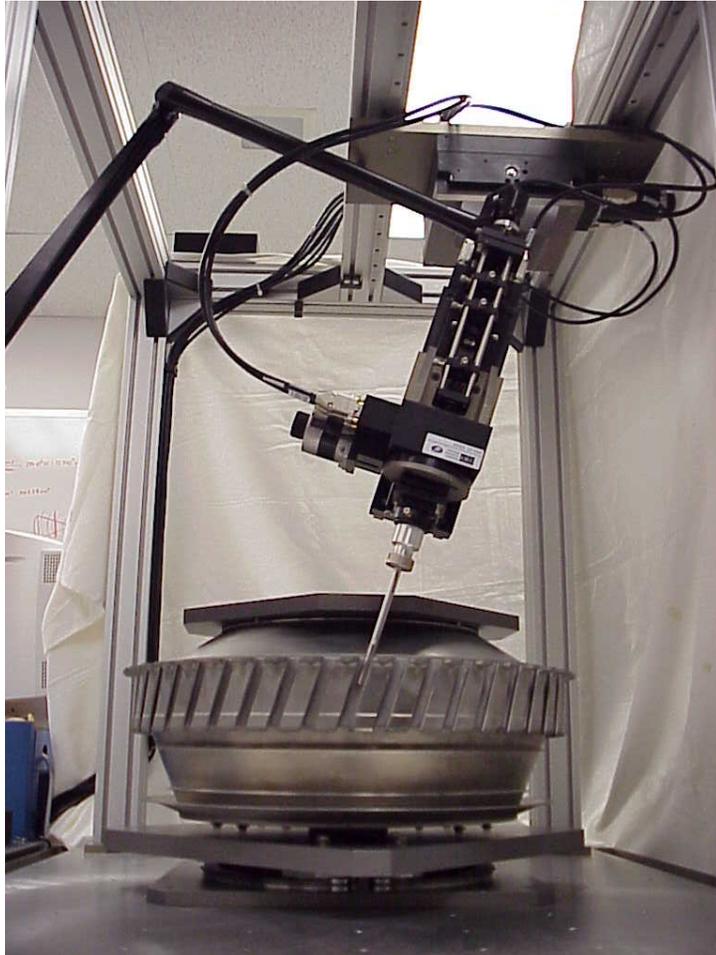
Processing Pen



Demonstrated laser peening on F110-GE-400 2nd stage fan disk with prototype system



Laser Peening of Dovetail Slots





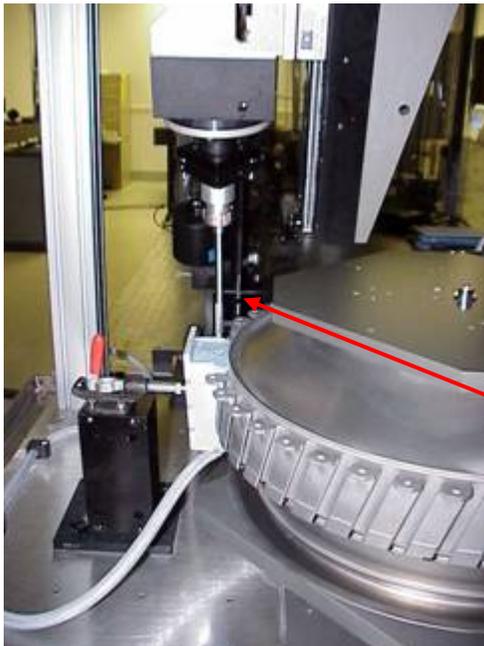
Laser Peening of Hidden Surfaces AF SBIR II Enhancement Program



Contract No. FA8650-05-C-5303

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.

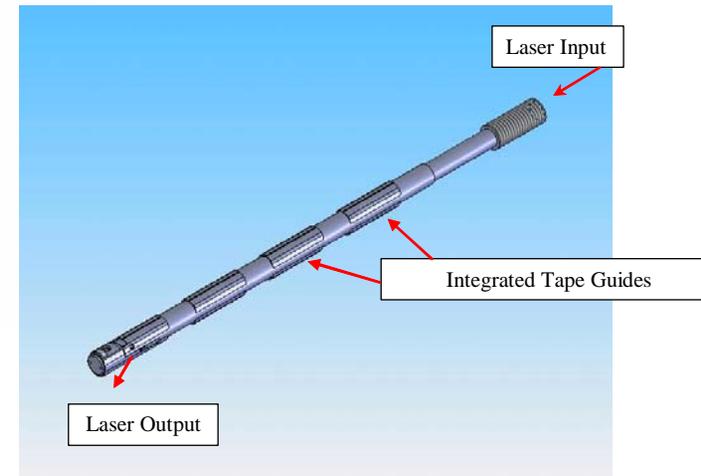
Additional Benefit: Small-scale system components can be integrated into a portable unit for deployment at AF repair depots in a follow-on engineering effort once high-repetition-rate laser peening is validated.



Processing pen



Continuum 9050 small-spot,
high-repetition-rate laser
system



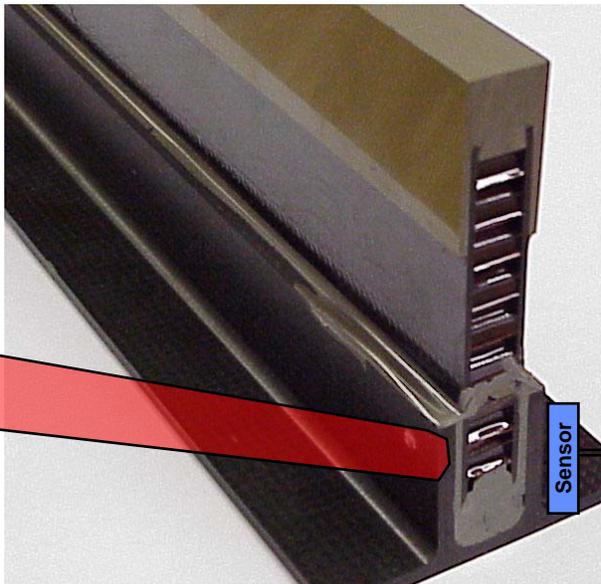
Processing pen schematic for
laser peening recessed areas



Boeing 787



Boeing UCAV X-45



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

