Determination of Maximum Allowable Repair Window for High Raised Process Column via Nonlinear Buckling Analysis

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Presentation Outline

- Introduction
  - Industrial challenges and solutions
- FEA modeling
  - How to make a simple model work
  - Wind load analysis
  - How to treat complicated load conditions
- Analysis and Results
  - ANSYS ready to use tools
  - Results
- Other applications
- Conclusions
Introduction

- High raised columns are one of most common process equipment
- Replacement cost is very high
- Normal design life is about 20 years
- Columns built 30 and 40 years ago still in service are very common.
- High pressure, high temperature and corrosive service conditions cause deterioration and damage
Introduction

Overview of a refinery complex
Introduction

A ULSD Unit
Introduction

- A Delayed Coking Unit
Introduction

- Process columns are complicated structure
Introduction

- Repair of damaged pressure vessel is common practice
- General and localized corrosion requires partial replacement of section
- Severe bulging and cracking require local component replacement
- Heavy lifting equipment is required for section replacement
- Lengthy turnaround time and high cost of repair
Introduction

Heavy Lifting Equipment used in Refinery Turnaround
Introduction

One of the Largest Cranes in the World
Introduction

Any incident could be very expensive. The scene shows a fall down crane in a refinery (not a Valero refinery) in Texas which killed 3 people in July 2008.
Process Column Repair Methods

• Shell Partial Replacement Methods
  – Section replacement
    • Requires lifting of the tower above the replaced portion
    • Long crane is required
    • Long T. A. requirement
    • High cost
  – Cutting window with shoring system
    • Labor intensive
    • Cost and time
    • Potential problem after removal of shoring
Process Column Repair Methods

- Shell Partial Replacement Methods
  - Cutting window without shoring
    - Fast turnaround with low cost
    - What is the maximum window size that could be cut
      - Large window requires less welding, and less repair time; large deformation, high risk of failure during repair
      - Small repair wind requires more welding and length repair time; less deformation and low risk
    - There is an optimum repair window size
    - Requires detailed engineering analysis
FEA Modeling

• A process column is a complicated structure
  – Vessel shell
  – Internals
  – Insulation
  – Piping attachment
  – Ladders and platforms

• A simple model without many details is desired
  – A cylindrical shell section with internal and external loads
Loads for FEA Model

- Weight of the column, including all structural attachment above the cutting windows
  - Vertical force
  - Bending moment
- Wind load
  - Bending moment acting on the top of the model
- Other external loads
FEA Modeling

- Wind load analysis
  - Basic wind speed
    - ASCE 7-05
    - Uniform Building Code (ICBO)
    - Weather broadcast
    - Site records and experience
  - Wind profile along column height
    - ASCE 7-05
    - Uniform Building Code (ICBO)
• Basic Wind Speed
  – based on nominal design 3-second gust wind speeds at 33 ft above ground
  – ASCE 7-05 Figure 6-1
• Wind velocity profile (schematic)

Figure from: Davenport, A.G.: Wind loads on structures.
• Wind load moment computation (1)
  – Integration over equipment height

\[ M_{\text{wind}} := \int_0^H d(y) \cdot p(y) y \, dy \]
FEA Modeling

- Wind load moment computation(2):
  - ANSYS FEA Approach
- Entire equipment modeling is required.
FEA Modeling

- Wind load moment computation (3):
  - ASCE 7-05 method, stepped velocity profile approach
  - Mathematically simple
  - Industrial standard
  - Small FEA model

\[
F_i := q_i \cdot G \cdot C_f \cdot A_f
\]

\[
M_{\text{wind}} := \frac{1}{2} \sum_{i=1}^{N} \left( d_i \cdot F_i \cdot h_i^2 \right)
\]
• Example of a simple cylindrical shell Model

Buckling Analysis for Flash Patch Repair
• How to imposed bending moment to the cylindrical model:
  - et,2,21
  - r,2,1e-20
  - type,2
  - real,2
  - csys,0
  - n,20000,0,0,L
  - e,20000
  - nsel, s, loc, z, L
  - rbe3,20000,roty,all
  - allsel
  - !Load case 1
  - f,20000,my,M
  - f,20000,fz,-sw*3.1415*2*RM*ts
  - finish
Analysis and Results

• Nonlinear buckling analysis implementation:
  - !SOLUTION
  - /SOLU
  - ANTYPE,STATIC
  - SOLCON,ON
  - NLGEO,ON
  - NROPT,AUTO
  - AUTOTs,ON
  - NSUBST,20,100,10
  - NEQIT,30
  - outres,all,all
  - SOLVE
  - SAVE
Analysis and Results

Figure 2
Example of buckled shell.
Central angle of the window is 50°; The maximum deflection is 2.095 inches. Deflection is enlarged for easy view.
Figure 3
Axial stress (Sz) distribution of shell with window central angle of 40° under 100 mph and tower weight.
Analysis and Results

Figure 5

Von Mises stress of shell with window central angle of 40° under 100 mph and tower weight.
Figure 6

Radius deflection at the window cut edge. Shell with window central angle of 40° under 100 mph and tower weight. The maximum deflection is 0.651".

Buckling Analysis for Flash Patch Repair
Figure 7
Vertical deflection at the window cut edge. Shell with window central angle of 40° under 100 mph and tower weight.
## Table 1. Summary of Nonlinear Buckling Analysis Results

<table>
<thead>
<tr>
<th>Window Central Angle</th>
<th>Window Width</th>
<th>Maximum Allowable Wind Speed</th>
<th>Maximum Radius Deflection at Window Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree</td>
<td>In.</td>
<td>MPH</td>
<td>In.</td>
</tr>
<tr>
<td>50</td>
<td>37</td>
<td>84</td>
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<td><strong>30</strong></td>
<td><strong>22</strong></td>
<td><strong>137</strong></td>
<td><strong>0.190</strong></td>
</tr>
</tbody>
</table>
Other Applications

• There are numerous applications of ANSYS nonlinear buckling analysis in the past few years. Few examples are:
  – Repair Plan for fractionator with long circumferential cracking
  – Fitness for service assessment for reactor with local corrosion
  – Fitness for service assessment for splitter column with fabrication damages
Conclusions

• With the help of ANSYS nonlinear buckling analysis, fast track and economic shell section replacement procedure has been developed resulting in significant time and cost saving. This paper illustrates how to economically model the highly complicated equipment and loading conditions via ANSYS with quick turnaround.

• ANSYS nonlinear buckling analysis is a powerful tool for the energy and refining industry.
Application of nonlinear buckling analysis for process columns

• Questions?

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