Effect of Laser Peening on Fatigue Life in an Arrestment Hook Shank Application for Naval Aircraft

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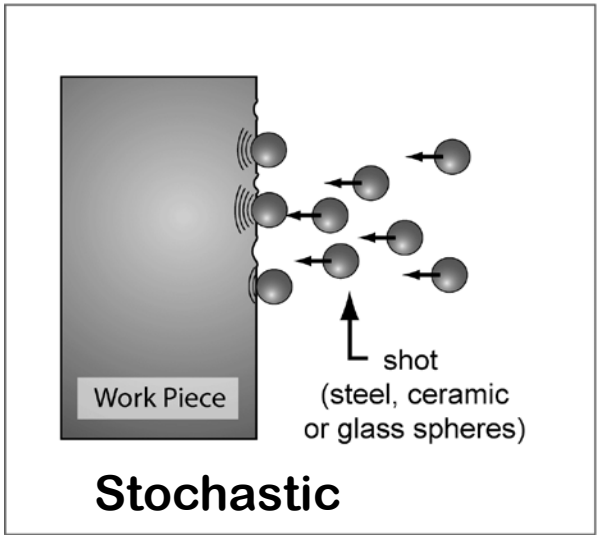
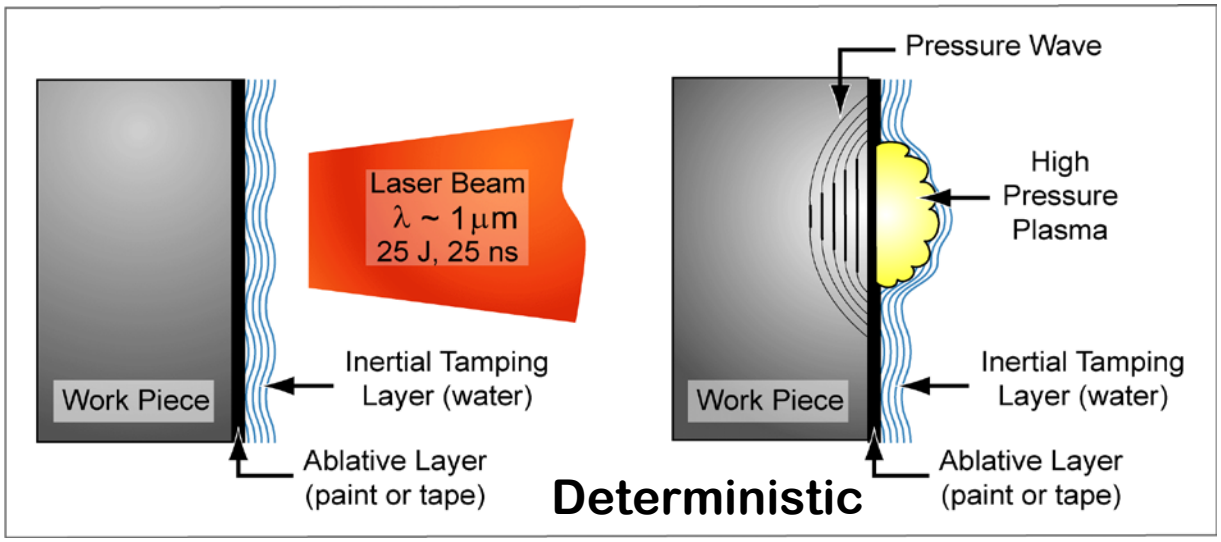
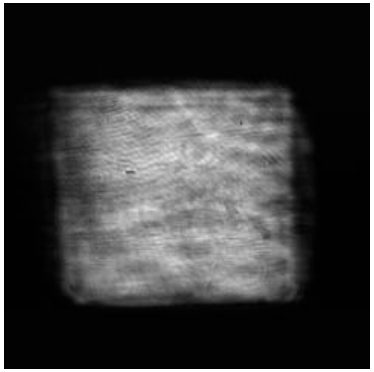
Laser Peening, a deterministic, highly controlled process

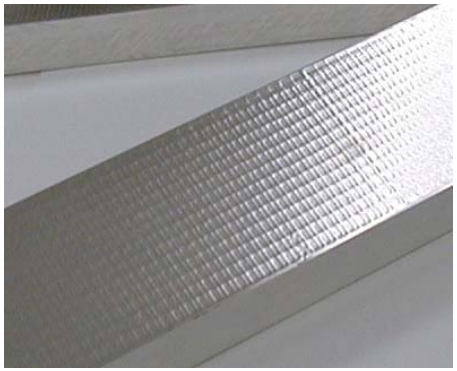




- Extension of conventional shot peening
- Laser peening provides
  - Highly compressive surface residual stress
  - Deep layer of compressive residual stress
  - Smooth surface
  - Deterministic, precise process control



Laser near field image



Laser peened aluminum

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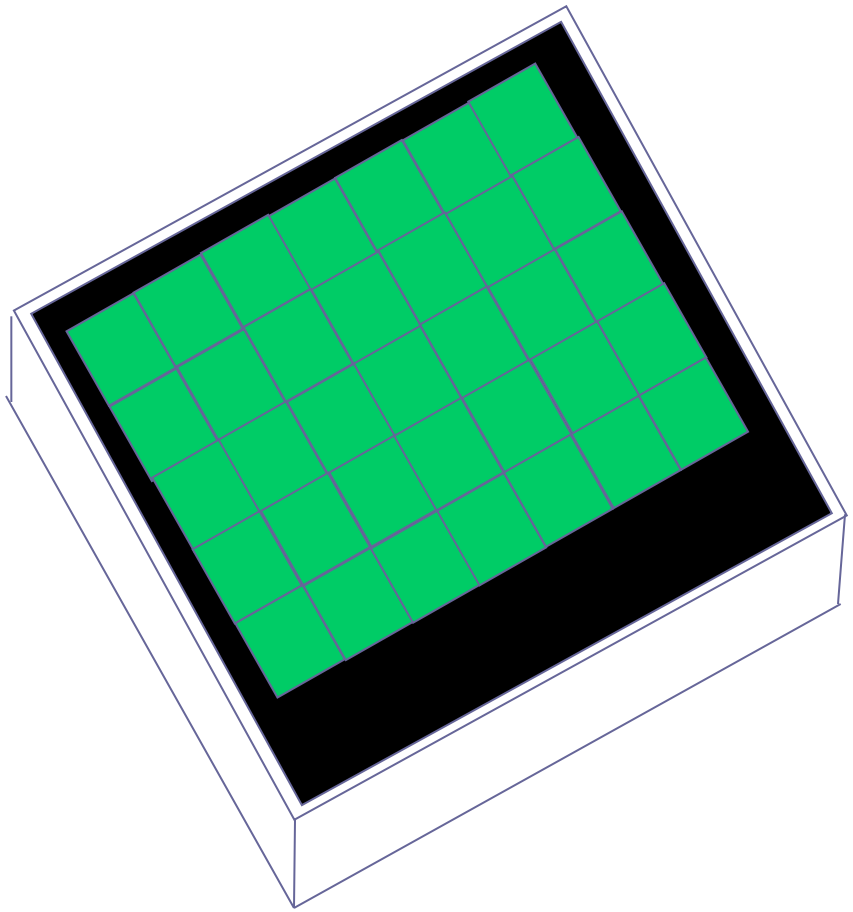
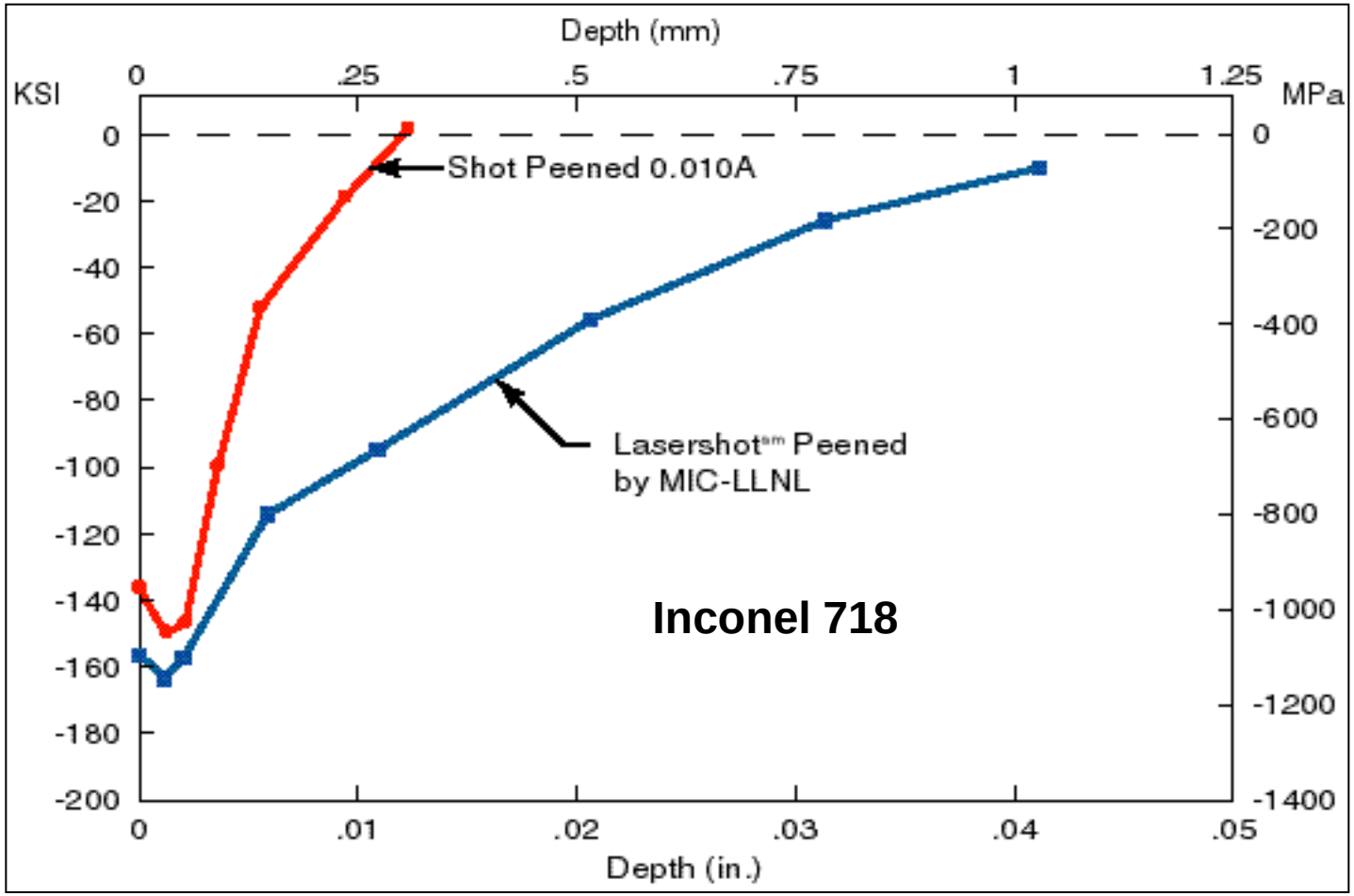
Laser Peening coverage is made highly uniform by rectangular pulse footprint

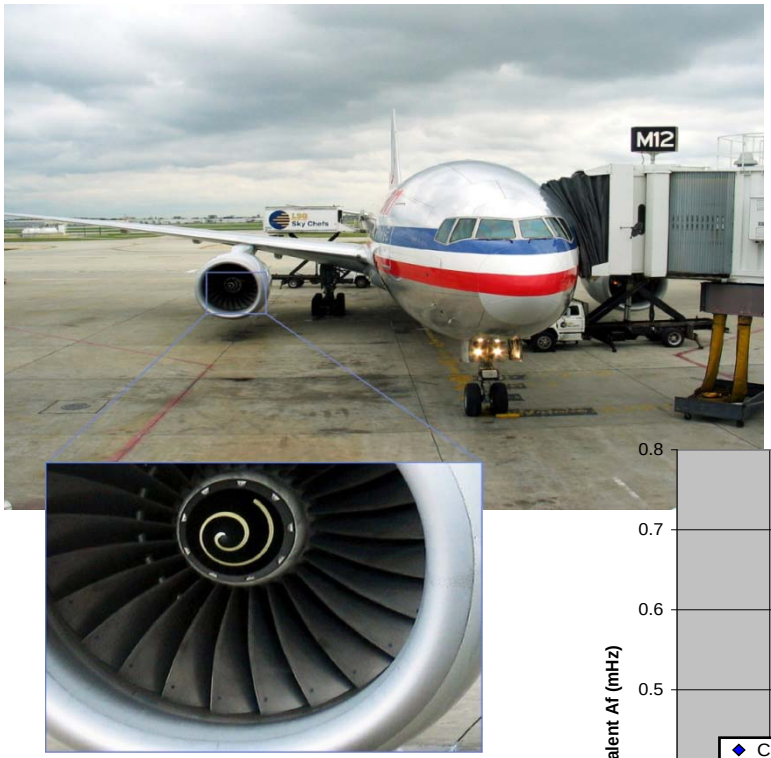


Rectangular, highly uniform laser beam intensity distribution is coupled to the part using an optical delivery system that preserves the uniform intensity. Peening pulses are applied sequentially in complete rows without the need for re-coating the surface ablation layer

Deeper residual stress provided by laser peening is especially important in high stress load applications

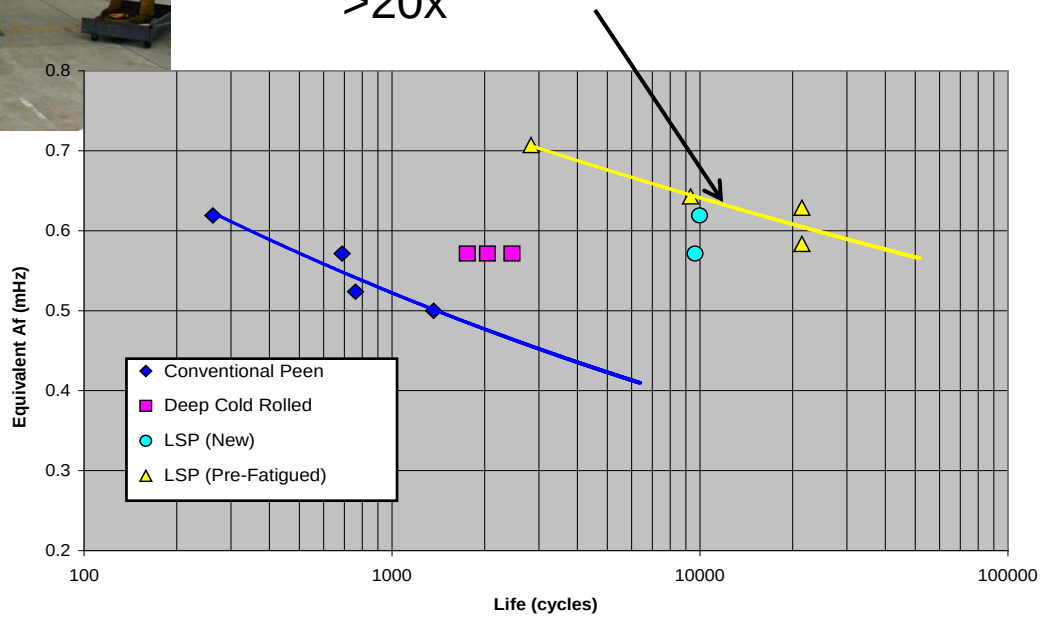


Since 2002, MIC has processed over 35,000 wide-chord fan blades for commercial aircraft



Boeing 777 with MIC laser peened blades

Laser peening extends lifetime of new and used blades by >20x



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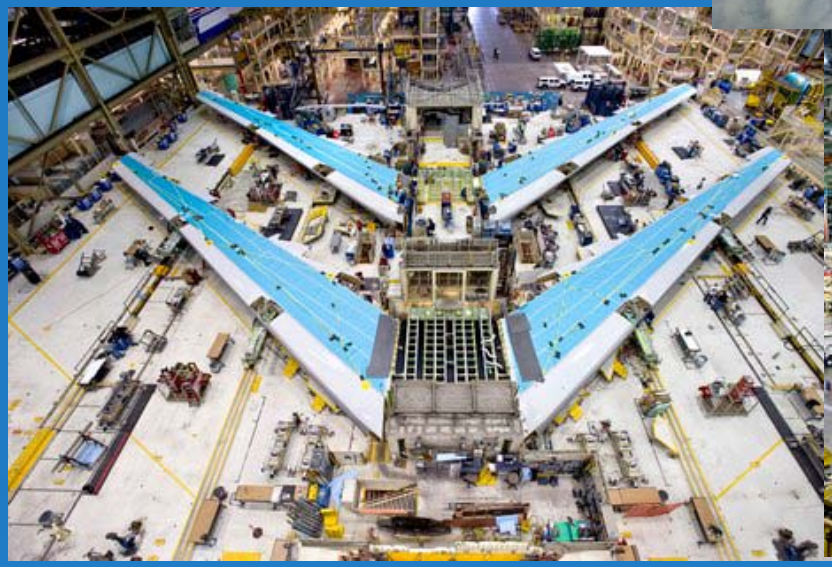
MIC laser peening is forming thick sections of the wing panels for the 747-8 Intercontinental & Freighter

Wing skin panels have been in laser peen forming production since 2008

First aircraft to fly with laser formed panels - flight occurred Feb 15, 2010



Laser Shot Peening Specification AMS 2546 - Released

SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE **AMS 2546**

Issued AUG 2004

Laser Peening

1. SCOPE

1.1 Purpose:

This specification covers the requirements for computer controlled laser peening of metal part surfaces to induce residual compressive stresses at and beneath the surface.

1.2 Application:

Laser peening is utilized to induce compressive residual stresses at and beneath the surface of metal parts to depths of 0.040" to 0.080" (1 to 2 mm) depending on the metal properties and the laser peening processing parameters. These residual stresses can provide improved fatigue life and stress corrosion resistance, although usage is not limited to such applications.

MIC Laser Peening is FAA and EASA approved

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Air Agency Certificate

Number MPKR633X

This certificate is issued to
METAL IMPROVEMENT COMPANY, INC d/b/a
METAL IMPROVEMENT COMPANY - LIVERMORE DIVISION
whose business address is
7655 LONGARD ROAD
LIVERMORE, CA 94551
upon finding that its organization complies in all respects with the requirements of the Federal Aviation Regulations relating to the establishment of an Air Agency, and is empowered to operate an approved REPAIR STATION
with the following ratings:
LIMITED - SPECIALIZED SERVICES

This certificate, unless canceled, suspended, or revoked, shall continue in effect INDEFINITELY.

Date issued: FEBRUARY 12, 2003
By direction of the Administrator
GARY L. BLOM, MANAGER

This Certificate is not Transferable, AND ANY MAJOR CHANGE IN THE BASIC FACILITIES, OR IN THE LOCATION THEREOF, SHALL BE IMMEDIATELY REPORTED TO THE APPROPRIATE REGIONAL OFFICE OF THE FEDERAL AVIATION ADMINISTRATION

Any alteration of this certificate is punishable by a fine of not exceeding $1,000, or imprisonment not exceeding 3

FAA Form 8000-4 (1-97) SUPERSEDES FAA FORM 396. AFS Electronic Forms System - JetForm FormFlow - 12/1998

JOINT AVIATION AUTHORITIES

JAR - 145 ACCEPTANCE CERTIFICATE

JAA.5573

...ant to JAR 145 paragraph 145-10(c) for the time being in force and subject to the conditions specified ...w, the Joint Aviation Authorities hereby certify FAA FAR 145 approved repair station:

METAL IMPROVEMENT COMPANY, INC d/b/a METAL IMPROVEMENT COMPANY - LIVERMORE DIVISION
FAA Repair Station Number: MPKR633X
7655 Longard Road
Livermore, CA 94551
USA

as a JAR-145 accepted organisation for maintenance of aircraft and/or aircraft components, as appropriate, under the regulatory control of the JAA member Authorities and the issue of related certificates of release/return to service using the above JAA reference number.

Conditions:

1. The scope of acceptance is limited to that specified on the FAR Part 145 repair station Air Agency Certificate, and the associated operations specifications for work carried out in the USA (unless otherwise agreed in a particular case by the JAA).
2. This acceptance requires continued compliance with FAR Part 145 and the JAA supplementary conditions, including the use of the FAA Form 8130-3 for release/return to service of components up to and including complete powerplants.
3. Certificates of release/return to service must quote the JAA acceptance certificate reference number quoted above and the FAR Part 145 Air Agency Certificate number.
4. Subject to compliance with the foregoing conditions and the payment of the required fee, this acceptance shall remain valid until:

1 November 2005

unless the acceptance has previously been surrendered, superseded, suspended or revoked.

Signed .....
J HALL
For the Joint Aviation Authorities

Date of Issue: 3 November 2003

- February, 2003 – MIC Livermore acquires approval as an FAA Repair Station, Specialized Service – Laser Peening. The first of its kind.
- November, 2003 – MIC Livermore acquires approval as a JAA approved Repair Station, also the first of its kind.

Tail hook shanks have fatigue issues at the hook attachment end

T-45 tail hooks statistically require replacement at 400 traps vs. goal of 2000

NAVAIR estimates replacement cost of $63k

T-45 hook shank (shown here)

MIC/NMC program with Navy has focused on improving the fatigue life of the T-45 tail hook shank

- T45 tail hook shank
  - shanks are currently shot peened
  - designed fatigue sample to replicate stress in full shank
  - tested with NAVAIR using realistic loading spectrum and inspection intervals

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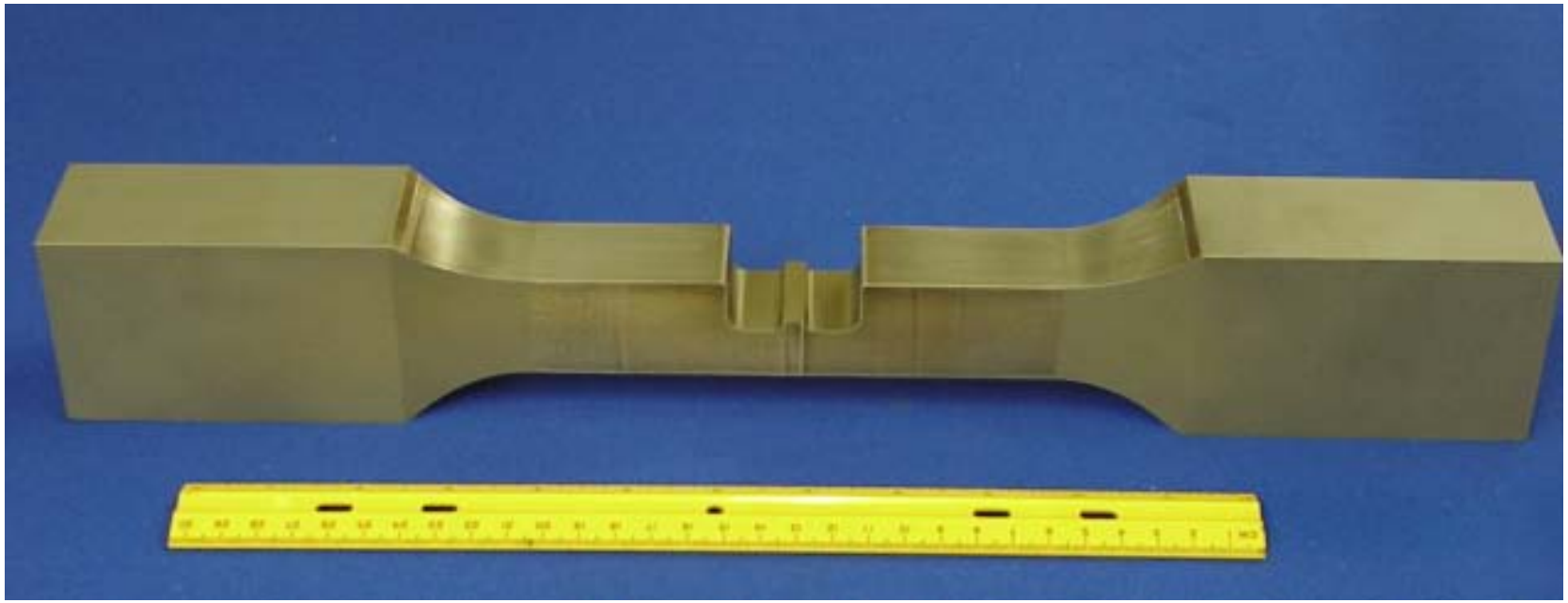
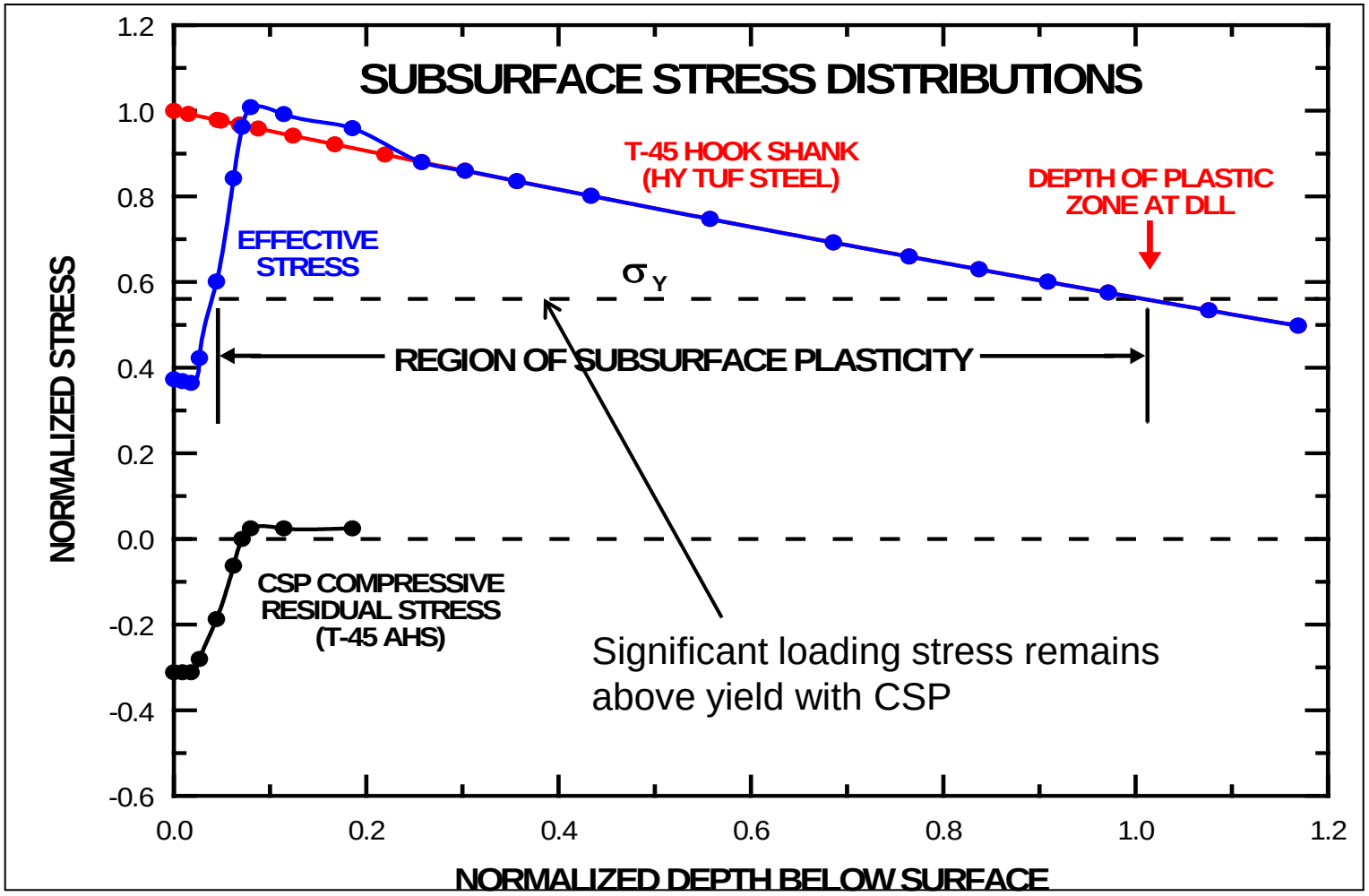
Fatigue coupon: Notched area of gauge designed to match geometry and loading of T-45 hook shank

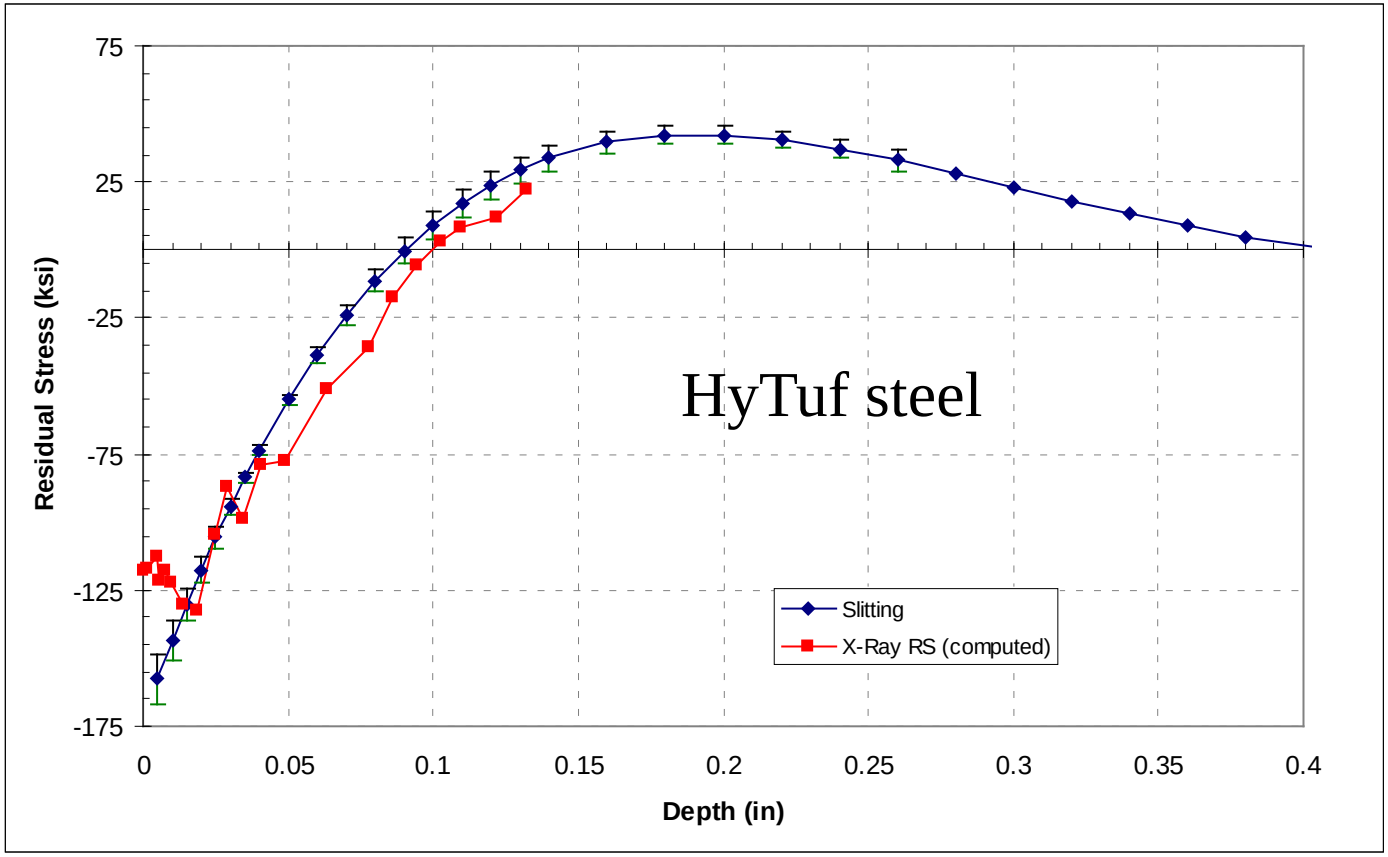


- Fatigue coupon loaded and tested in a manner consistent with carrier operations
- Coupon inspected between blocks of fatigue cycles and determined as failed if a crack is detected
- Observable crack typically 0.02 inches

T-45 arrestment hook shank RS with conventional shot peening (CSP) only counteracts loading stress to a depth of ~0.01 inches

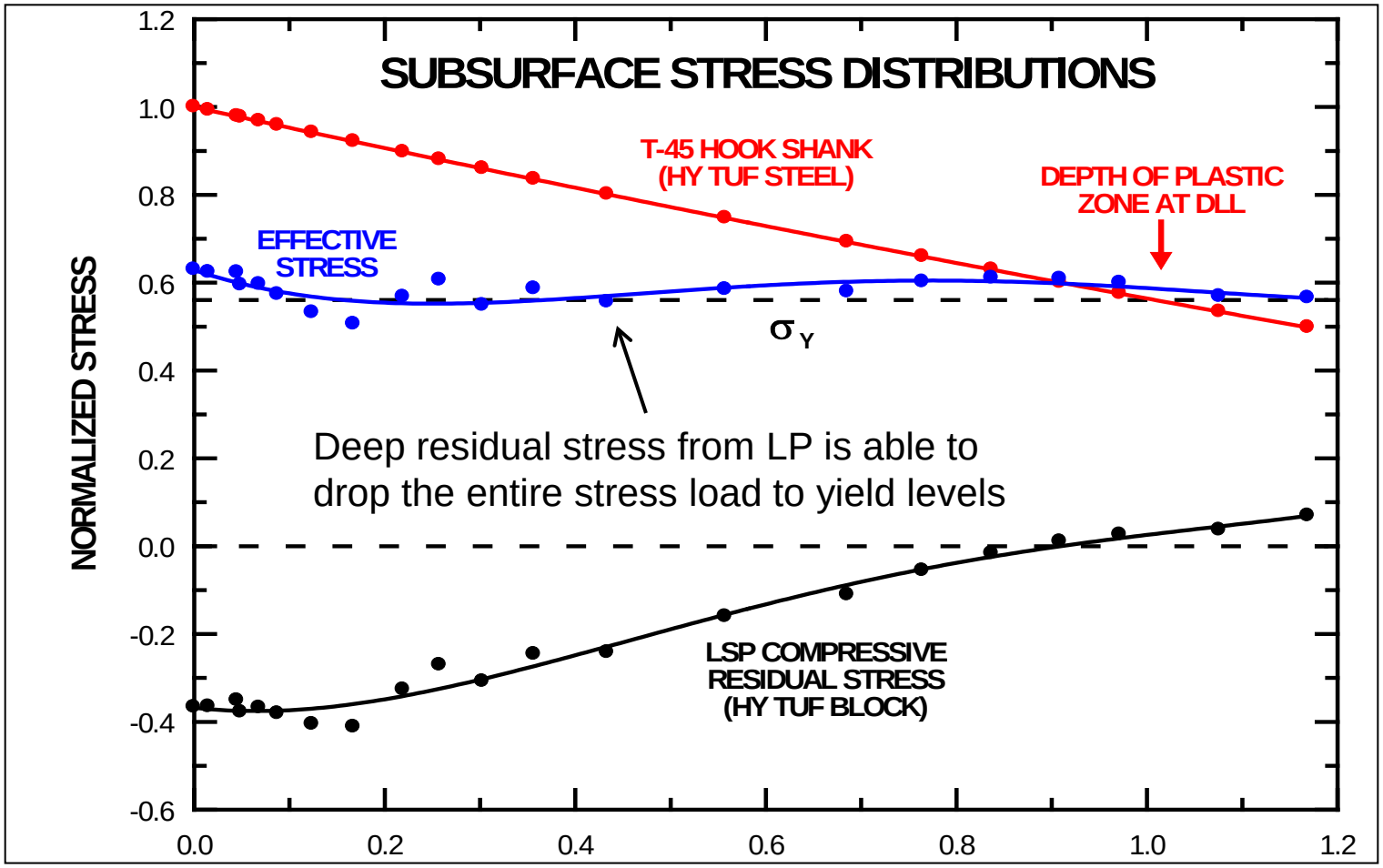


Laser peening in landing gear steel provides residual stress to 0.10 inches (2.5 mm) depth enabling mitigation of loading stresses



X-ray diffraction picks up near surface detail that the slitting technique overestimates

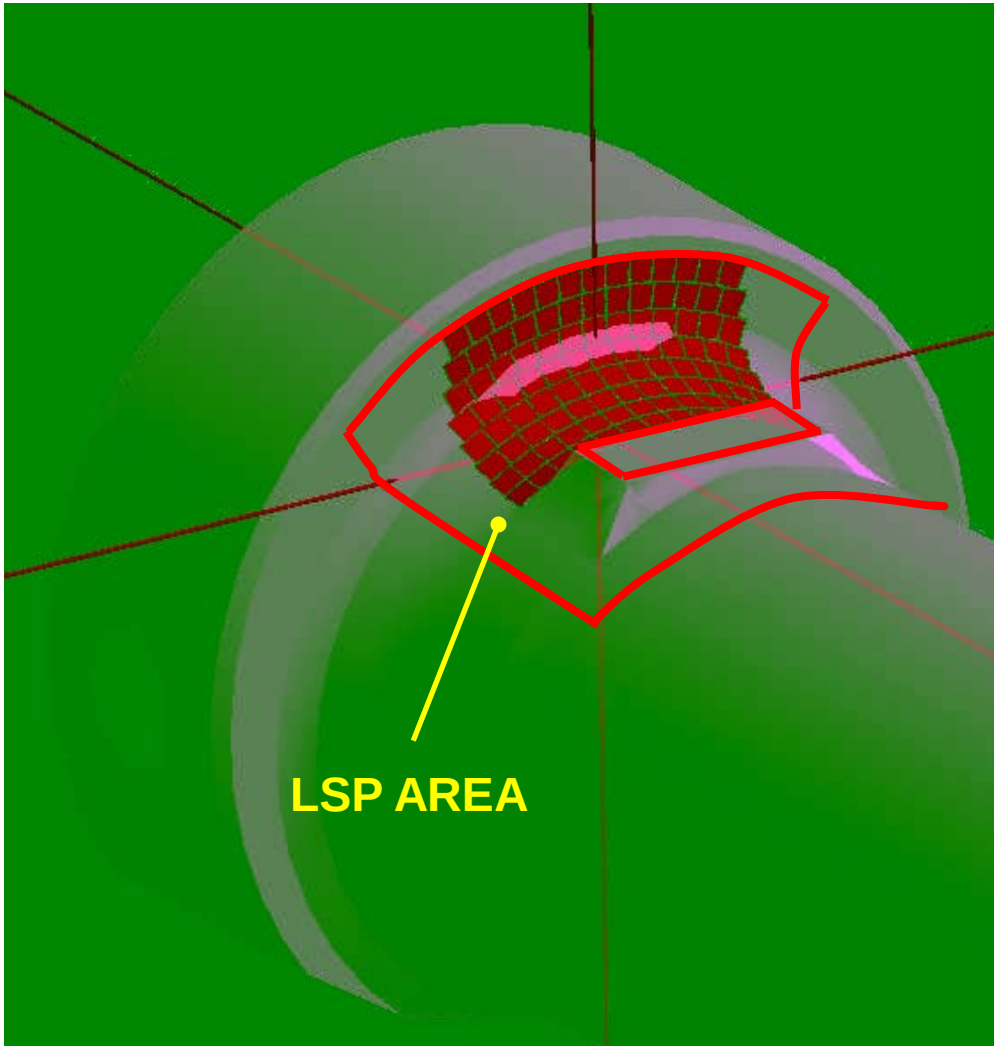
Deep residual stress generated by laser peening can dramatically change the load stress profile



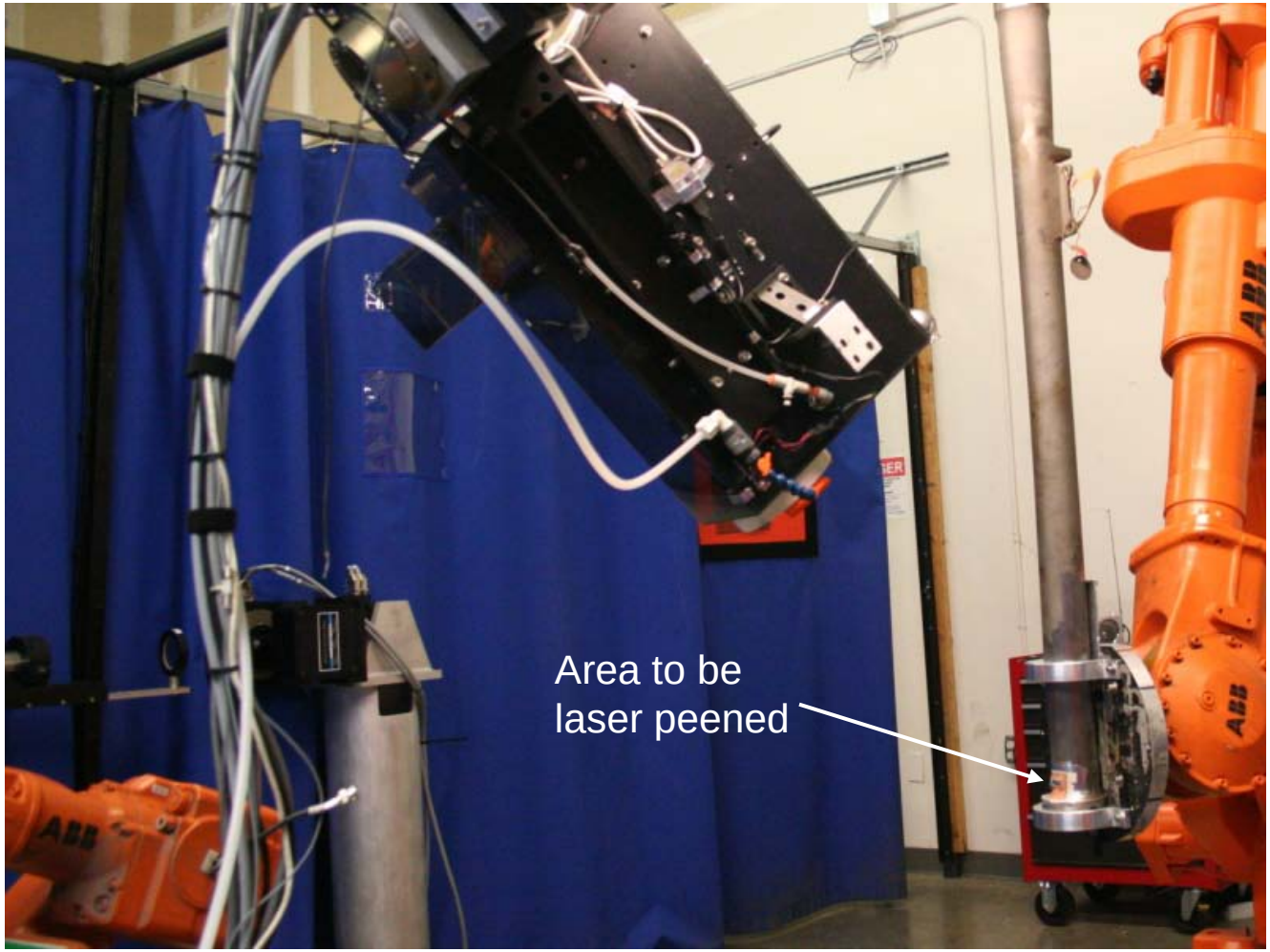
Operational cost savings and enhanced safety become compelling reasons to deploy laser peening for T-45 hook shank

- 250% lifetime increase for T-45 hook shank could generate significant savings over 27 year lifetime of aircraft
- Extended lifetime and reduced crack growth rate enhance safety
- Positive ROI could occur in the first year of deployment

Laser shot peening pattern covers high stress boss area with overlapping pattern

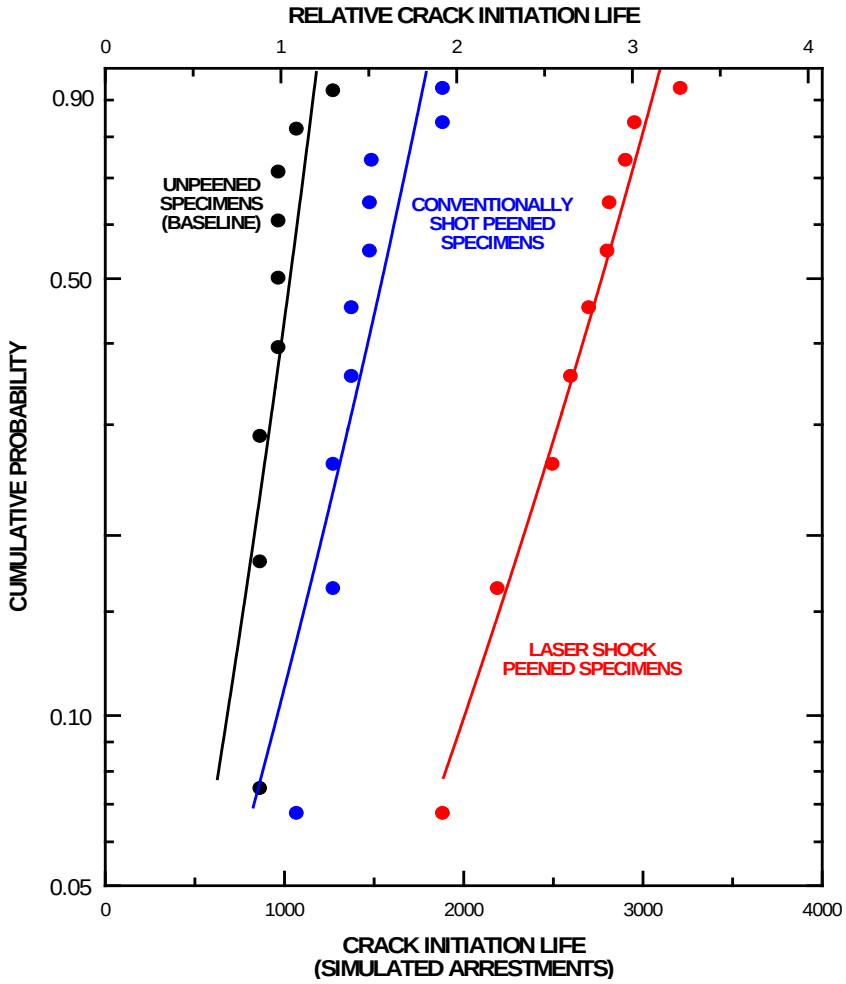


Tail hook shank mounted on robot for laser peening

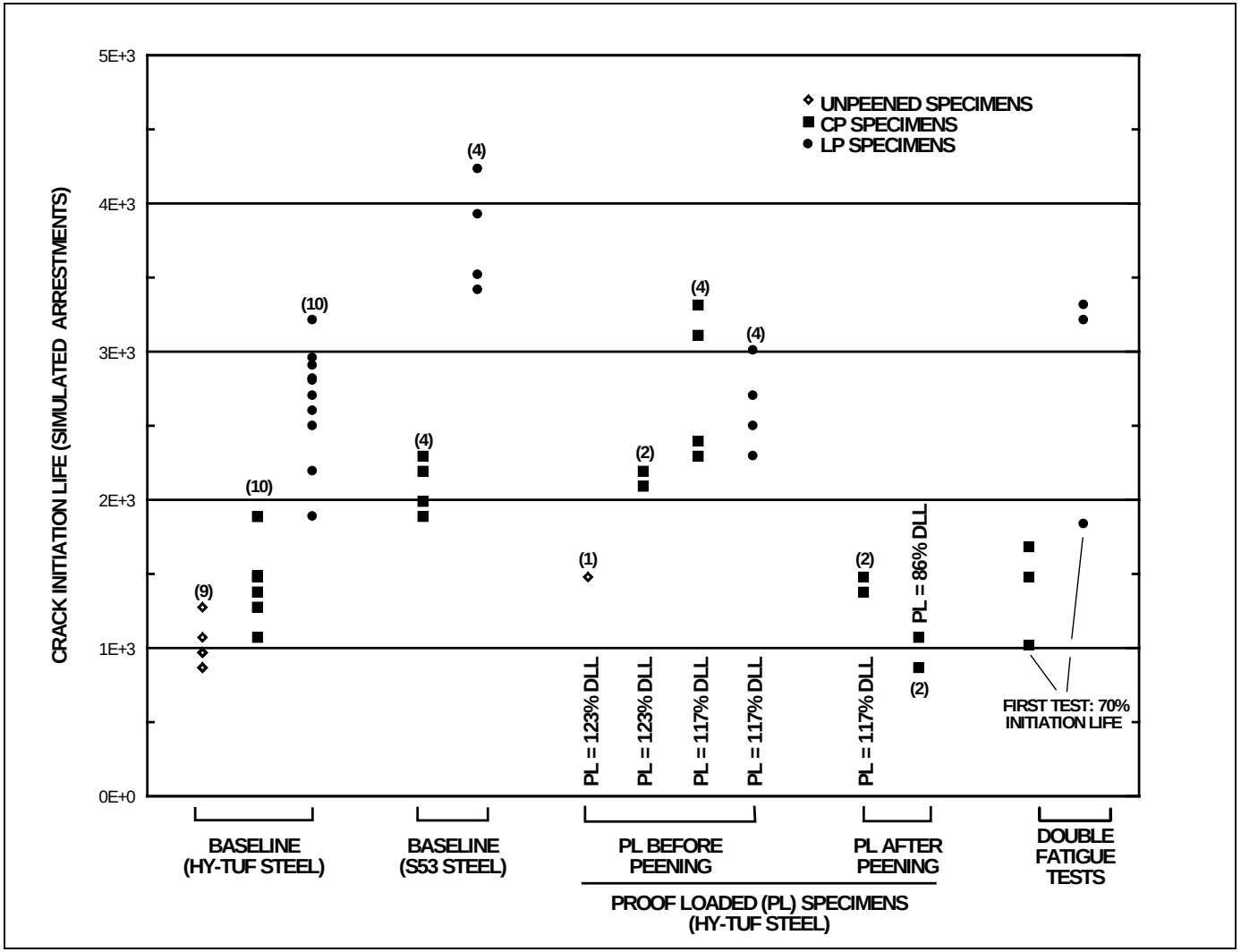


Laser peening is providing impressive lifetime improvement to tail hook like fatigue specimens

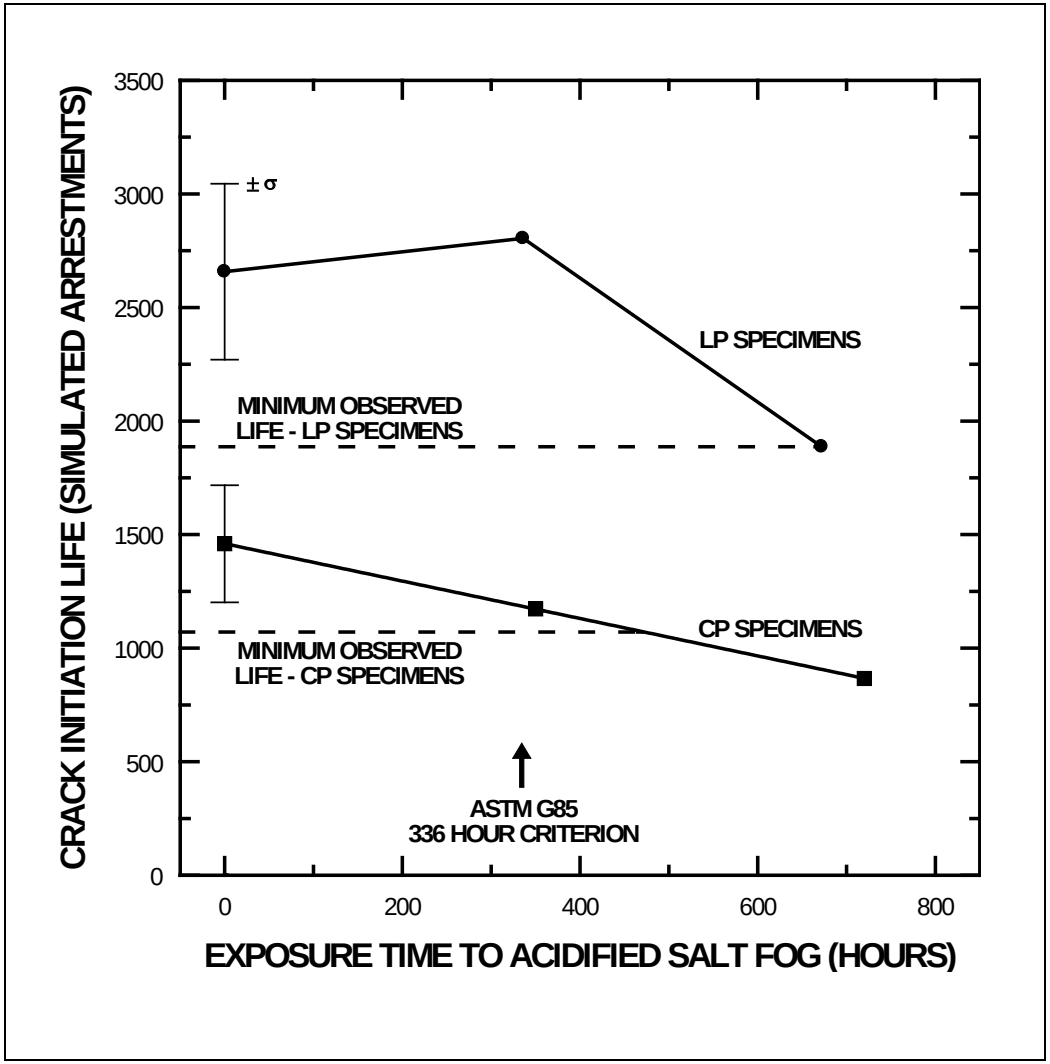
- Laser peening provides 250% lifetime increase over conventional shot peening
  - Performing an S-basis estimate for the crack initiation life gives results of:
    - 439 arrestments for unpeened (1x)
    - 423 arrestments for shot peened (0.97x)
    - 1102 arrestments for laser peened (2.5x)
- This analysis generalizes the performance of a large population of tests from a smaller test sample



Baseline and Supplemental Test Results



Corrosion Fatigue Test Results positive for laser peening



Momentum is slowly building to enable deployment on T-45

- More definitive data required to calculate the expected return on investment from deploying laser peening
  - NAVAIR has estimated hook shank replacement cost is $63k
  - Laser Peening of hook shank would cost less than a few percent of replacement cost
  - What is mean rate of replacement of hook shanks in the 235 aircraft fleet? 1 per 3 years?
  - Assuming above above replacement rate is correct, over 27 year deployment savings would be in range of $70M

- Steps for process qualification and process certification are being taken to enable deployment of laser peening of arrestment hook shank aboard T-45 aircraft

Summary

- Laser peening has been shown to provide >2.5x lifetime enhancement against fatigue failure for coupons replicating T-45 arrestment hook shanks

- Deployment on aircraft would reduce maintenance costs and add to aircraft availability