Laser Peen Forming
Webinar: Technology and Applications

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LSP Technologies, Inc.

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Our Company

- Founded in 1995 to satisfy industrial demand for laser shock peening equipment and technology

- Industrial production processing of components since 2003

- Business evolved into three primary revenue streams surrounding laser shock processing technologies:
  - Production services
  - Custom equipment solutions (design/build/integrate)
  - Research and development
Collaboration Across Industries
Global Presence – R&D and Production

LSPT World Headquarters
Dublin, OH
Services:
- Design/Build Engineering
- R&D
- Production

MTLS Factory
Weifang, China
Services:
- Production

ZAL
Hamburg, Germany
Services:
- R&D

GDUT
Guangzhou, China
Services:
- R&D
Laser peening can be used to:
- Extend service life
- Create parts with complex curvatures
- Reshape/straighten parts

Benefits:
- Predictable shape formation
- Repeatable process
- Scalable technique
- Zero to minimal tooling
The Laser Peening Process
Overview

- **Pulsed laser system**
- **Power delivered in \( \text{GW/cm}^2 \) scale per pulse**
- **Optional opaque overlay absorbs laser beam energy to create plasma**
- **Transparent overlay confines plasma to increase pressure**
- **Shockwaves generated by rapid pressure rise**
- **Shockwaves develop plastic strain in target**
- **Plastic strain leads to residual stress and/or deformation.**
### Material Response to Surface Treatments
Plastic strain drives elastic response

<table>
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<tr>
<th>STEP 1</th>
<th>STEP 2</th>
<th>STEP 3</th>
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<tr>
<td>Surface enhancement applied</td>
<td>Processed volume plastically deformed (cold worked)</td>
<td>Surrounding material elastically adapts to plastic strain volume</td>
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- **Surface enhancement applied**: The surface is modified to enhance certain properties.

- **STEP 1**: Surface enhancement is applied to the material.

- **STEP 2**: The processed volume is deformed plastically, resulting in a decrease in dimensions compared to the original material.

- **STEP 3**: The surrounding material elastically adapts to the plastically deformed volume, leading to the creation of residual stress.

LSP Technologies, Inc. Proprietary Information
• Misfit strain can manifest as:
  - Residual stress (laser peening)
  - Deformation (laser peen forming)

• Structural stiffness determines magnitude of each component

Residual Stress Distribution

\[ h \propto \frac{1}{t^2} \]
Laser Peening Process Area Effects
What to expect when laser peening a product

- Compressive stresses on processed and flexed surfaces
- Compensating tensile stresses distributed through core
  - Increased stress corrosion resistance
  - Increased fatigue performance
  - Surface finish modification from laser spot impressions
  - Gradual geometry changes
- Maximum deformation depends on material thickness

- Adjustable up to maximum deformation by controlling:
  - Power Density
  - Pulse Width
  - Layers

- Additional constraint can preferentially mitigate/enhance deformation
Laser Peen Forming Variations

Process can be applied in different methods to achieve specific results

- **Free form**
  - Part held at benign location
  - Beam directed to target locations and progressively forms part

- **Elastic Pre-strained**
  - Constrain or pre-strain part to modify standard strain input.
  - Another method of adjusting laser peening process

- **Combinational**
  - Mechanical forming operation in combination with laser peen forming
Predicting Shapes in Laser Peen Forming
Modeling basis required for complex shape correction

- Large objects, complex shapes, and different inputs → FEM

- Eigenstrain models provide accurate prediction of residual stress and deformation profiles
Examples: Peen Forming Shapes

2' x 2' Panel
Example: Peen Forming Shapes

2’ x 2’ Panel Constraint

- Elastic constraint example
  - Free deflection: ~25mm
  - Stiffened direction: ~ 4mm
Peen Forming Panels

Larger 4’ x 6’ Panels
4’ x 6’ Panel Examples
Shape Correction Example: Wankel Crankshaft
Correcting unacceptable distortion and runout
Wankel Crankshaft Example
Using models to predict deformation

Runout predicted w/o corrective LSP: 0.052 mm

Average measured runout (8 shafts) w/o corrective LSP: 0.05 mm
Wankel Crankshaft Example
Using models to optimize corrective treatment

Runout predicted with corrective LSP: 0.004 mm

Runout with corrective LSP (24 shafts) < 0.010mm (max spec.)
Example: Frame Shape Correction
In-plane dimensional adjustment of cabin frame
Example: Frame Shape Correction

Out-of-plane dimensional adjustment of cabin frame
What’s Next in Peen Forming?

• Further automation
  ▫ Automated scanning/point cloud mapping
  ▫ Feedback loops in forming/shaping correction

• Alloy specific optimization
  ▫ Most peen forming done on aluminum
  ▫ Titanium growing interest
  ▫ Steel common for shape correction, such as shafting

• On-site system integration
  ▫ Systems designed for specific forming operations
  ▫ Reduce cost by keeping parts/process in-house
Questions?

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