Defect Analysis of Vehicle Compressed Natural Gas Composite Cylinder

A China Paper on Type 4 Cylinder,
translated and presented by

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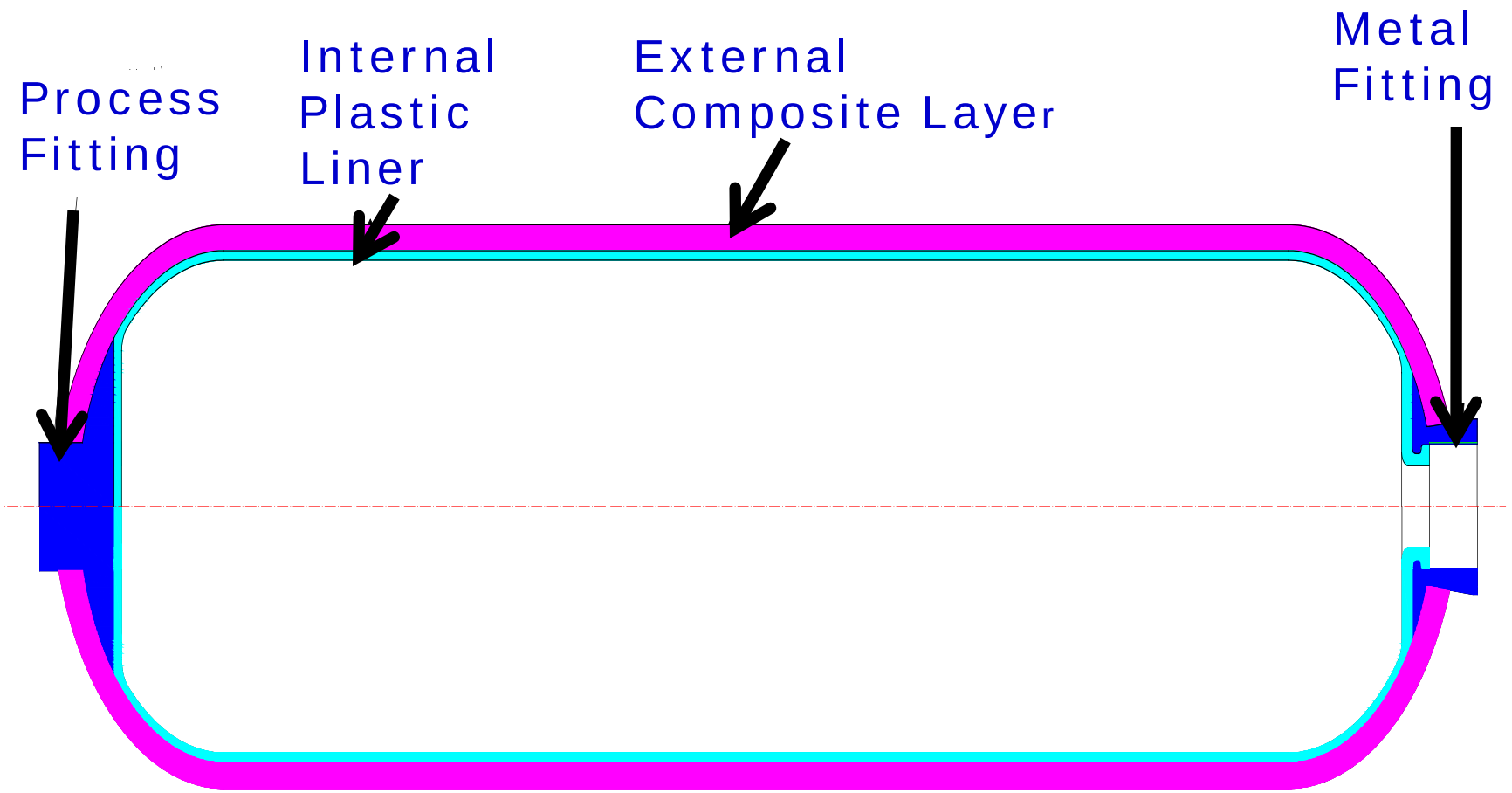
Reason for Defect Analysis of CNG Composite Cylinder

- Safety Issue - Four explosion accidents of auto used CNG composite material cylinders resulting huge personnel and vehicles loss.
- Low Compliance Rate – Inspect 12119 Auto used CNG composite cylinders and only 3868 are qualified with compliance rate of 32%.

Plastic CNG Composite Cylinder



HDPE Cylinder Liner

- HDPE has a high density, great stiffness, good anti-permeability and high melting point, but poor environmental stress cracking Resistance (ESCR).
- The defects of cylinder liner quality can be directly unveiled by cut opening the cylinder liners.

Problems Found in Cylinder Liner

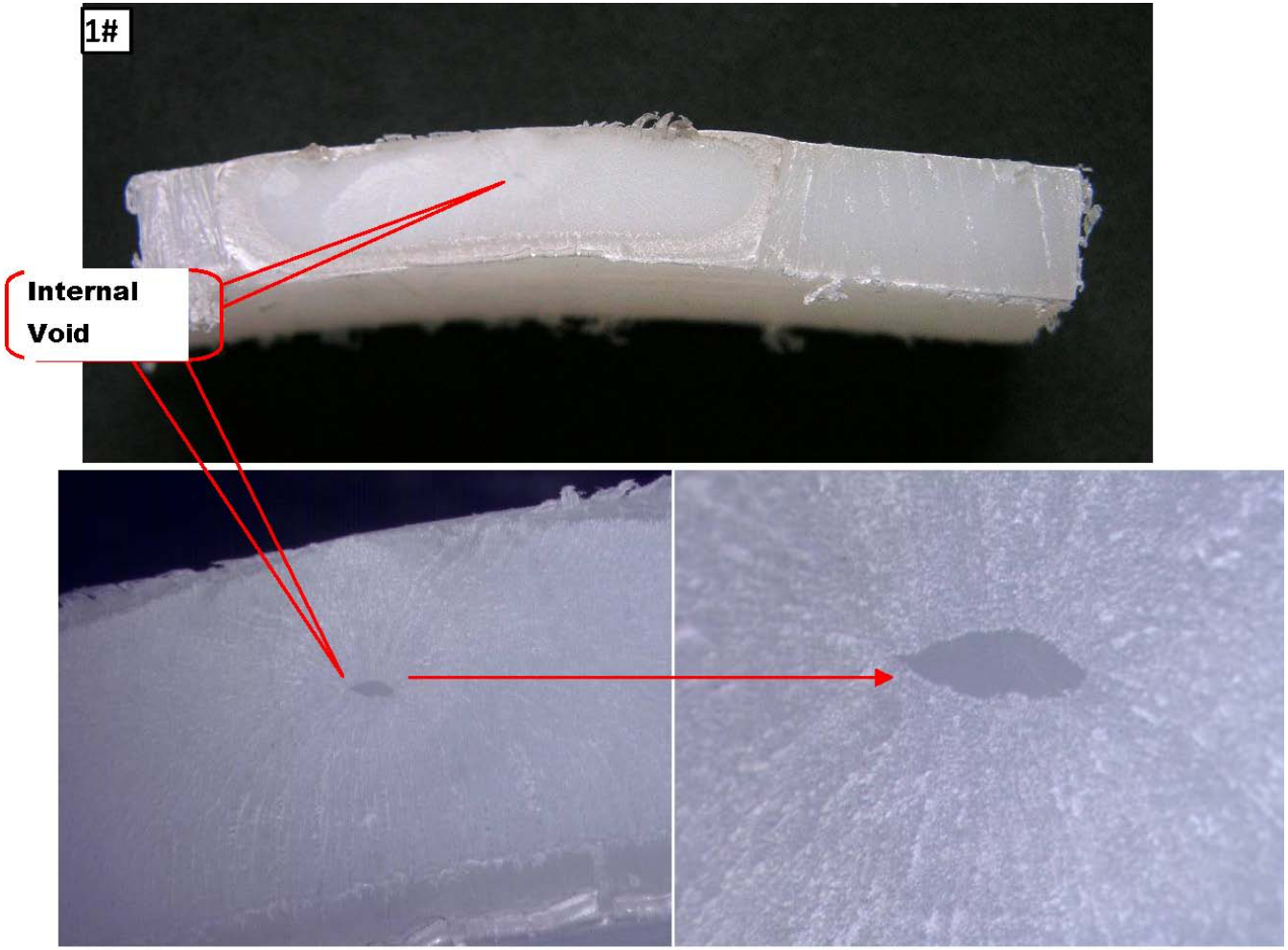
1. Crease on Internal Liner

Problems Found Cylinder Liner

2. Noticeable Macro Crack on Cylinder Liner

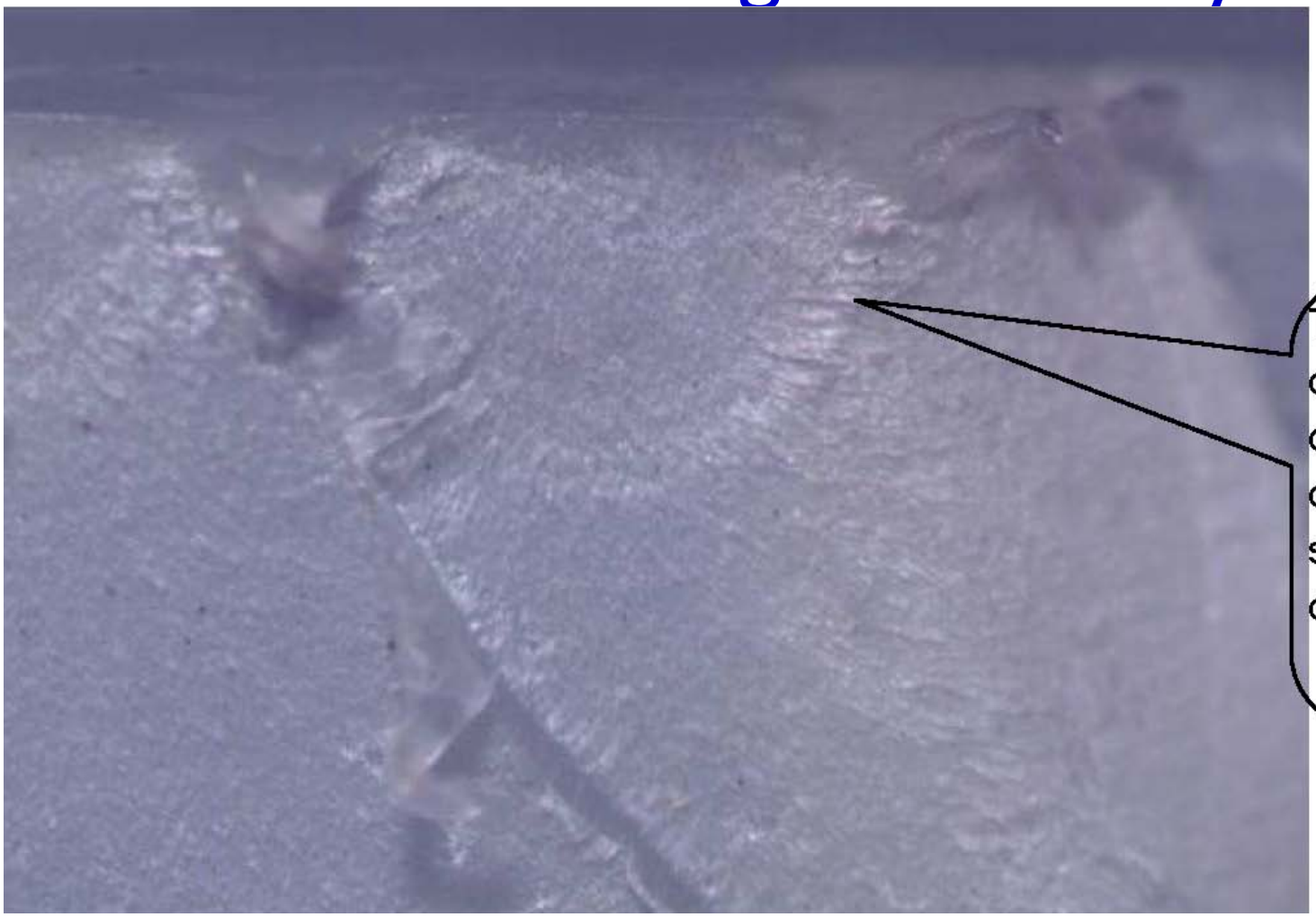
Quality of Plastic Cylinder Liner

1. HPDE Liner Layer Cavities



Quality of Plastic Cylinder Liner

2. Crazing in Liner Layer



Quality of Plastic Cylinder Liner
3. Coarse Crystalline

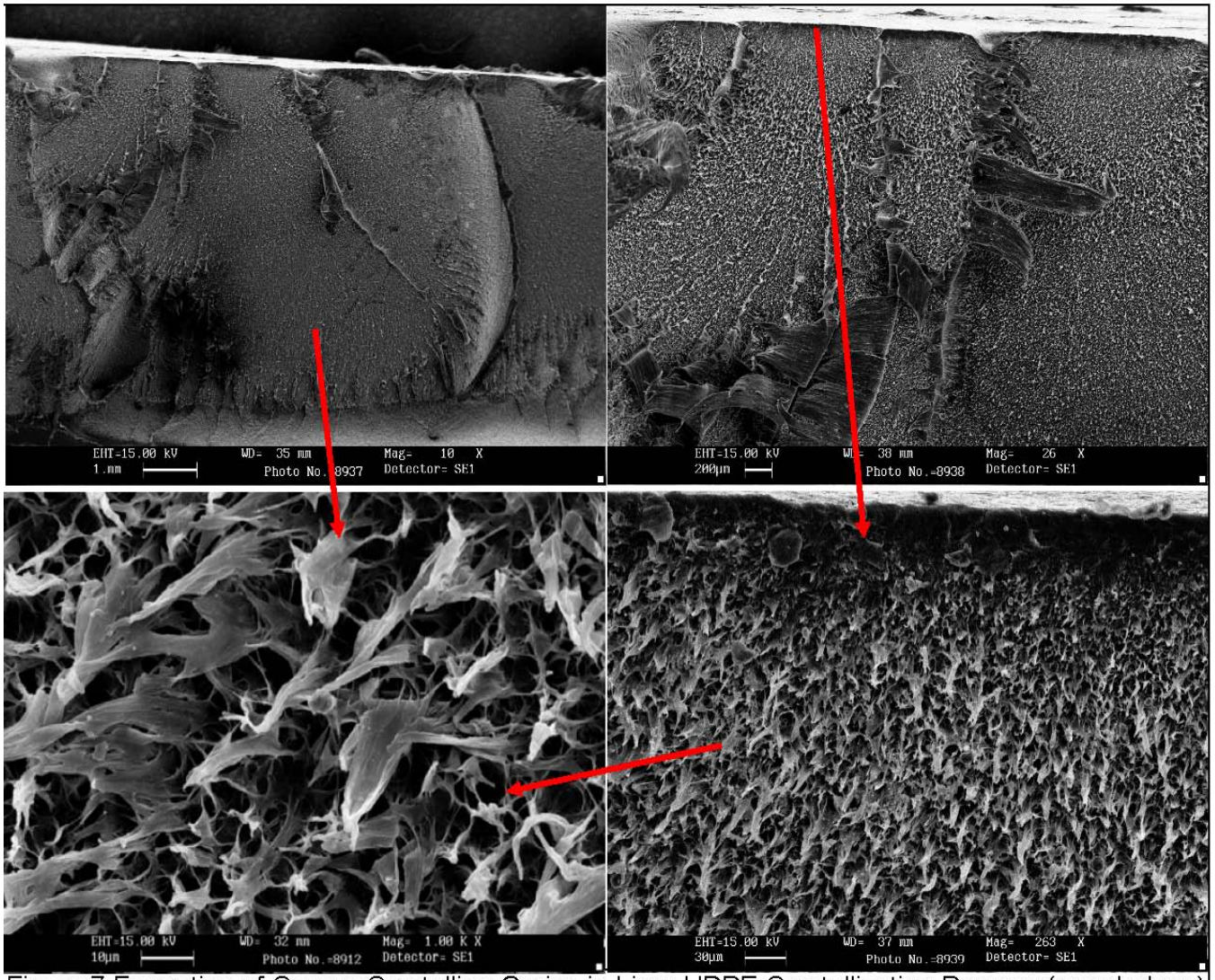


Figure 7 Formation of Coarse Crystalline Grains in Liner HDPE Crystallization Process (morphology)

Cylinder Liner and Composite Layer

1. No bonding between Liner and Composite layer

Figure 8 Internal and External Surfaces of Cylinder Liner

Liner Mechanical Property Testing Results

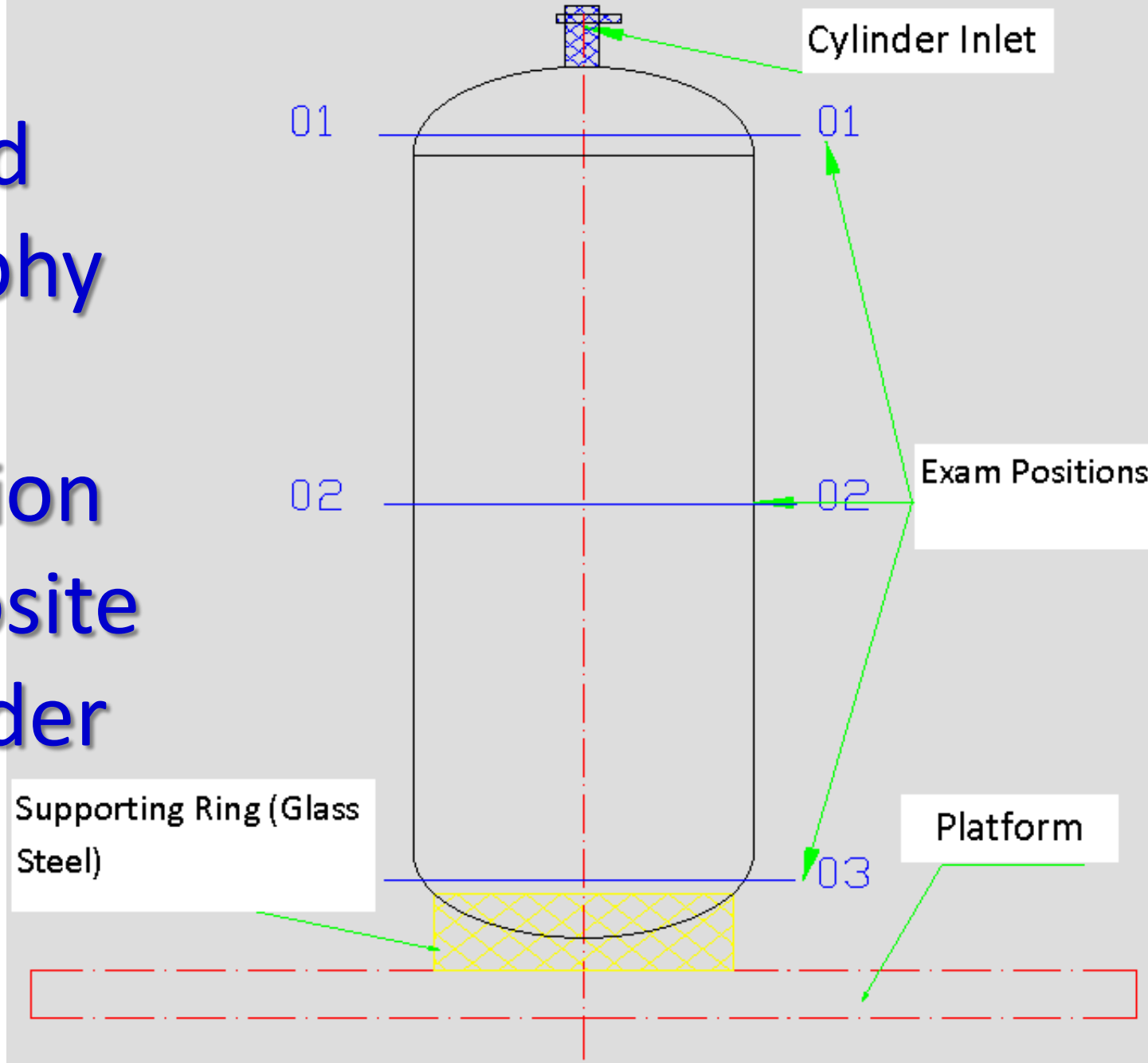
- Tensile strength at 70^0C is approximate 50% at room temperature,
- Tensile strength at -20^0C is approximate 160% at room temperature, and
- Modulus at -20^0C is approximately 200 times of that at room temperature.

Cylinder Liner and Composite Layer

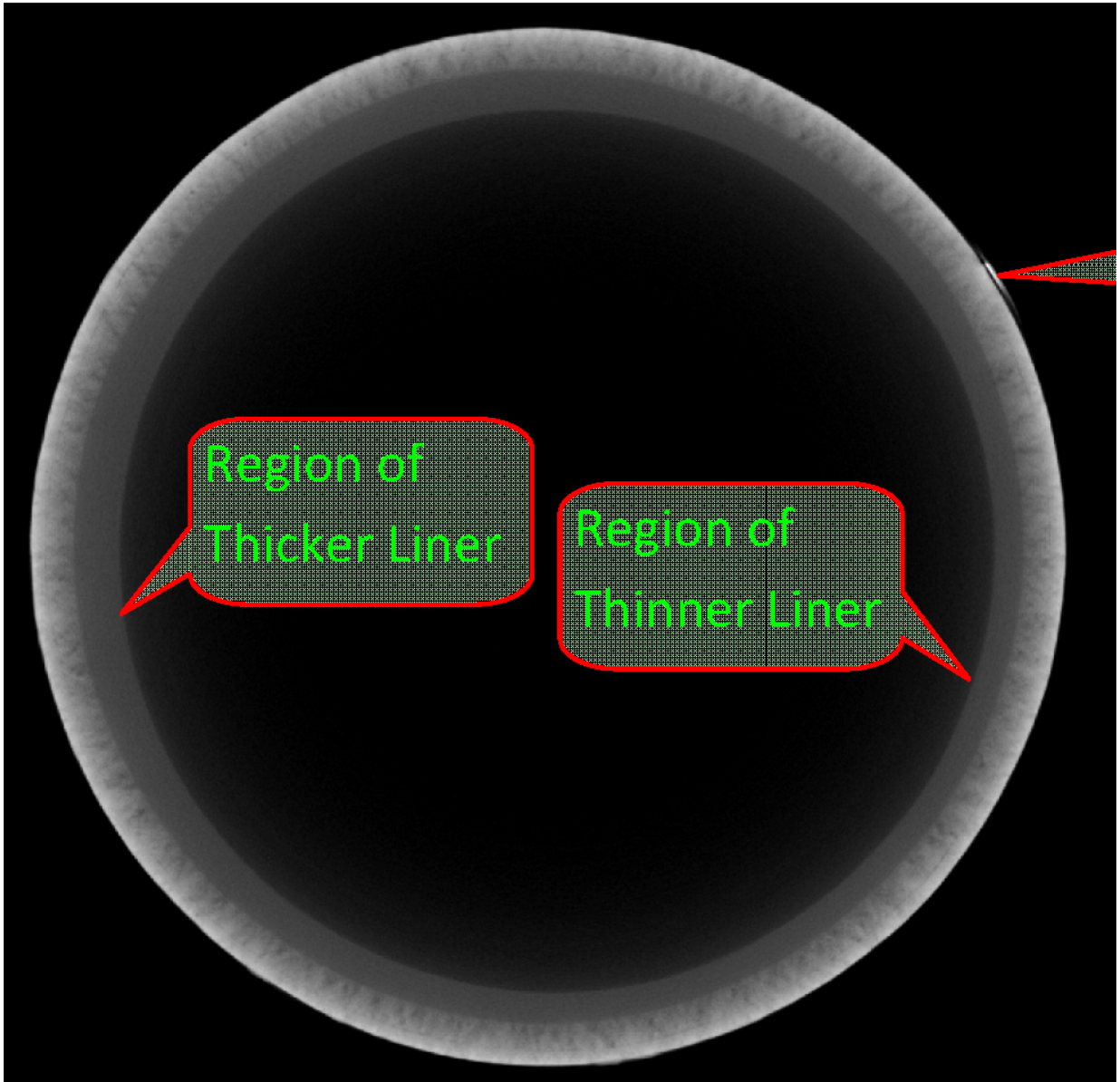
2. > 10 Times Difference in Linear Expansion Coefficient

Average Linear-Expansion Coefficients		
Temperature	70^0C	-20^0C
Composite Layer	11.2	11.8
Liner	210	160

Industrial Computed Tomography (CT) Examination of Composite Gas Cylinder

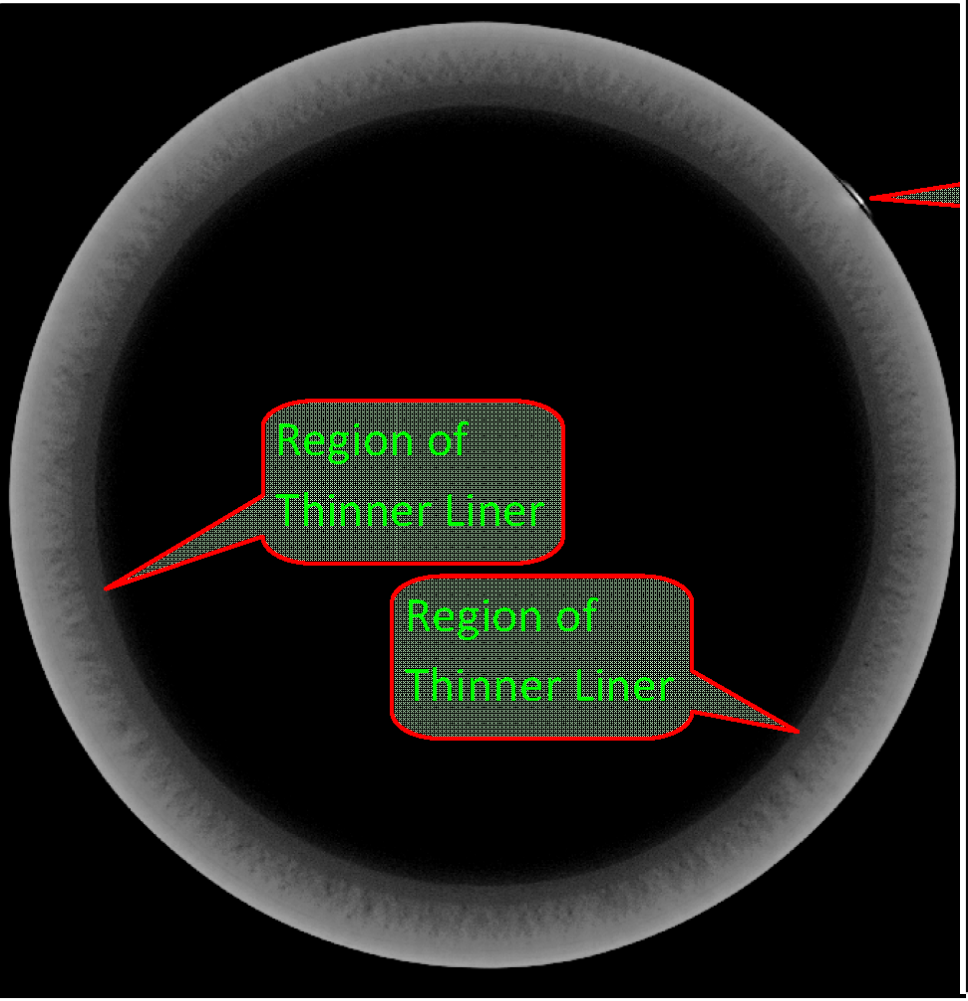


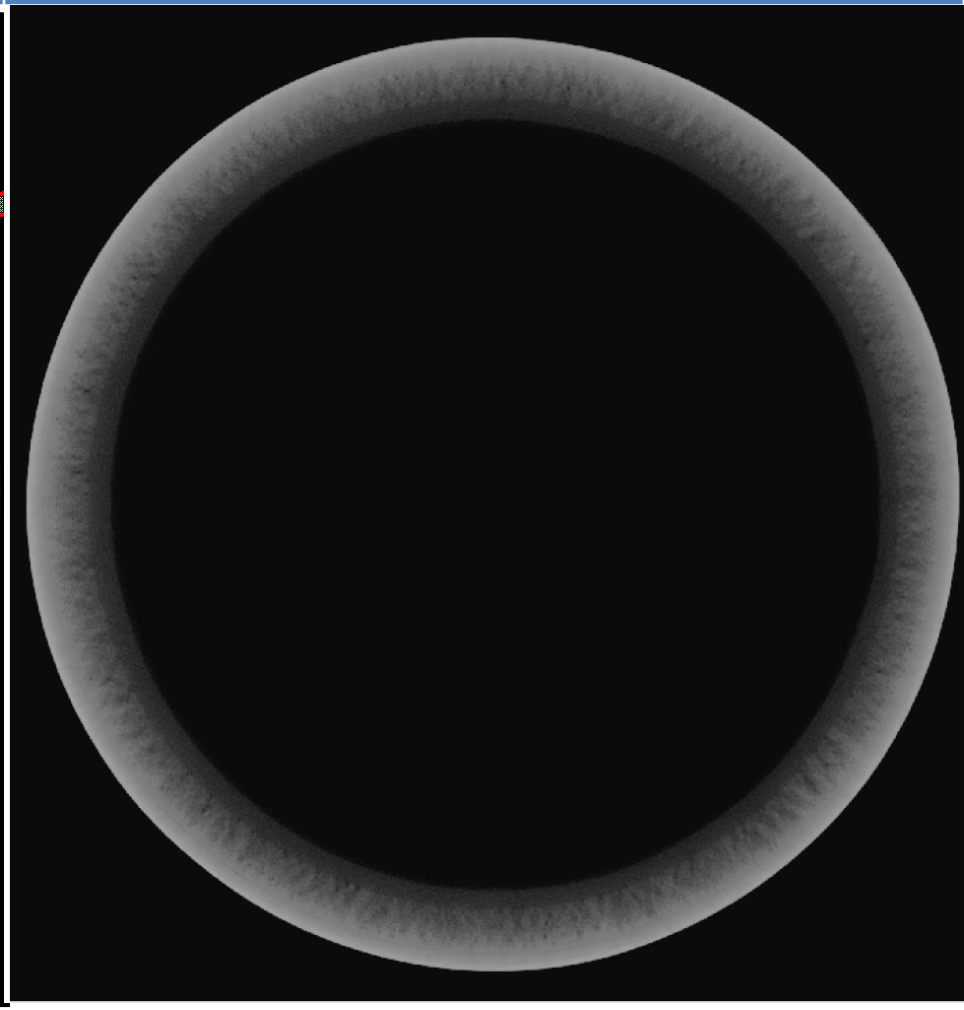
CT of 01-01 Layer at 4.8MPa Pressure Uneven Thickness



CT of 02-02 Layer: slightly uneven thickness

4.8MPa Pressure	2.3MPa Pressure





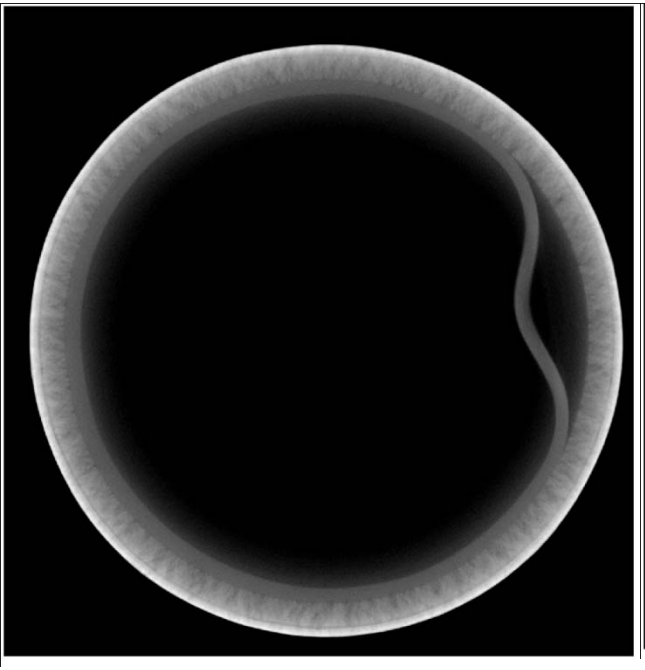
CT at 1MPa Pressure

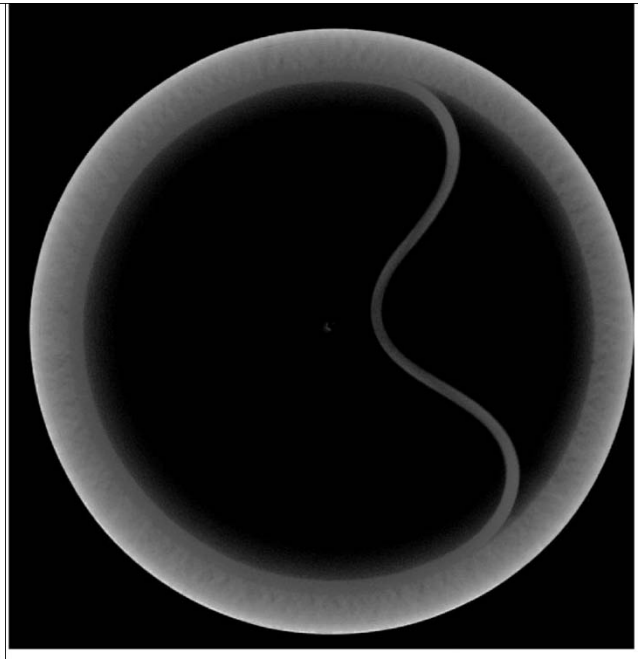
01-01 Layer
Crease
Thickness

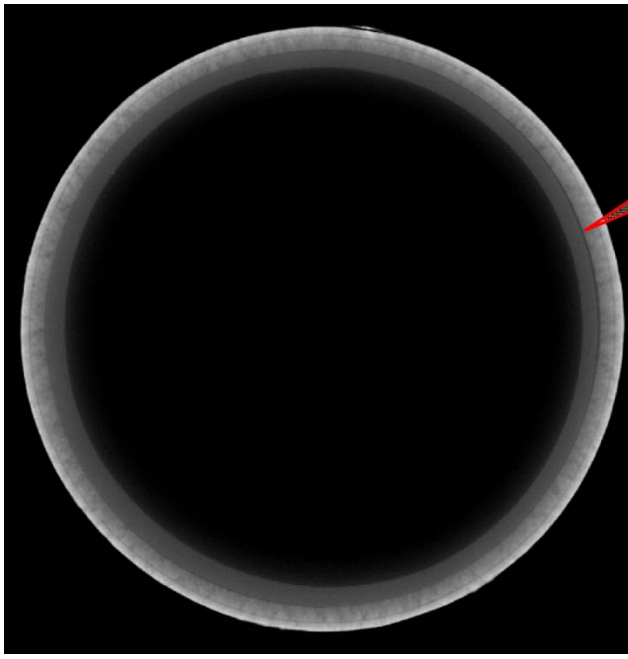
02-02 Layer
Crease

03-03 Layer
Uneven
Slightly Separation

All Near Thinner Thickness







Analysis of Results
Liner significantly changes along with the pressure variation

- Cylinder pressure ≥ 2.3MPa, the internal liner maintains original structural condition and fits tightly the external composite layer, which always has uniform thickness and structure with no exception.
- Cylinder pressure drops to 1MPa, the internal liner has apparent crease deformation.

Summary

- **The difference in linear expansion coefficients and slow cylinder pressure and temperature cycle during the gas compressing and releasing processes are the direct causes for liner defect** - Since the linear expansion coefficient of internal liner is much larger than that of the external composite layer, the internal stress of the liner will gradually increase following the increasing in liner volume expansion. While the internal stress increases over a critical value, an unstable local area of the liner turns inward deformation. After many cycles, the extent of deformation exceeds the liner deformation limit, this will lead to damages and cracks.

Recommendation

- Cylinder Pressure should be above 2.0MPa