Bulging Assessment and Long-Term Repair of Coke Drums

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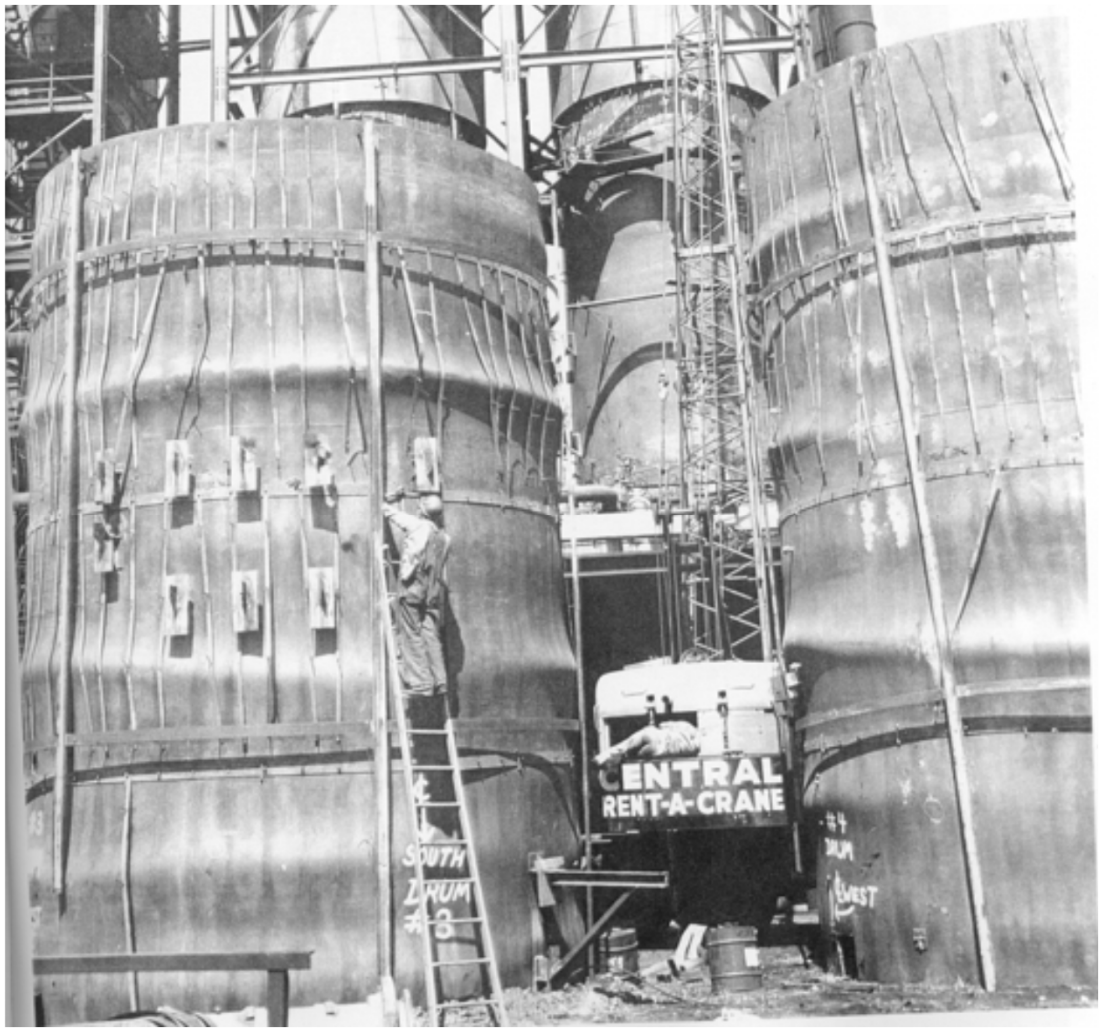
BR

Coke Drum Bulging

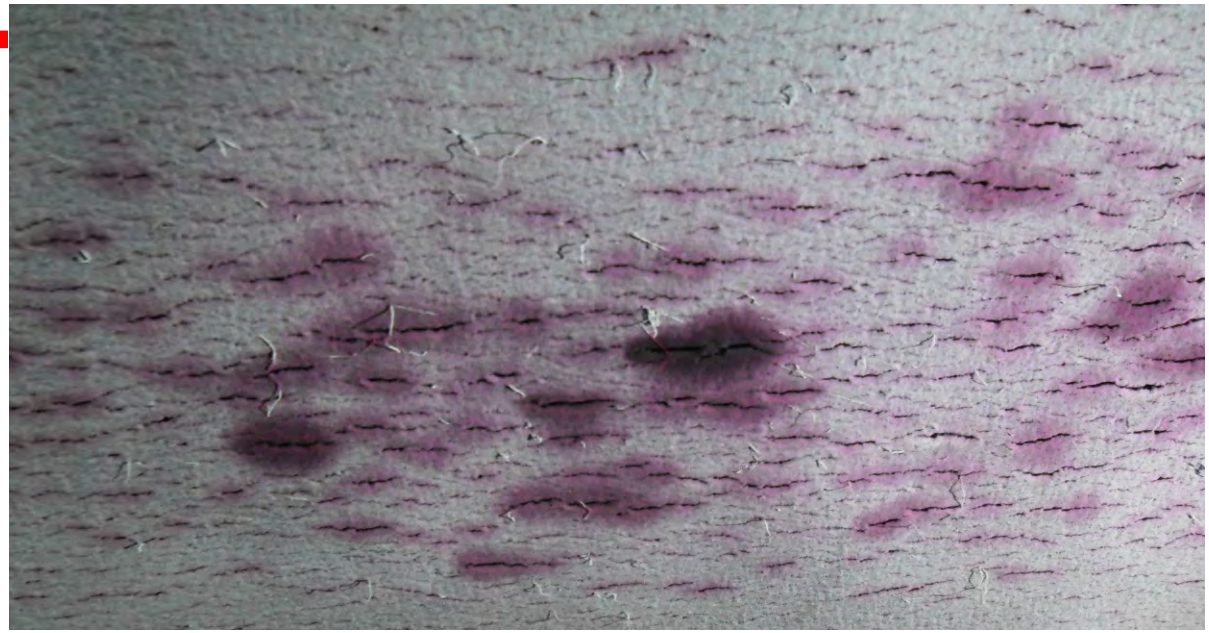
- Known for decades.
- Potential serious consequences.
- Premature drum replacement.
- Despite design improvements, still very common.

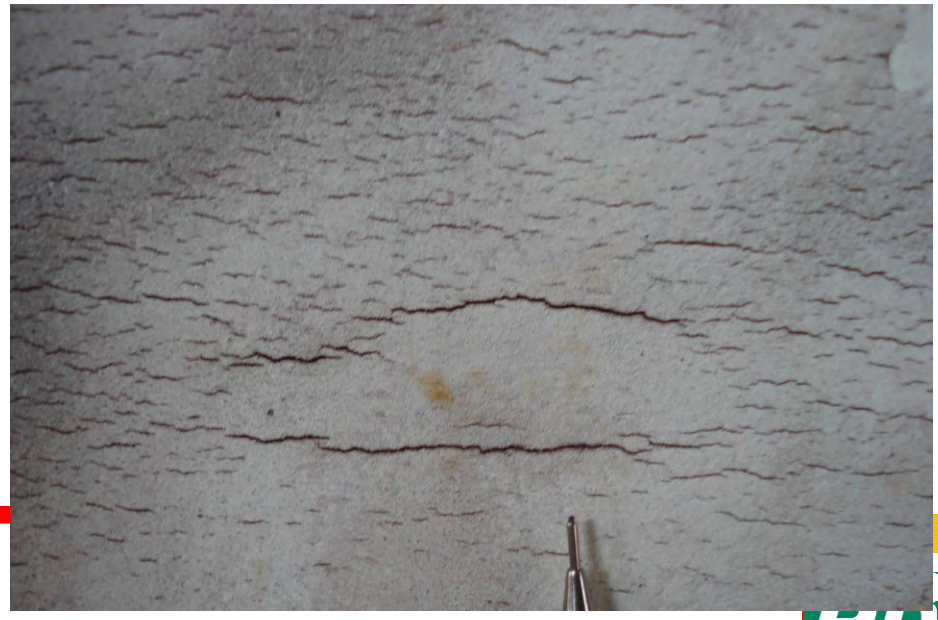


Courtesy of CB&I

Bulging-Induced Cracks

INTERIOR





EXTERIOR

Bulging Assessment per API-579 / ASME-FFS

- Level 1: N/A to coke drums
  - Fabrication tolerance.
- Level 2: N/A to coke drums
  - **Stress analysis criterion removed** after 2001 Edition. **No replacement yet**.
- Level 3: Infeasible and costly process
  - Lack of proper load definition.
  - Costly to obtain data.
  - Prohibitive to simulate bulging.

Current Industry Practice

- Stress analysis
- Strain analysis

Stress Analysis

- Linear elastic finite element analysis under unit load.
- Initial drum geometry includes bulges (no plastic strain).
- Assumes that stress concentration factors (SCF) correlate with severity.
- Advantages
  - Simple
- Disadvantages
  - Unrealistic model.
  - Excludes primary cause of bulging failure.
  - Susceptible to several error sources
  - Does not correlate with cracking history. Minimum SCF at peaks of bulges where most failures are observed.

Strain Analysis

- Plastic Strain Index (PSI)™
- High strain correlates with severity.
- Relates to failure limit of API 579/ ASME FFS
- Advantages:
  - Focuses on primary mode of failure.
  - Excellent correlation with bulging cracks.
  - Failure limits from an industry standard.
- Disadvantages:
  - Relatively new (since 2011).

Case Study

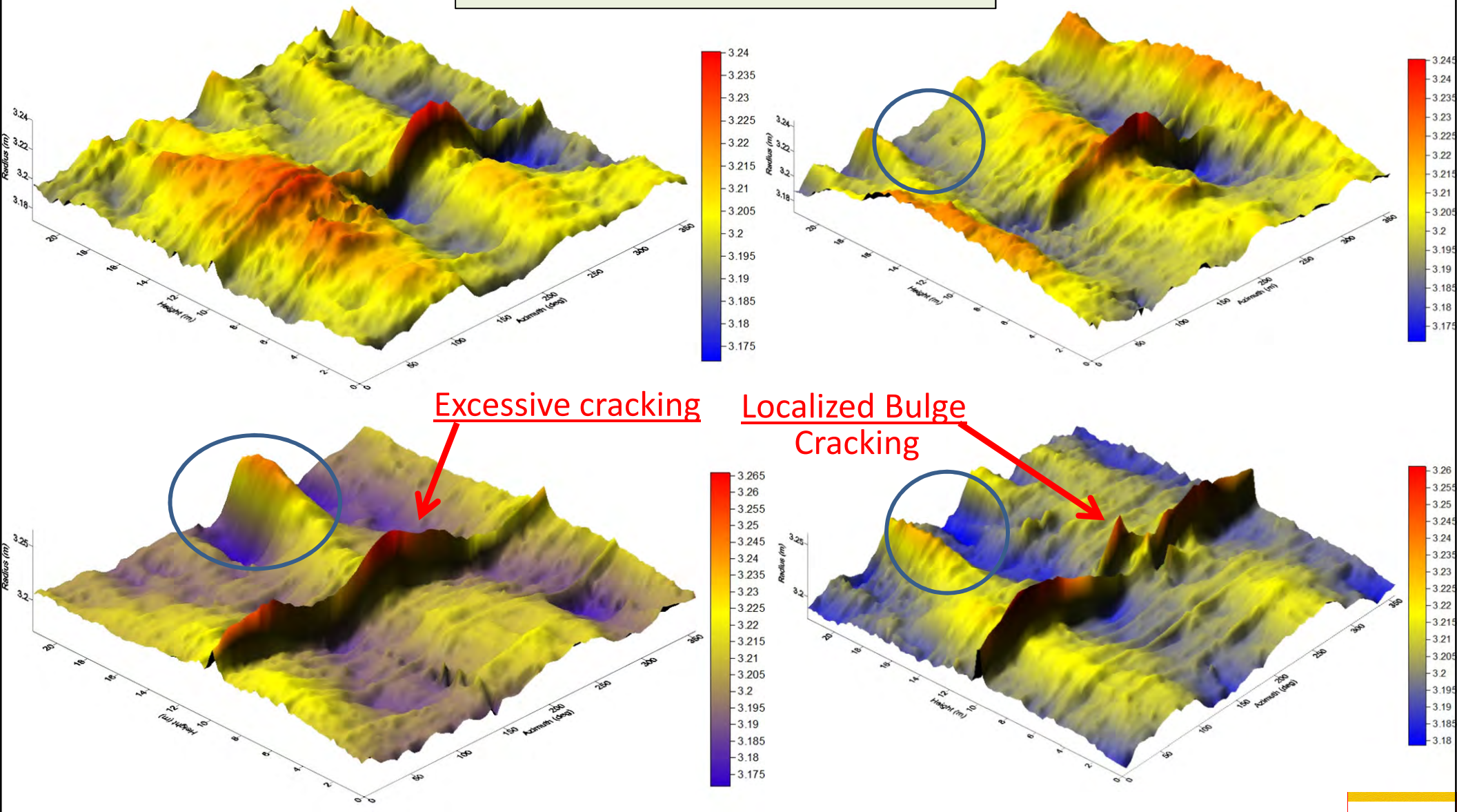
- Four sister drums commissioned in 1994.
- Observed bulging to various degrees
- Observed cracking
- Need:
  - Assess bulging and compare to cracks
    - SCF
    - PSI
  - Perform long-term repairs as needed

Equipment Description

- Inside diameter: 6.400 meters (21 ft).
- Tangent-to-tangent length: 22.6 meters (74 ft)
- Material: 1Cr - 1/2Mo with stainless steel clad (SA-240 TP405).
- Variable wall thickness: 12.5 to 25 mm (0.492 to 0.984 inch) with 3 mm clad.
- Nominal 48 hour full cycles (24 hour fill).

Radius Map

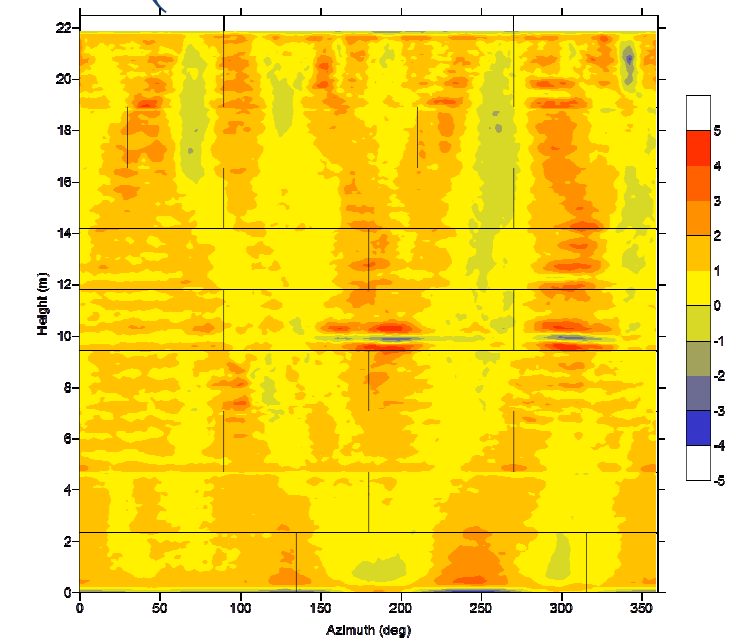
Various degrees of ovality circled

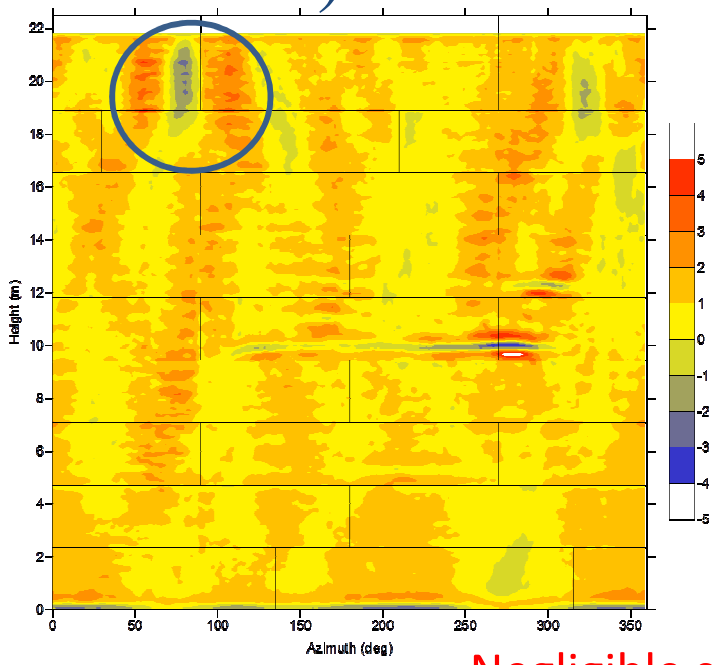


Stress Concentration Factor

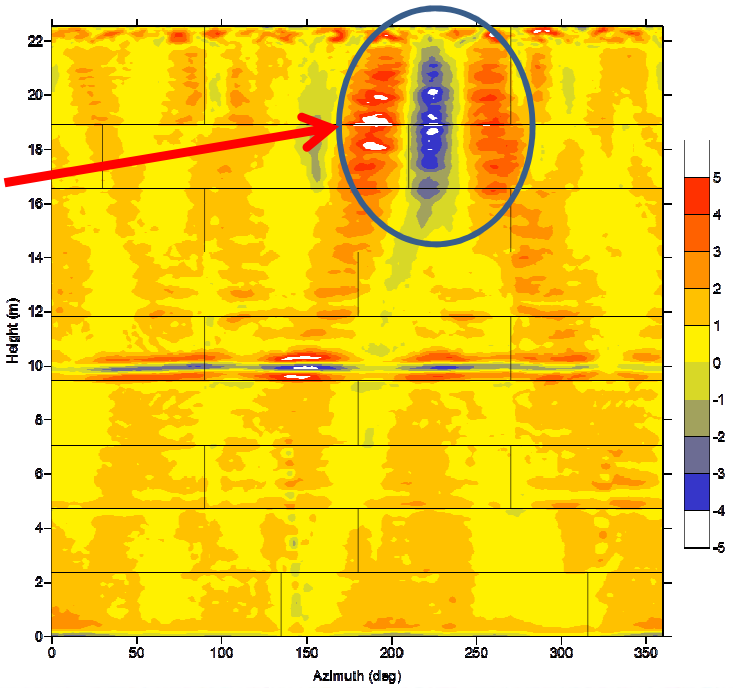
(axial SCF @ outside surface)

Ovality-based
High stress
concentrations
highlighted

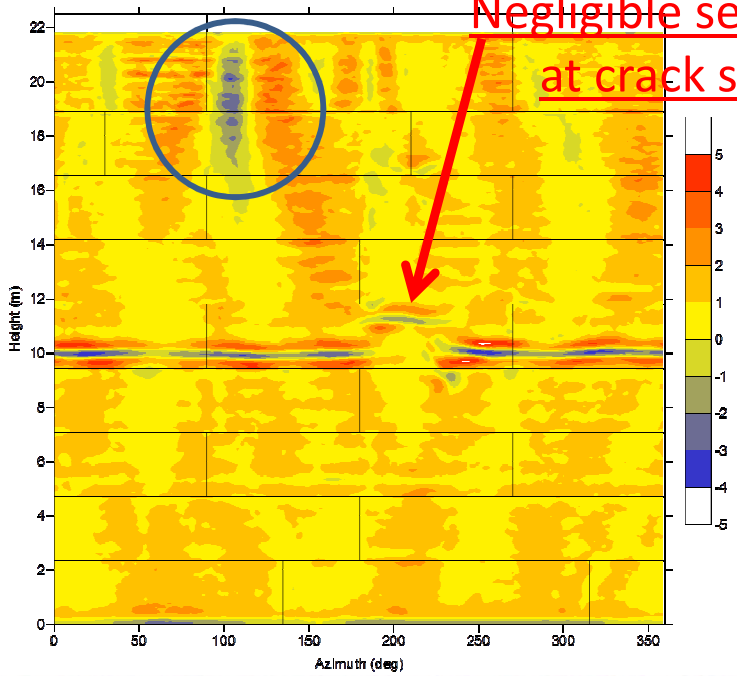




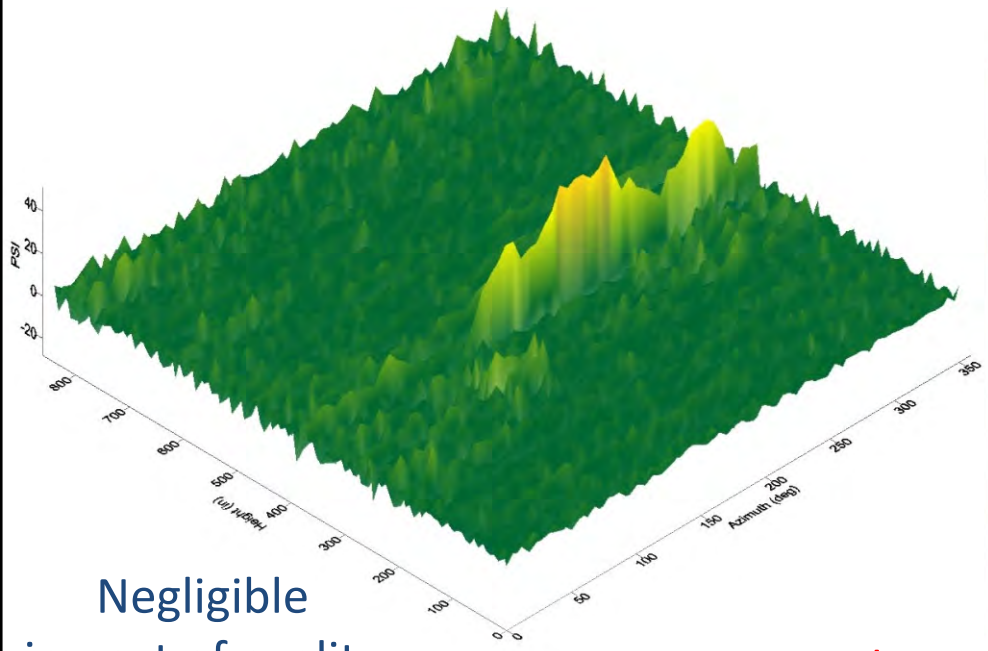
Highest SCF

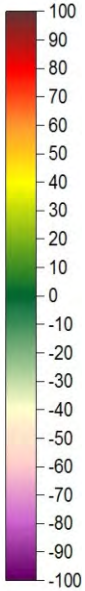


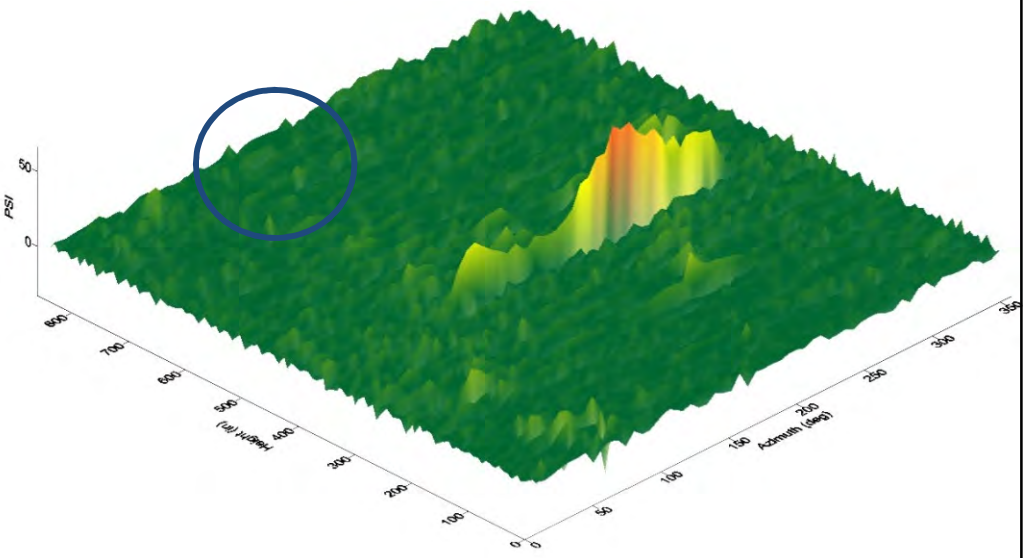
Negligible severity
at crack site



Plastic Strain Index (PSI)

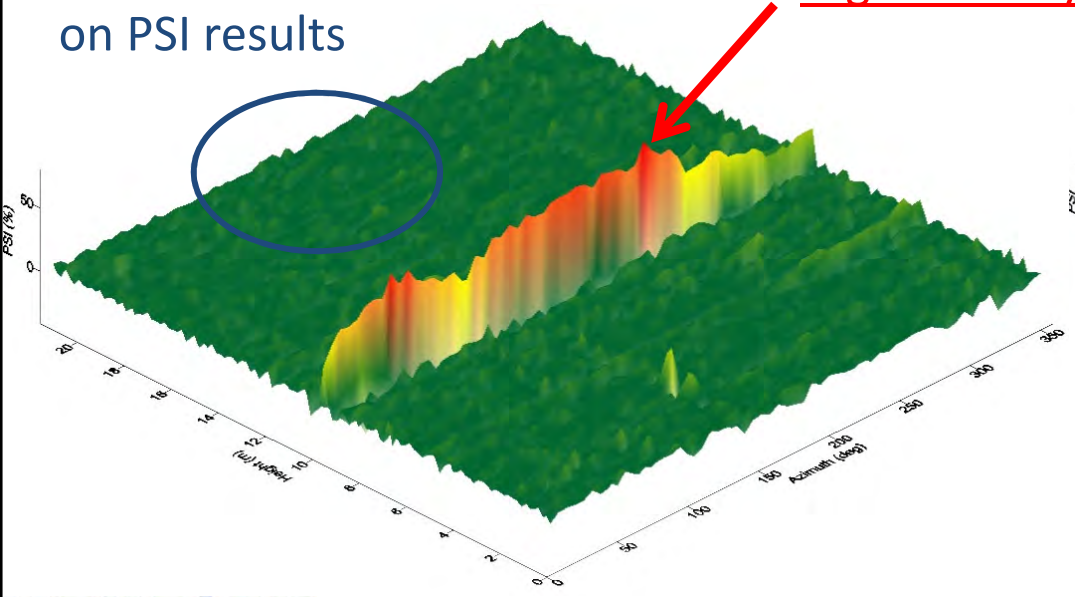


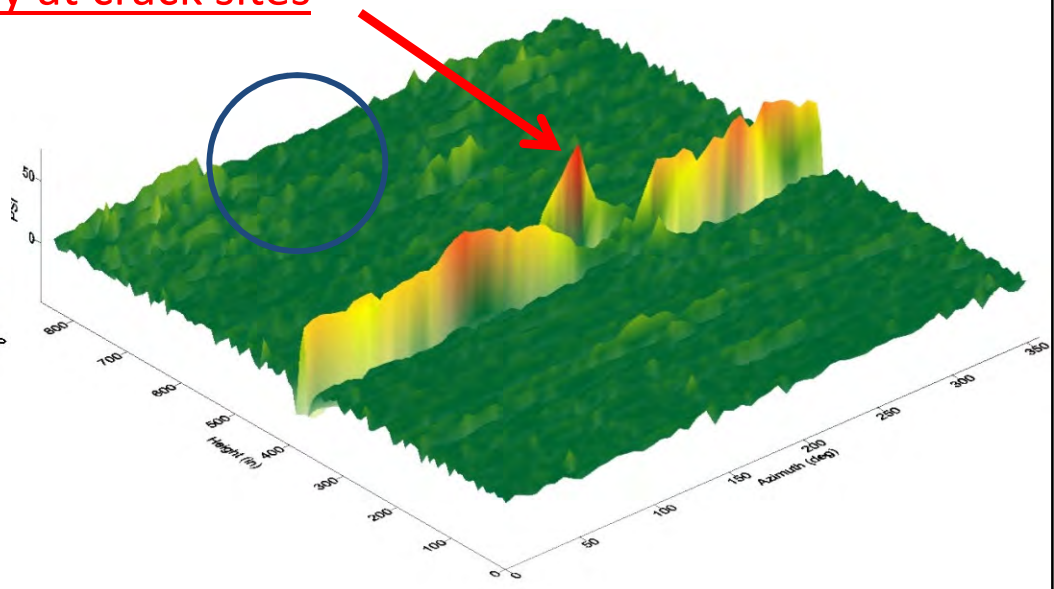




Negligible impact of ovality on PSI results

High Severity at crack sites





Conclusions from Assessment

- Stress (SCF) and strain (PSI) analysis techniques produced significantly different results.
- SCFs appeared to be susceptible to several error sources such as drum ovality and bulge shape.
- PSI has correlated well with bulging-induced cracks.

Long-Term Bulging Repair

- Plan developed based on PSI results.
- Automated weld overlay is preferred because:
  1. Vast majority of drums are in excellent condition.
  2. No advanced-stage bulging found.
- Automated weld overlay repairs:
  - Advantages.
  - Disadvantages.

Repair Plan

Plan developed based on PSI results

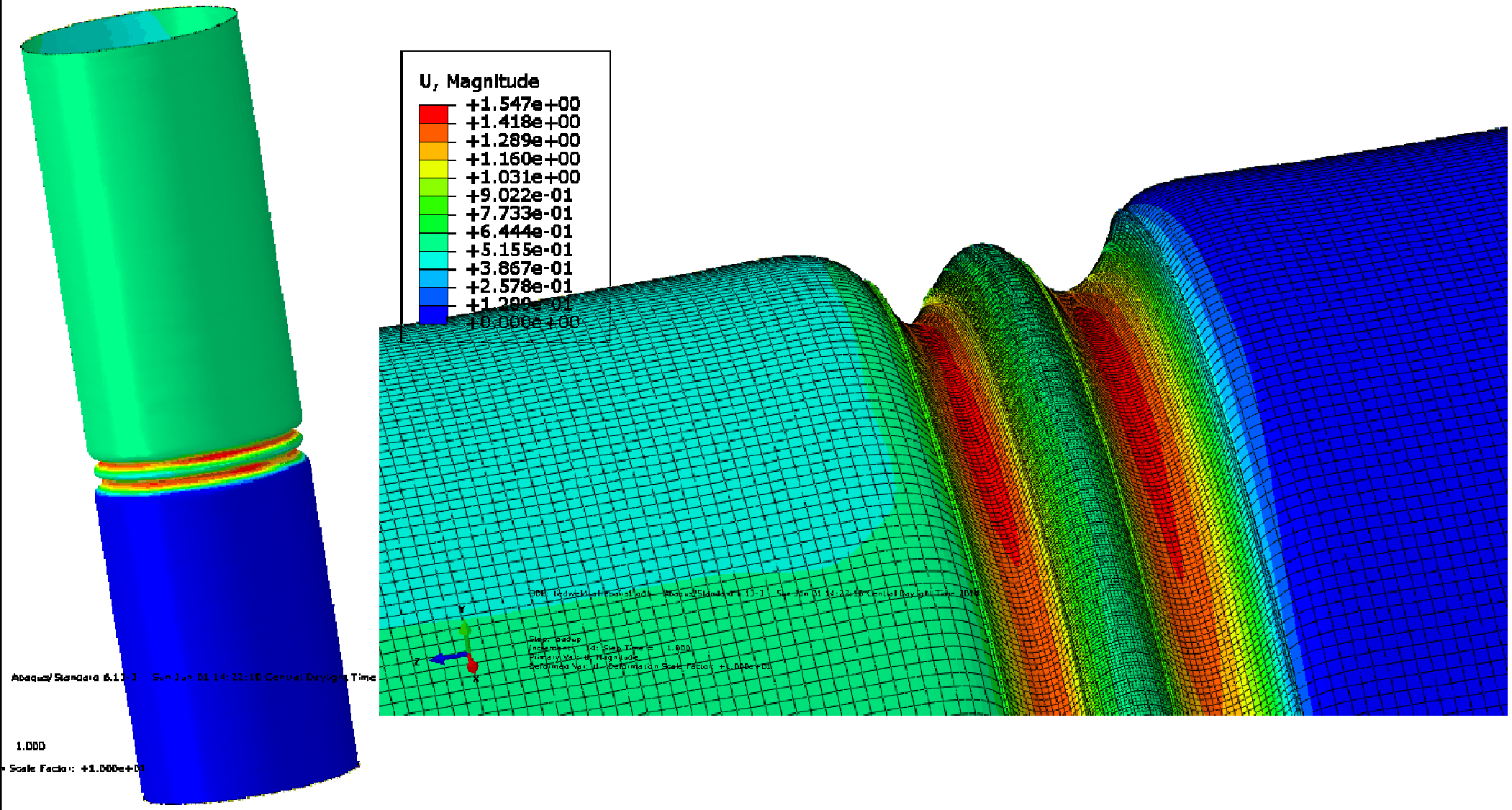
- Weld material and procedure
- Application side
- Thickness and layers
- Welding direction
- Weld overlay finish
- Clad removal
- Need for PWHT
- Perimeter Edge geometry and preparation
- Inspections

Analysis of Repairs

- Equivalent layer method
- Pass-by-pass simulation

Equivalent Layer Method

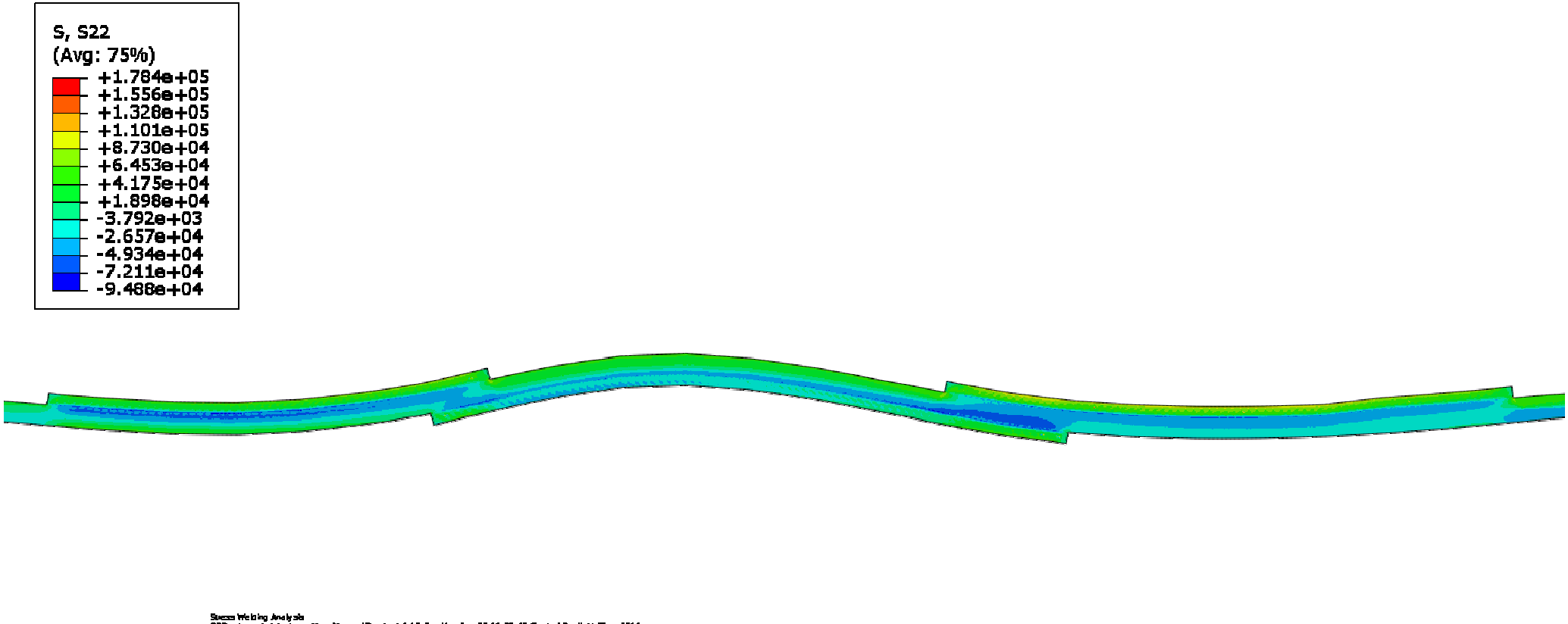
displacement magnitude



Pass-By-Pass Simulation
displacement magnitude

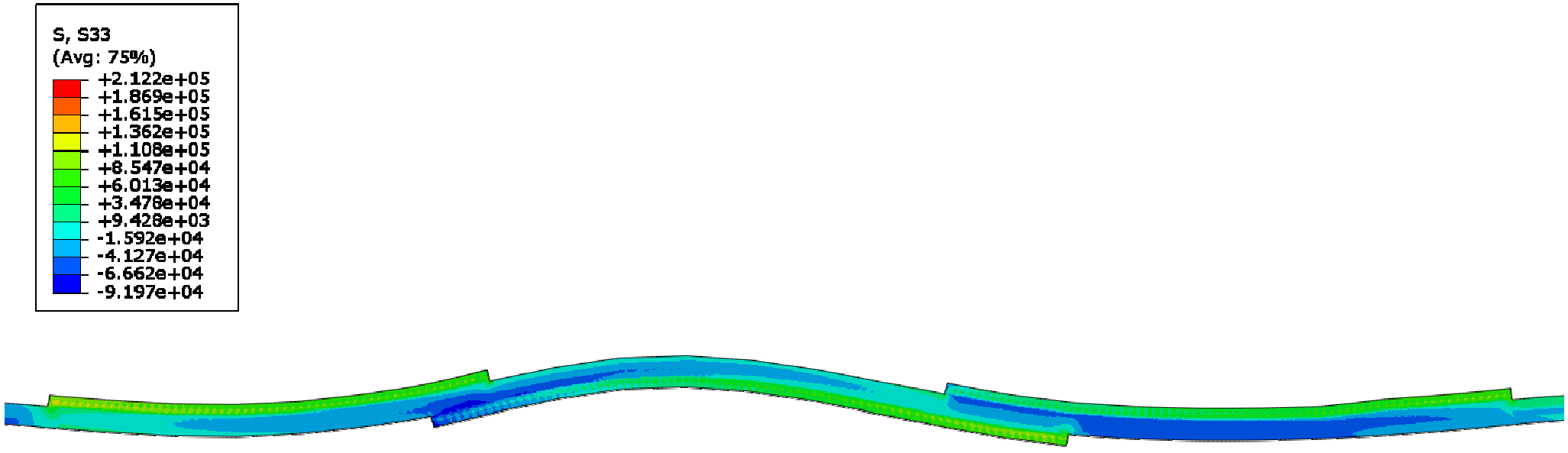
Pass-By-Pass Simulation

axial stress



Pass-By-Pass Simulation

hoop stress



Summary

- Four coke drums experienced different levels of bulging and cracking.
- Bulging severity was assessed using PSI and results were used to develop a long-term repair plan for most severely bulged drum.
- To estimate distortions, the repair plan was analyzed using two methods. Results were compared.
- Experience with repairs are discussed.