Automated Multiple 3D Crack Modeling

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Presentation Outline

• About Structural Integrity Associates, Inc. (SI)
• Background on 3D Crack Modeling
• SI’s Approach and Implementation
• Capability and Flexibility
• 3D Crack Modeling Procedures
• Example Models and Analyses
• Conclusions
About SI

- Engineering Consulting Firm
  - Founded in 1983 in San Jose, California
  - Specialized in Prevention/Control/Repair of Structural/Mechanical Failures
  - Consulting Services/Research and Development/Software and Data Acquisition Systems
  - Strong Participation in Industry Codes and Standards Activities
  - Over 200 Full Time Technical Staff
Our Offices
(Special Markings for NPS Offices)

- Headquartered in San Jose
- Branch offices throughout the United States and Canada
- Affiliates in China, Taiwan, South Korea, and Spain
- Serves clients worldwide
Divisions and Service Offerings

NUCLEAR POWER

FOSSIL POWER

ALTERNATIVE POWER

PROCESS INDUSTRIES

GAS & OIL

Complete Engineering Services

- Structural and Stress Analyses
- Fracture Mechanics Analysis and Risk Assessment
- Management of Aging Buried Piping
- Materials/Metallurgical/Corrosion Engineering
- Nondestructive Examination (NDE)
- Root-Cause Failure Analysis
- Welding Engineering and Residual Stress Analysis
- Vibration Analysis and Monitoring
- Fatigue Monitoring and Management
SI’s ANSYS FEA Usage

Design

Refurbishment

Crack Analysis

Fabrication
Background on 3D Crack Modeling

• Multiple cracks of different types and forms can co-exist in a single component
  – Interaction between cracks within close proximity

• General crack modeling macros and software that interface with ANSYS
  – Typically only capable of modeling a single crack
  – Limited to predefined shapes and types
  – Multiple crack modeling via 3rd party proprietary software
  – Added cost in quality assurance
SI’s Approach

• Automated multiple 3D crack modeling
  – Works on existing mesh
  – Combined to form irregular crack profiles
• Crack profiles do not need to conform to predefined shapes
• Crack types can be combinations of
  – Half cracks
  – Full cracks
  – Surface cracks
  – Sub-surface cracks
  – Partial surface cracks
• Quick FEA solutions using close approximation of actual crack shapes
Implementation

- Logics encoded in ANSYS APDL macros called “AnTip”
- Modify elements and insert spider-web type mesh pattern along 3D crack fronts
  - Native ANSYS commands and procedures
  - Native ANSYS models and analyses
- Automated results post-processing
  - Stress intensity factors (K_I, K_II, K_III) are automatically extracted
  - Use ANSYS KCALC command
  - Results saved in comma separated values (CSV) file format
  - Automated K extractions for transient analyses of multiple load steps
- Results ensured by the existing quality assurance of the ANSYS software
Optional GUI to Create ANSYS Input Files

- Inputs
  - Database to convert:
  - Crack definition file:

- Outputs
  - Output directory:
  - Output filename:

- Special Features
  - Create crack face stress application routines?
  - Stress database:

- Crack Property Inputs
  - Same type, co-planar cracks (one CSYS)
  - Varying types or varying planar cracks
  - Non-planar cracks or missing crack CSYS
  - Crack front no. (99 max)
  - Crack plane CSYS:
  - Crack type:
    - Half surface crack
    - Full surface crack
    - Half subsurface crack
    - Full subsurface crack
  - Apply symmetry BC on half crack plane?
    - No
    - Yes

# Settings must be stored via [Update Settings] #

[Update Settings] [Stored] [Review Settings] [OK] [Exit]
3D Crack Modeling Procedures: Select Location

Location of corner crack to be inserted
Procedure: Run Macro and Perform Analysis

Crack tip elements inserted around crack fronts
Procedure: Review K Result Outputs

• Results saved as .CSV files
• K results for each crack front node
• Direct open in spreadsheet program for further processing
Procedure: Define Crack Plane and Crack Front

Crack Plane

- FACE1 and FACE2
- FRONT2 (3 nodes)

- FRONT1 (7 nodes)
Capability and Flexibility

- Multiple cracks
- Combined crack types
- Non-planar and arbitrary crack planes
Capability and Flexibility

- Cracks initiate in the middle of another (T-Crack)
- Cracks crossing each other (Cross-Crack)
- Cracking along seam welds
Capability and Flexibility

- Approximate irregular crack shapes
- Map stresses from separate analysis as crack face pressure load (based on linear super position principle)
Capability and Flexibility

- Overlapping cracks
- Approximate crack growth
- Evaluation acceptability of crack depths
CONCLUSIONS

- Multiple 3D crack modeling and post-processing tool
- Native ANSYS models, analyses, and results
- Work with existing FE models and mesh
- Support any user definable crack profiles
- Automated process and streamlined post-processing
- Enable detailed evaluations of interactions between multiple cracks and irregular cracks within a significantly short amount of time.
Questions?