Surface Technologies Division

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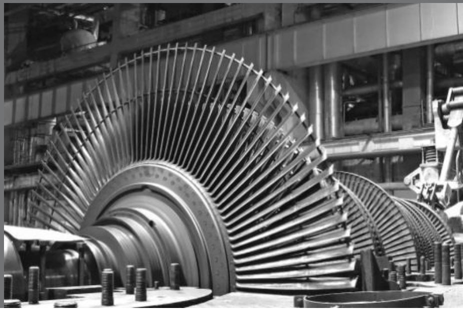
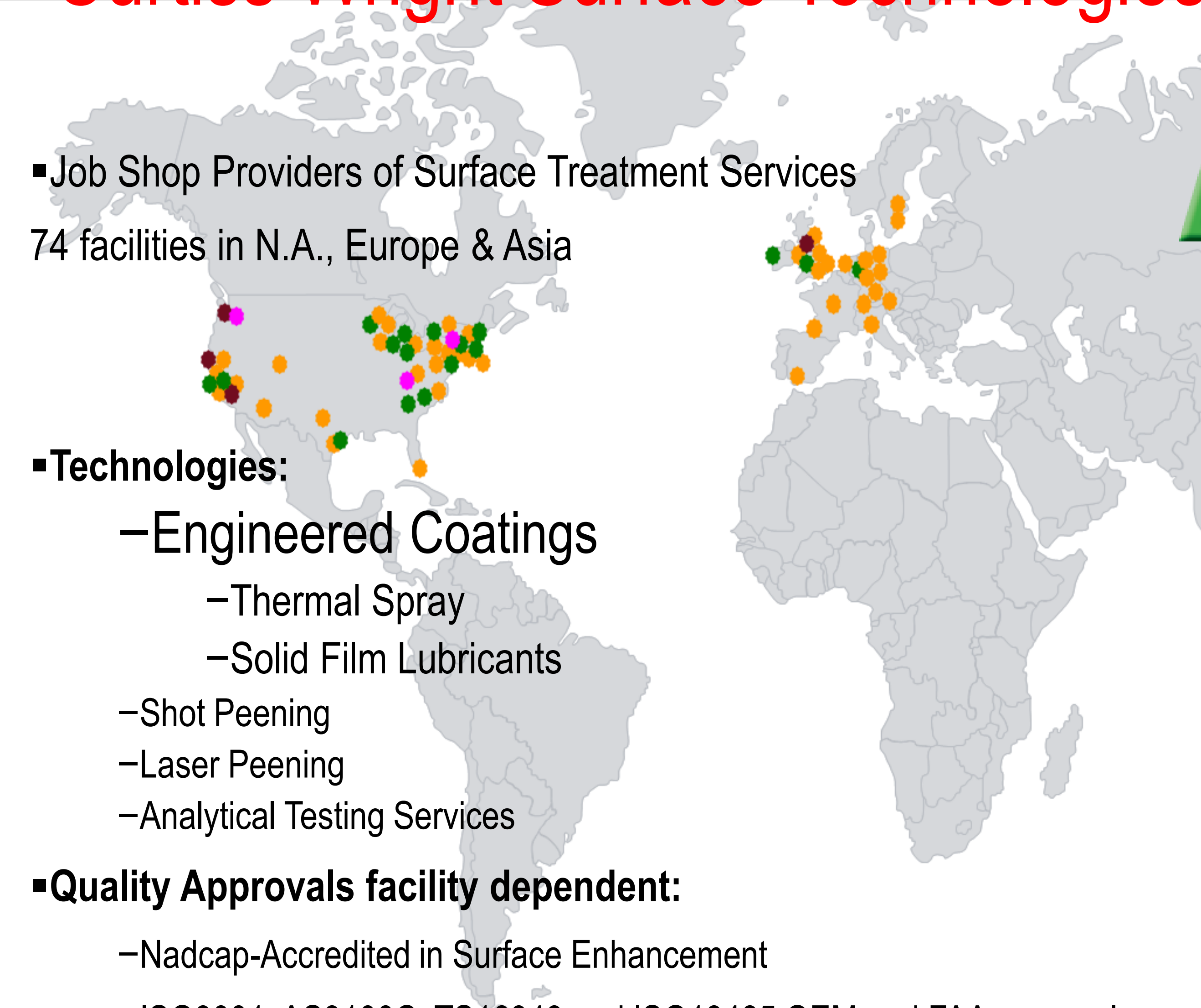
Overview of laser peening simulation

04/15/2020



Curtiss Wright Surface Technologies



- Job Shop Providers of Surface Treatment Services

74 facilities in N.A., Europe & Asia

- **Technologies:**
  - Engineered Coatings
    - Thermal Spray
    - Solid Film Lubricants
  - Shot Peening
  - Laser Peening
  - Analytical Testing Services
- **Quality Approvals facility dependent:**
  - Nadcap-Accredited in Surface Enhancement
  - ISO9001, AS9100C, TS16949 and ISO13485 OEM and FAA approvals

Metal Improvement Company

E/M Coating Services – Engineered Coating Solutions

IMR Test Labs

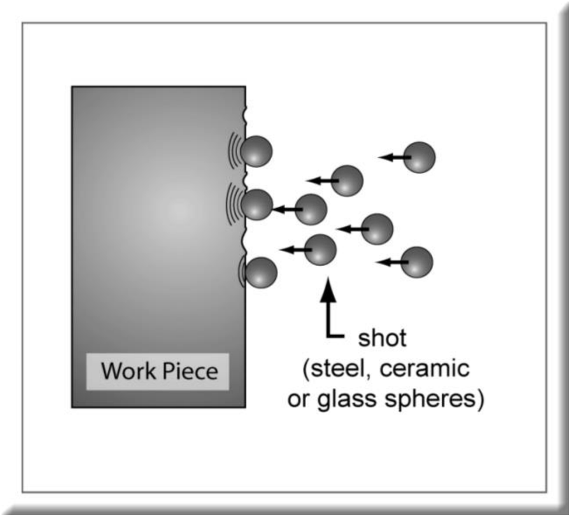
Parylene Coating Services – A Division of Metal Improvement Company – "The first name in Parylene"

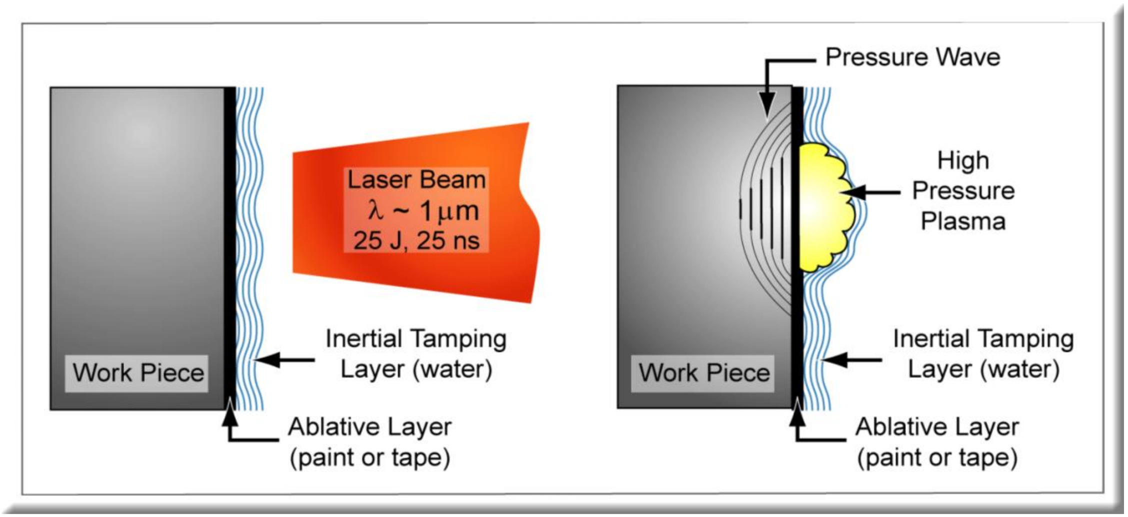
Everlube Products

Gartner – Since 1923

Curtiss-Wright

Basic concept of laser peening



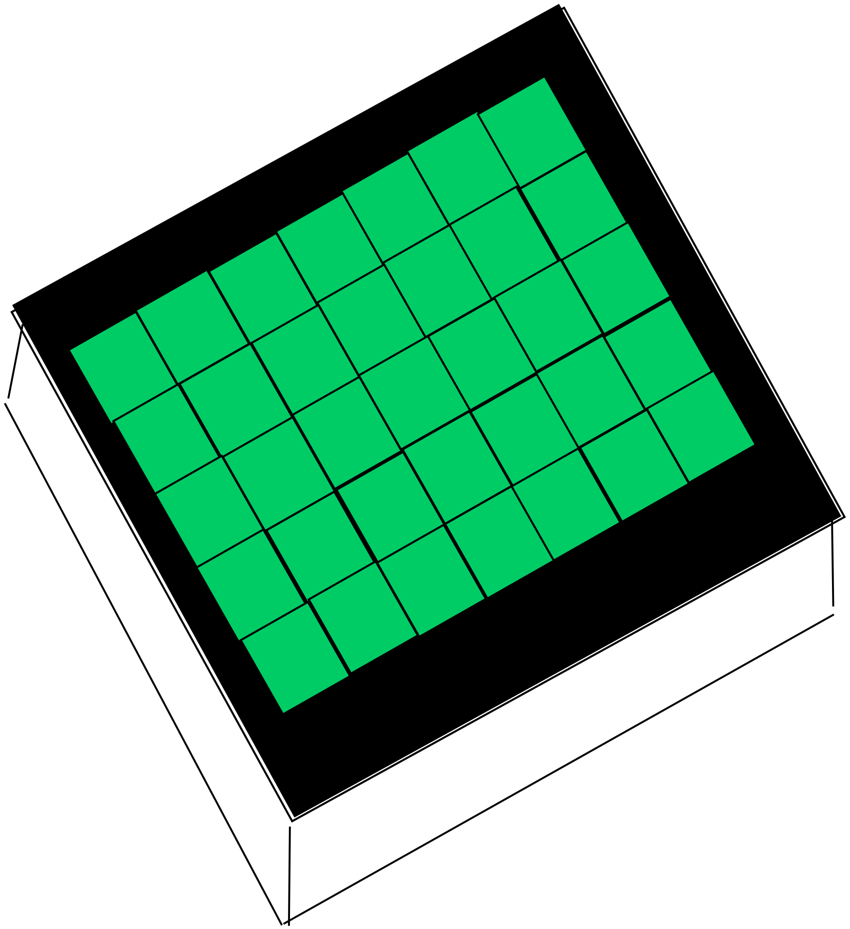


An extension of conventional peening

Laser peening provides

- Highly compressive residual surface stress
- Deep layer of compressive residual stress
- Smooth surface
- Excellent process control.

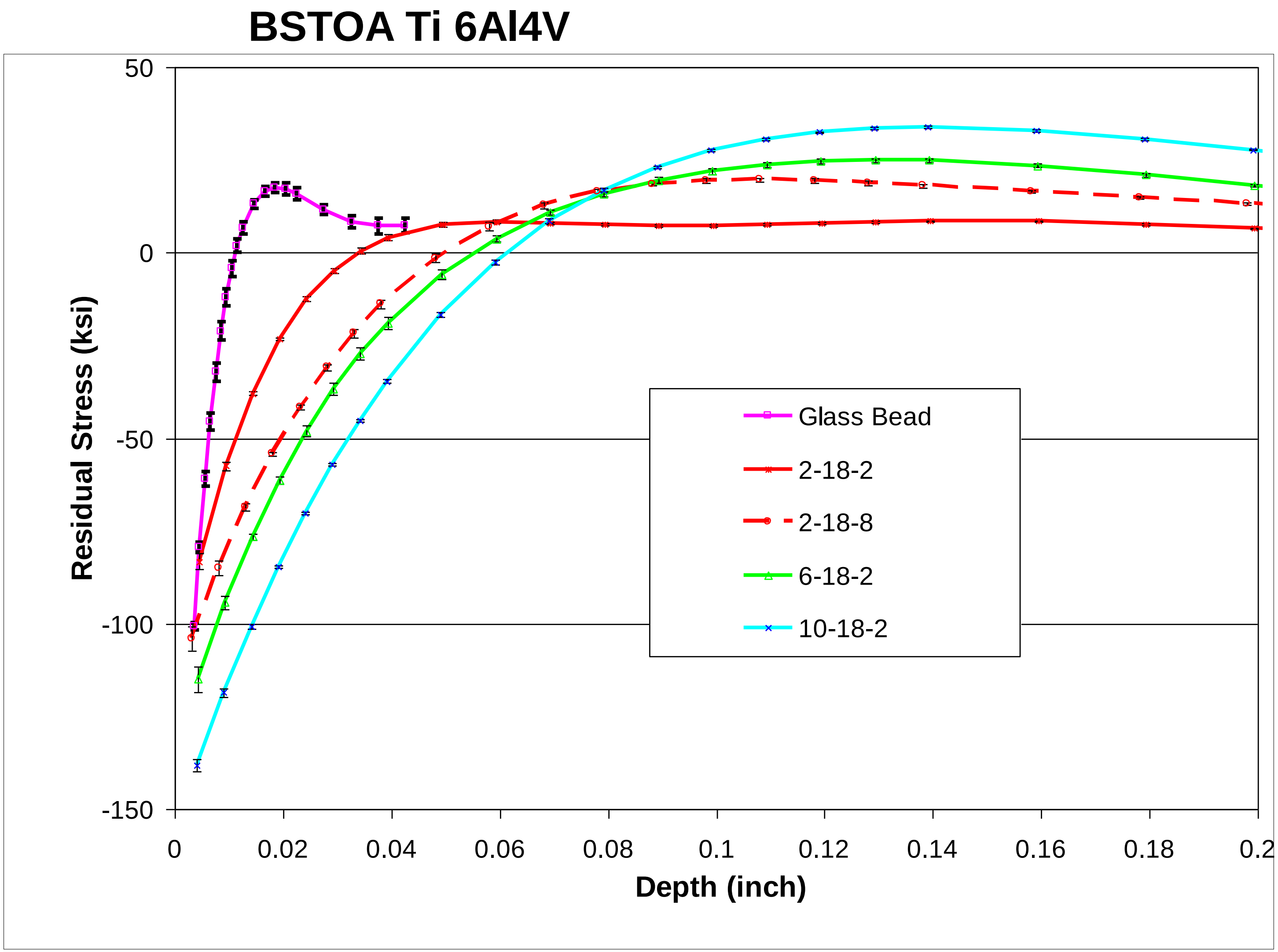
Square spots provide uniform coverage

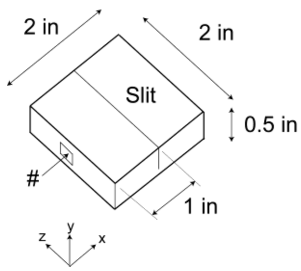


- Square spots provide efficient coverage in a single
- treatment layer
- Constant irradiance (flat-top) beam profile provides
- highly uniform stress
- Polarized beam provides efficient peening at up to
- 70° incidence angle
- Competitive approaches have reduced performance:
  - Round beam with peaked profile results in non-uniform coverage
  - Lower pulse energy in a small spot results in shallower stress, requiring more treatment layers

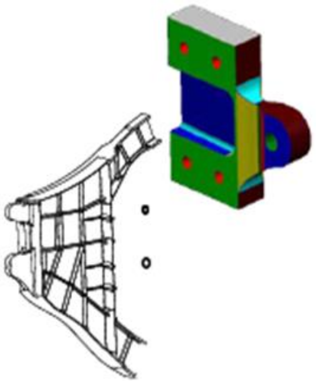
CURTISS WRIGHT
Surface Technologies

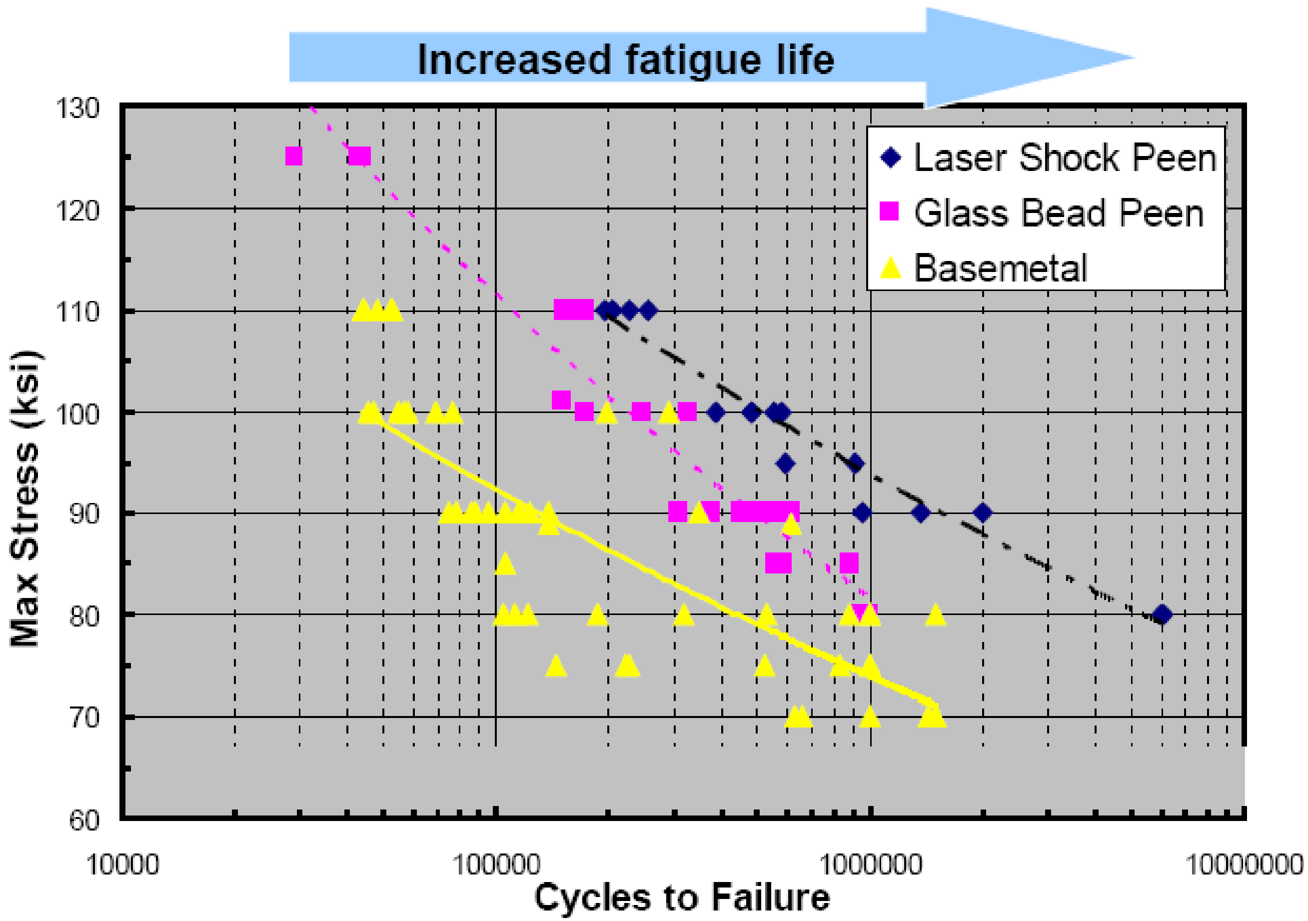
Engineered residual stress: Depth and intensity of residual stress is precisely controlled via laser settings





Glass bead and laser peening fatigue life benefit





Ref; D. Jensen, 2nd Intl. LP conf. 2010

CW laser peening meets ASM 2546 requirements, FAA and EASA approved

- **MIC has been laser peening under FAA and EASA approval since 2002 in the US and Europe**
- **Approved production applications include:**
  - Jet engine fan blades and discs
    - Trent 800 for Boeing 777 (on-site Singapore 2 systems)
    - Trent 500 for Airbus A340 (processed in our Earby U.K facility)
    - BR710 for Gulfstream V and Bombardier RJs
    - Trent 1000 for Boeing 787
    - F-100 Engine blades
    - F-136 Blisks
  - Gas and steam turbine blades for major power systems;
  - G.E., Siemens, RR and Alstom
  - Nuclear waste containers (on site 4/17)
  - Forging press 20 ton threaded posts (on-site (finished 1/16)
  - Forming of Boeing 747-8 Wing Skins
  - Wing Attach fittings for F-22 fleet. (on-site Palmdale then moved to Hill AFB)
  - F-15 Vert stab actuator.
  - F-35B Bulkheads (on site Cherry point April 2020)
  - F-35C Mod program (on site Hill AFB Utah Sept. 2020)
  - T-45 Tail hooks

- **Major applications in development for deployment on**
  A-10, C-17, F15, F-16, F-18, B-1, Navy propulsion shafts, Chemical, Nuclear Industries, and Horizontal drilling.

FEA simulation of laser peening residual stress

- **Simulation**
  - Geometry, loading, material properties from customer
  - Peening measurement (slitting) provides seed for FEA (effect vs. depth)
  - Apply initial LP pattern to areas of interest (fatigue hot spot, area susceptible to corrosion, etc.) on CWST or customer FE model
  - Iterate LP pattern to optimize post LP stress state
  - Customer runs fatigue lifetime analysis to predict improvement
- **Confirmation**
  - Design fatigue article or use full scale component, critical step
  - Test and iterate as applicable

FEA Inputs

- LP Parameters & Pattern
- Geometry
- Material Properties
- Service Loading / Boundary conditions

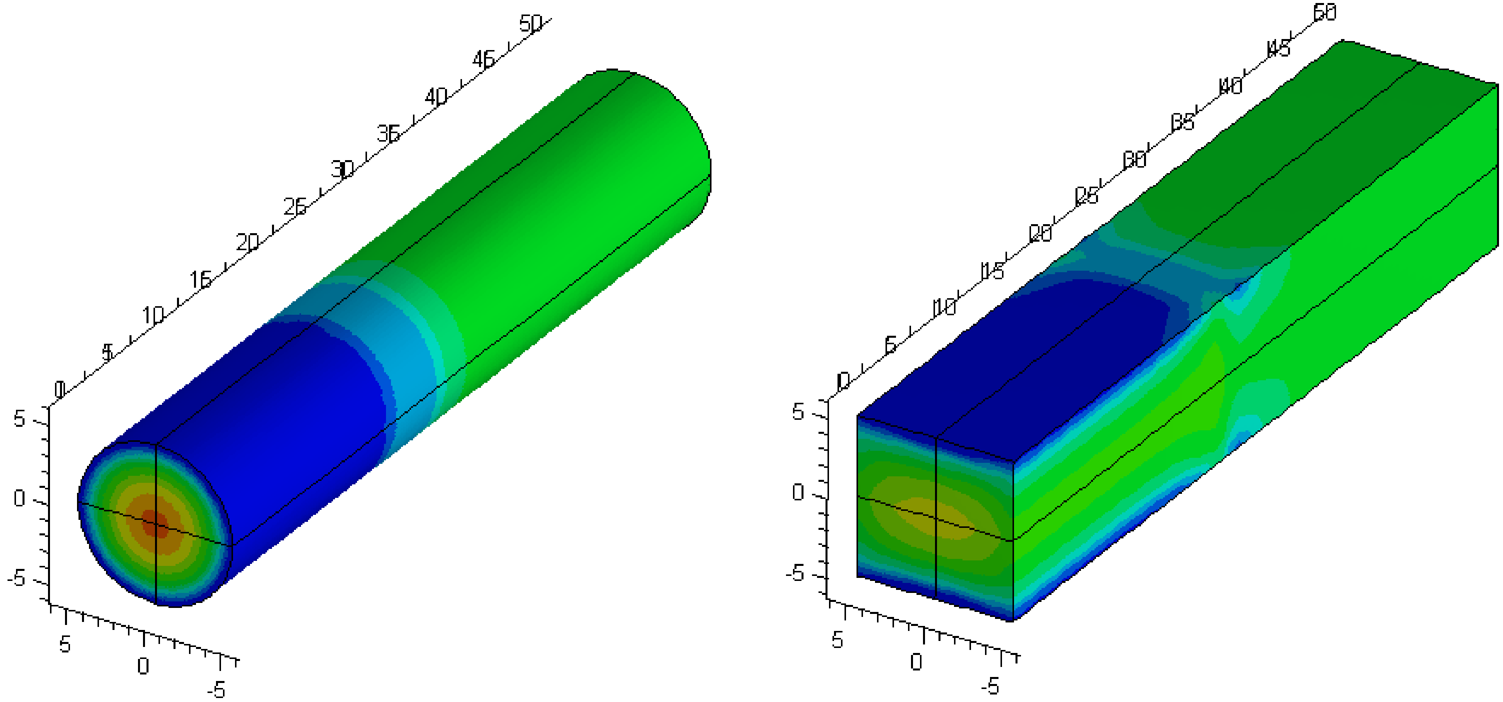
→ Linear elastic analysis →

FEA Results

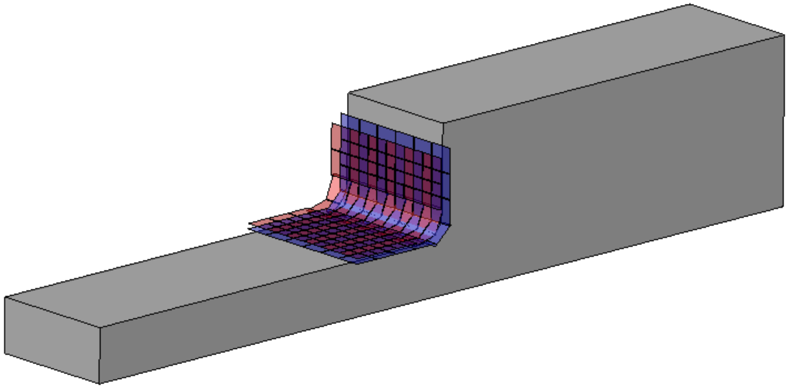
- Stress State
  - Compressive – beneficial
  - Tensile – balancing
- Deformed State

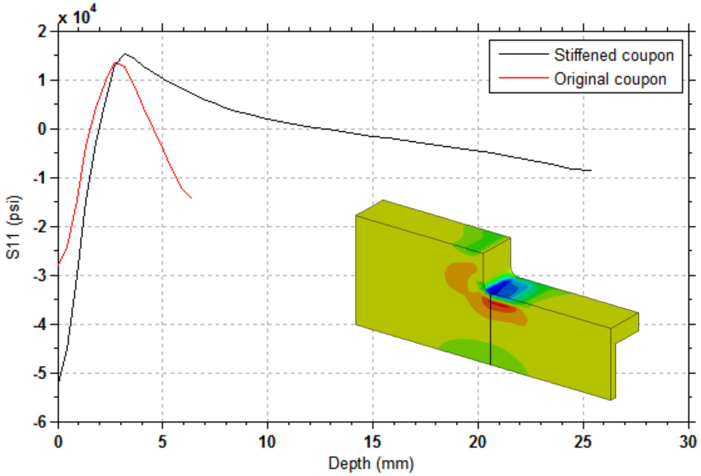
Eigenstrain simulation shows influence of geometry on peening

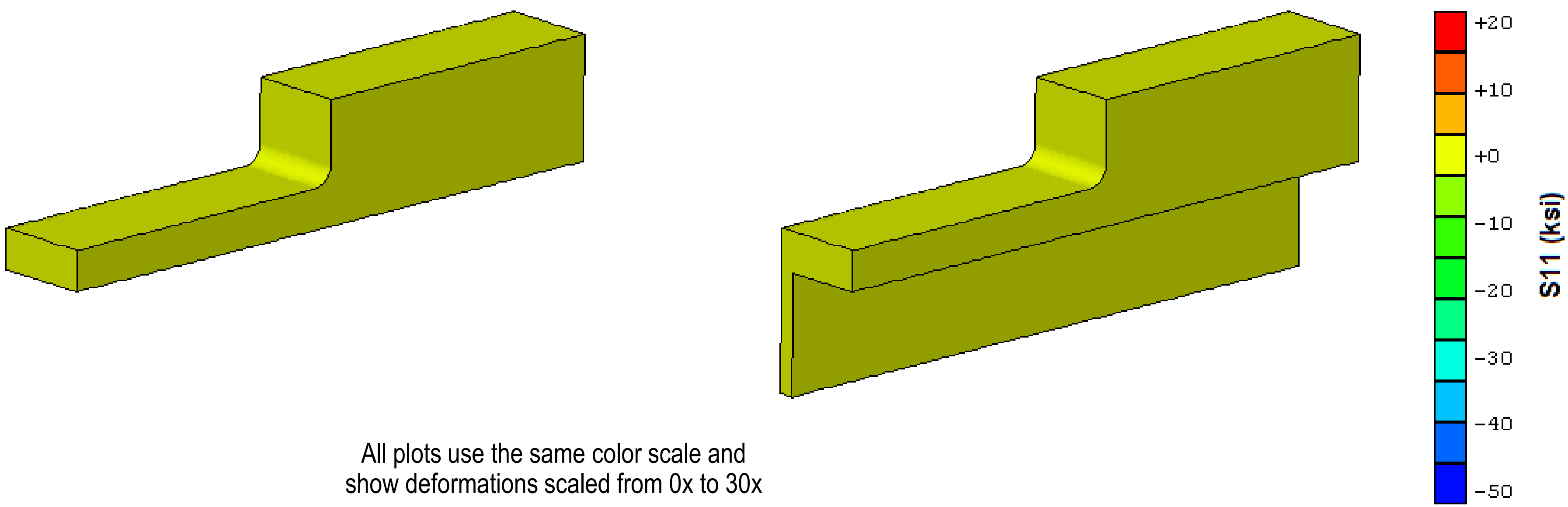
- **Measure residual stress in laser peened simple block coupons**
- **Compute the effect of laser peening effect for combination of material and peening process (the Eigenstrain)**
- **Use FEA to predict final stress in real part geometry**



Response depends on geometry - stiffener increases retained RS by 86% for the same simulated treatment







All plots use the same color scale and show deformations scaled from 0x to 30x

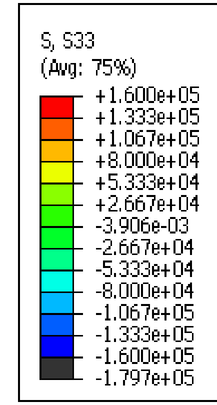
CWST software tool

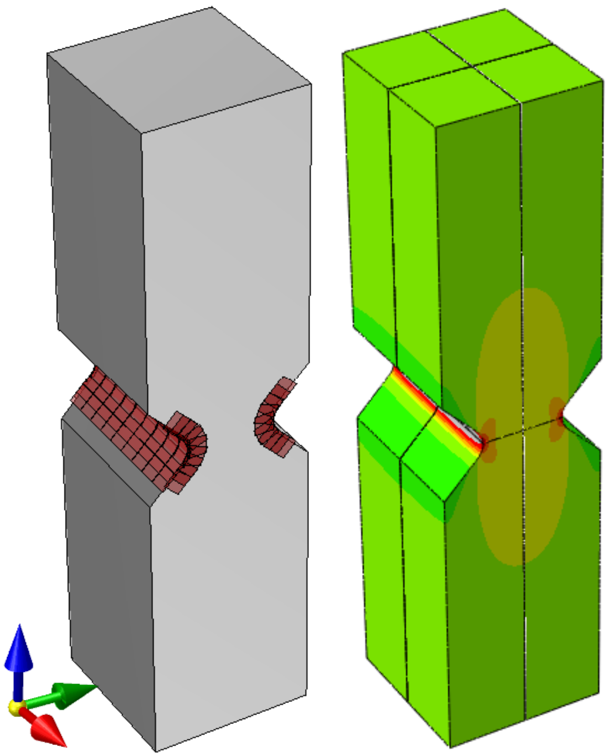
- **In-house developed Matlab pre and post processor for ABAQUS**
  - Read FEA mesh in ABAQUS compatible format
  - Computes strains for a selected pattern coverage / intensity using a pattern generated with the tools graphical interface
  - Writes ABAQUS input deck
  - Use ABAQUS solver to resolve stresses and strains
  - Post processes ABAQUS output
    - Results can also be viewed in ABAQUS CAE or other visualization tool

FEA simulation of a fatigue specimen

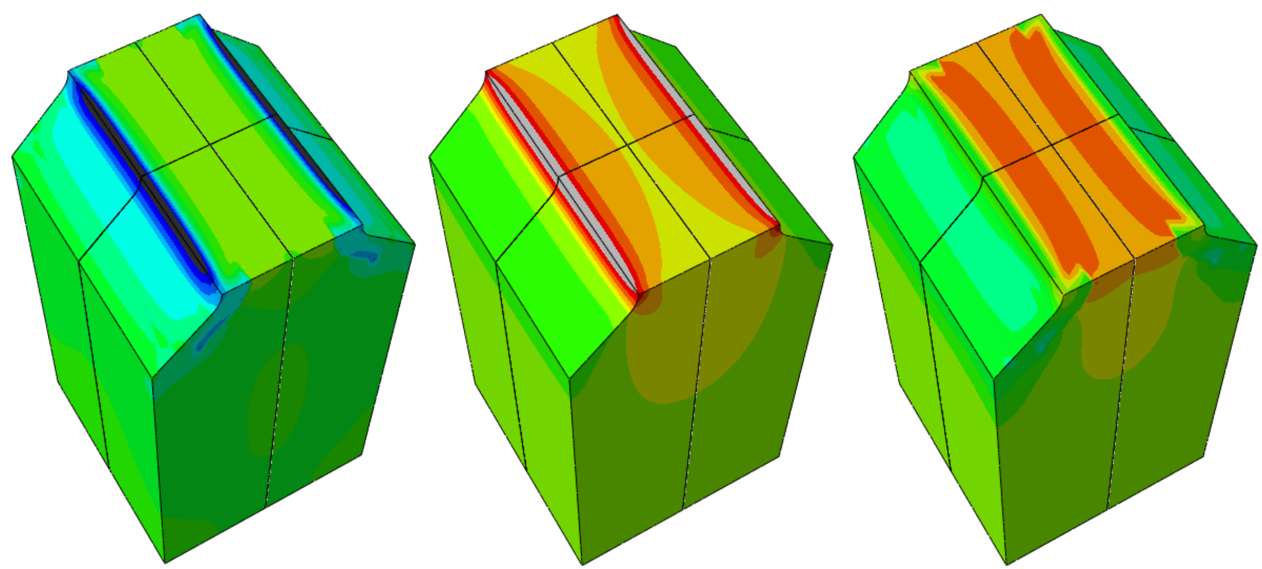
Without peening, under load

Results can be interrogated for stress, strain or displacement





Laser peening pattern

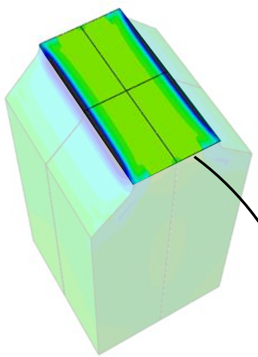


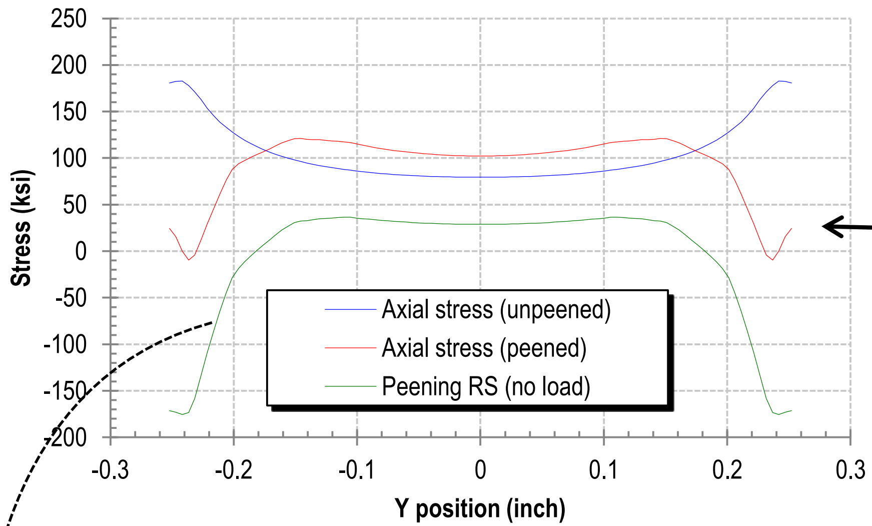
Effect of laser peening (without load)

Without peening – Peak axial stress is 183 ksi

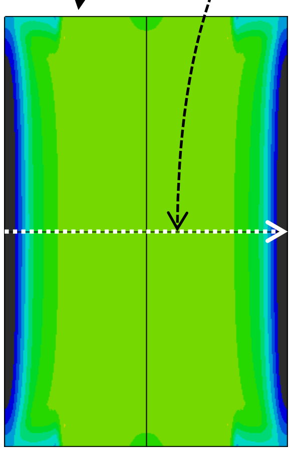
With laser peening – Peak axial stress is 132 ksi

FEA predicts stress reduction from laser peening

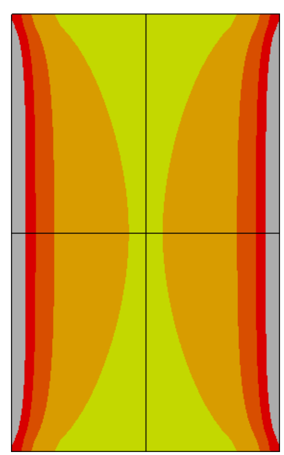




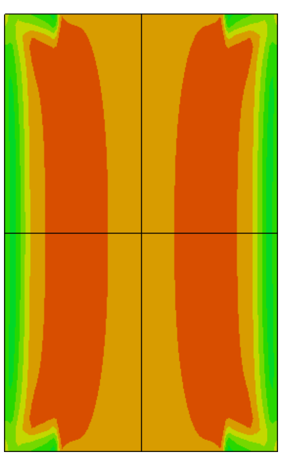
- **86% reduction in surface stress**
- **28% lower peak stress**



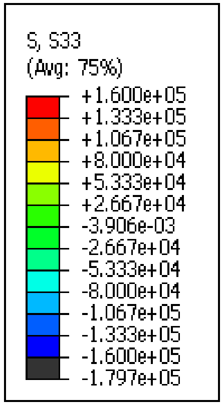
Effect of laser peening (without load)



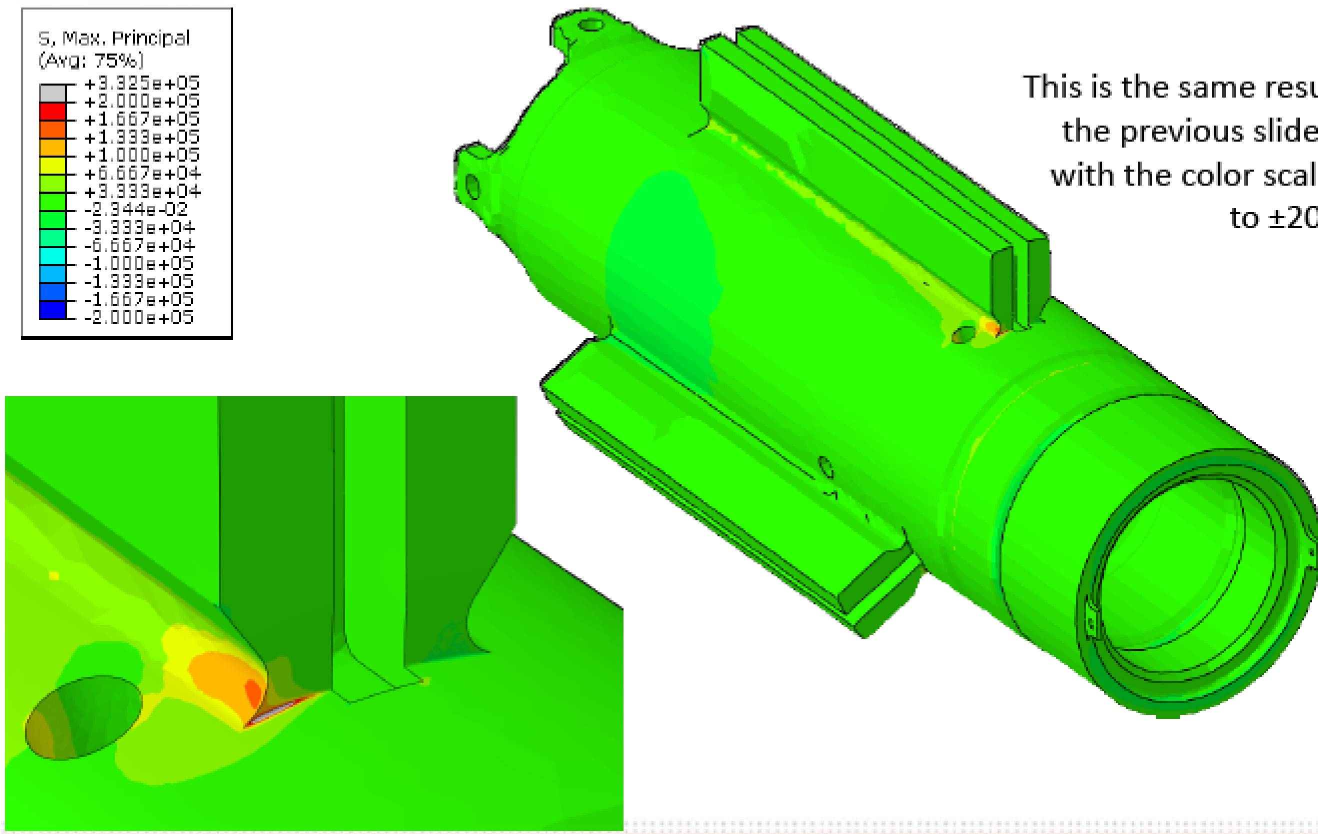
Without peening – Peak axial stress is 183 ksi



With laser peening – Peak axial stress is 132 ksi

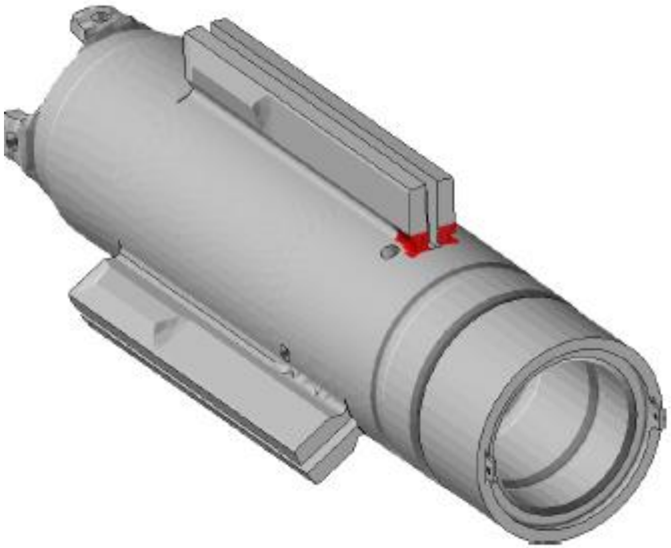


Baseline FEA Applied Load Only

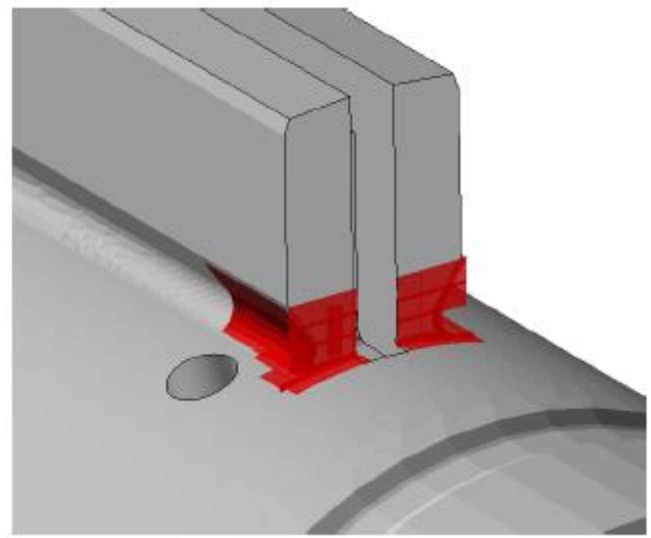


This is the same result as the previous slide, but with the color scale set to ±200 ksi

Suggested Laser Peening Pattern



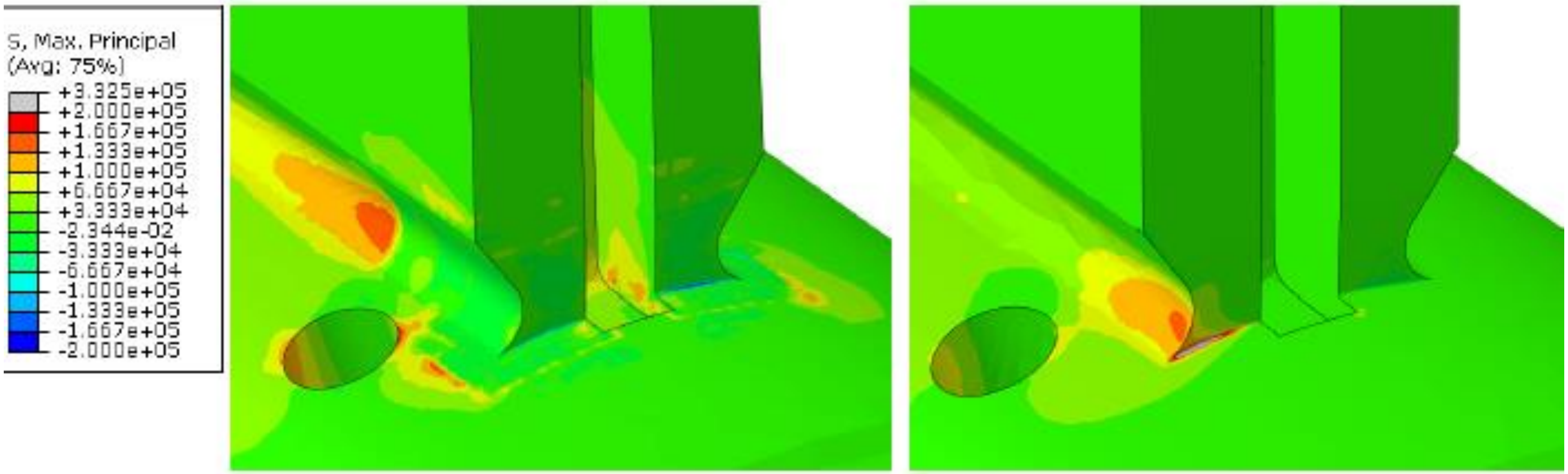
The red areas indicate the laser peened region



MIC Model Show LP Mitigates Stress in Filet by 45% but will Require Additional Peening.

Laser peen + load

Baseline case



Peak stress 184 ksi (away from stress riser)

Peak stress 333 ksi (in notch)

Conclusions

- **CWST is routinely using FEA during process development**
- **FEA guides coupon design, pattern placements and peening intensity**
- **Adding analysis to a program doesn't eliminate experimental validation but reduces:**
  - Entry cost
  - Number of iterations required
  - Schedule and cost risk