TECHNOLOGY REPORT

*Laser Technology Inc.*

# Laser Shearography Inspection of Composite Over-wrapped Pressure Vessels (COPV) and Filament Wound Composite Rocket Motors

Composite over-wrapped pressure vessels (COPV) with aluminum or non-corrosive steel liners that house liquid fuel and chemicals or filament wound composite rocket motors can become hazardous if damaged. The integrity of these vessels need to be inspected for liner to composite disbonds, natural disbonds between composite and liner at the end dome welds, delaminations within the composite and impact damage. Laser Shearography has shown to be an effective inspection method, fast and accurate defect location and sizing.

**COPV**

**Tank:** Steel Liner, Carbon Fiber wound Fiberglass Wrap, 140 x 25 inches, 9,500 psi operating pressure.

**System:** LTI-5100 Laser Shearography inspection system.

**Stress Method Options:** Thermal, Pressure or Vacuum.



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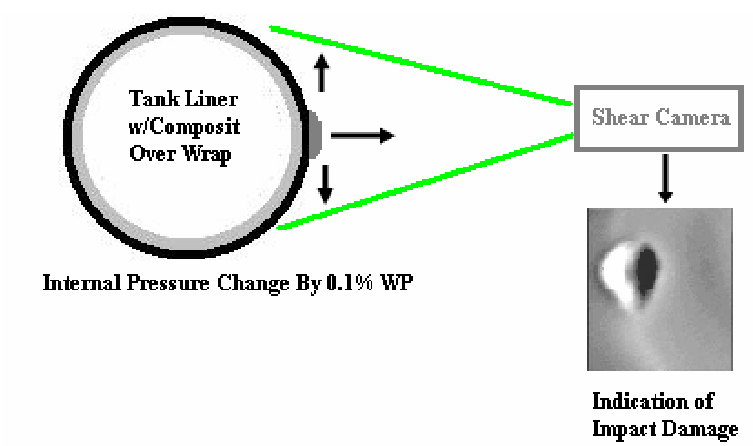
**Laser Shearography Technology**

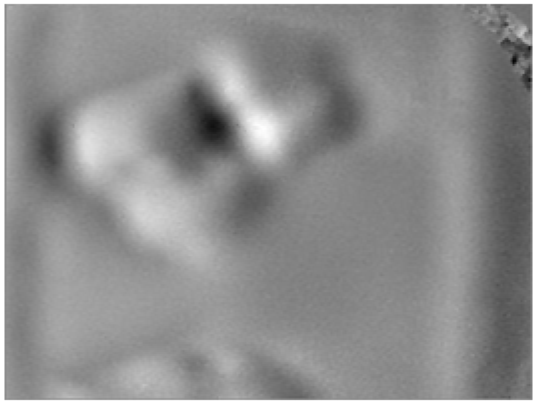
Laser interferometric imaging NDT techniques such as holography and shearography have seen dramatic performance improvements in the last decade and wide acceptance in industry as a means for high-speed, cost effective inspection and manufacturing process control. These performance gains have been made possible by the development of the personal computer, high resolution CCD and digital video cameras, high performance solid-state lasers and the development of phase stepping algorithms. System output images show qualitatively pictures of structural features and surface and subsurface anomalies as well as quantitative data such as defect size, area, depth, material deformation vs. load change and material properties. Both holography and shearography have been implemented in important aerospace programs providing cost effective, high-speed defect detection. With the large increase in the use of composite materials and sandwich structures, the need for high speed, large area inspection for fracture critical, sub-surface defects such as disbonds, delaminations, sheared core or non-visible damage in aircraft, missiles, rocket motors, pressure vessels and marine composites led to broad acceptance of laser based NDT methods.

Shearography NDT systems use a common path interferometer to image the first derivative of the out-of-plane deformation of the test part surface in response to a change in load. This important distinction is responsible to two key phenomena. First, shearography is less sensitive to the image degrading effect of environmental vibration. Shearography systems may be built as portable units or into gantry systems, similar to UT C-Scan systems, for scanning large structures. Second, the changes in the applied load required to reveal subsurface anomalies frequently induce gross deformation or rotation of the test part.

Shearography images show changes in surface slope, in response to a change in applied load. Shearography whole field, real-time imaging of the out-of-plane deformation derivatives is sensitive to subsurface disbonds, delaminations and impact damage.



**Shearography Deformation Imaging and Measurement of COPV**



**Shearography images of COPV with damage**

Shearography image above, showing Z Axis out-of-plane deformation rate due to 0.3 psi applied to the COPV. The Laser illumination angle is 10° above the tangent to the midpoint on the COPV allowing shearography imaging of in-plane strain. Also, the Shearography image shows X/Y in-plane deformation rate. When laser illumination angle is 90° above the tangent to the midpoint on the COPV, it is allowing only out-of-plane or Z axis. The Z-axis deformation rate for COPV under pressure loading is identical to pure in-plane deformation rate.

With increased pressure it increases uniform hoop and longitudinal strain on the tank surface. The Z axis component of strain concentrations are detected by the shearography camera and imaged as seen above illustration. Pressurization load offers the best stress method to detect liner-to composite bonds.

Thermal stressing applied to carbon fiber and Kevlar wound material will show deformation due to changes of coefficient of expansion of the material and are detected by the shearography camera and imaged. Typically surface and sub-surface damage like impact damage are detectable by the shearography camera.

Surface deformation, as small as 2-3 nanometers can be detected and quantitatively measured using laser shearography. The shine condition of a surface, like dark glossy surface can deflect the laser speckle pattern and a coating to dull the surface may be required.

## Laser Shearography Applied Stress Chart for COPV

| Stress Method | Vacuum | Thermal | Pressure |
|---|---|---|---|
| **Defect Condition** | | | |
| Liner Buckling | X | | X |
| Liner-to-Composite Disbond | X | | X |
| Liner-to-Composite Disbond at end dome weld | X | X | X |
| Delaminations within the Composite | X | X | X |
| Impact Damage | X | X | |
| Loss of Composite material properties due to chemical attack, radiation, high temperature exposure. | X | | X |
| Layer Cracking | X | X | X |
| Interfacial Debonding | X | X | |
| Fiber Breakage | X | X | |
| Detect Strain Concentrations | X | | X |

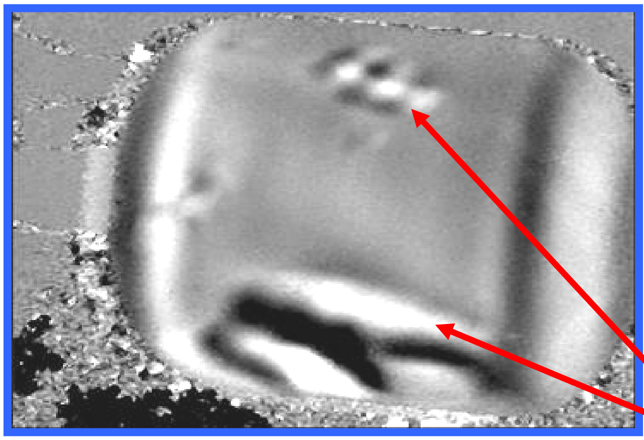
**Note: The stress method marked is a suggested recommended method more likely to be effective in the shearography test and which is dependant on the tank configuration and material.**

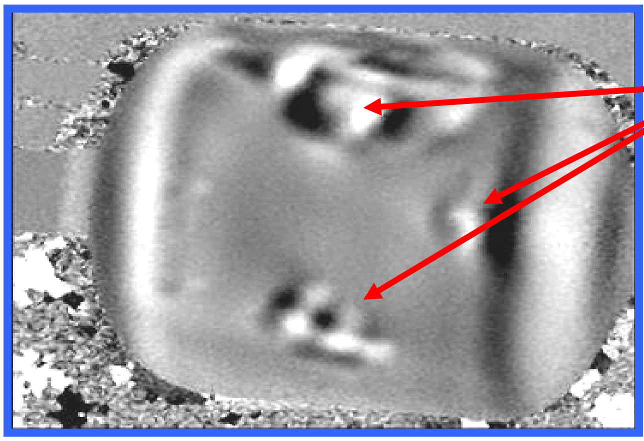
**LTI-5100 System**

- **Shear Camera**
- **Computer**
- **Software**
- **Post Analysis Software**
- **Vacuum Pump**

**Laser Shearography Set Up for COPV Test**

**Filament Wound Test Tank**





**Non-visible damage detected with pressurization shearography**



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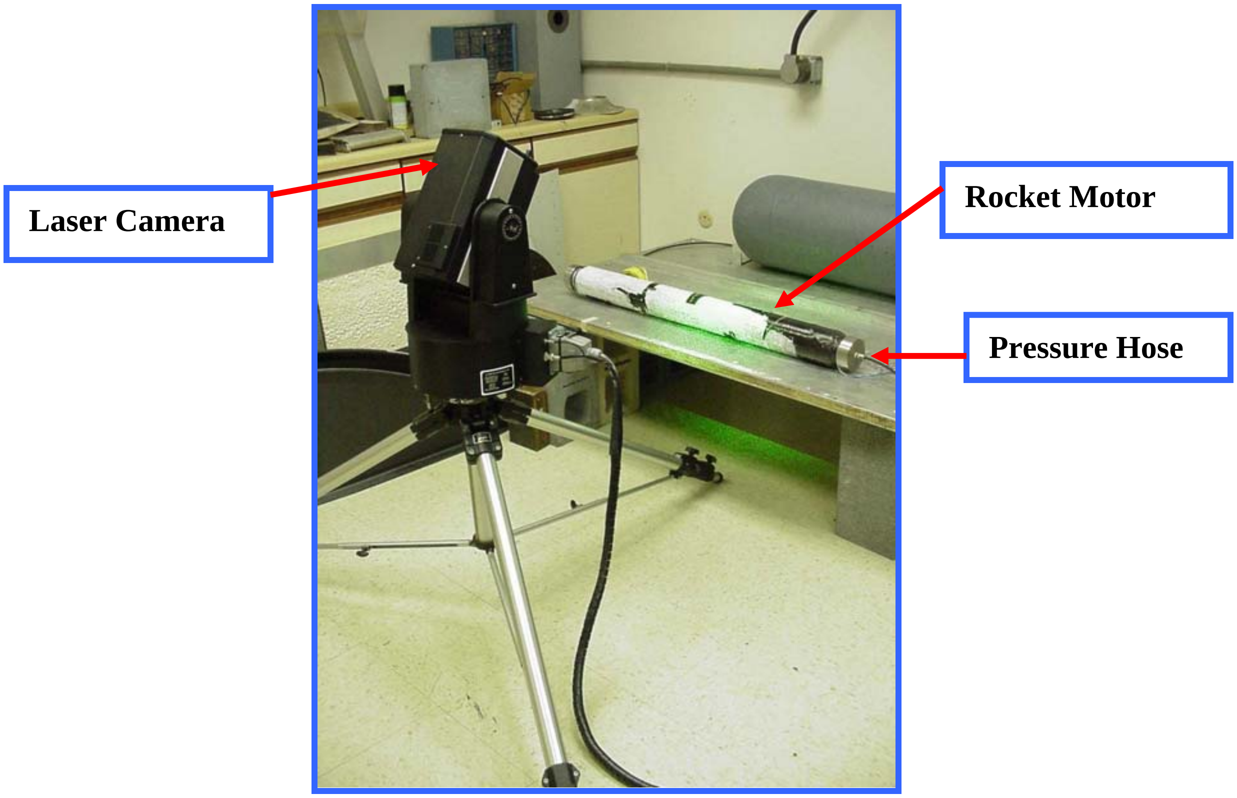
## Small Solid Fuel Rocket Motor Encased with Filament Wound Material




**Laser Shearography Inspection of Solid Fuel Rocket Motor**

**Similar to filament wound bottles, the solid rocket motors react to pressurization to make visible impact damage with laser shearography where otherwise not visible to the look.**

**Multiple Impact Damage Area Shearography**

**The Shearography techniques described in this document is protected under US and Foreign patents and additional patents pending.**



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