Mechsafe Engineering - Overview

• Formed in 2016 in Perth, Western Australia

• Specialising in:
  • Advanced failure analysis
  • Advanced fatigue design and analysis
  • Reliability, availability & maintainability analysis
  • Engineering critical & fitness-for-service assessments
  • Strain gauging and condition monitoring
  • Cathodic protection and corrosion analysis
  • General design / verification / simulation
• Matt Rudas background
  • MPhil – WIT/University of Swansea (UK) - fracture of FRP composites
  • PhD - University of Western Australia - crack propagation in metal-ceramic composites
  • Fatigue design, failure analysis, stress analysis, strain gauging
  • Two Australian design patents (international patents pending)

• Strong background in both finite and boundary element techniques
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- Gas turbine blade fatigue failure
- Railway bridge fatigue failure
- Rotating machinery fatigue failure
- Gear tooth failure
- Shaft fretting fatigue failure
- Rolling contact fatigue failure
- Rail head check fatigue failure

Image source: eurailscout.com
Engineering Failure Analysis

• Component Failure Analysis (CFA)
  • Considers physical influences such as loads, material properties, environment
  • Identifies failure mechanism

• Root Cause Investigation (RCI)
  • Increases the detail of a CFA
  • Considers human factors

• Root Cause Analysis (RCA)
  • Causal factor charting
  • Considers management systems
  • Interested in causes over which there is control
Component Failure Modes

- Fatigue (44% - Reliability Center, Inc.)
  - Poor design
  - Incorrect operation
  - Incorrect assembly/installation
  - Change in operating parameters
- Corrosion
- Wear / maintenance failure
- Manufacturing
  - Heat treatment

Image source: reliasoft.com
Component Failure Modes

- Overload
  - Plastic collapse
  - Instability (buckling)
- Serviceability
  - Vibration
  - Deflection

Image source: shellbuckling.com
Fatigue Failure

- Fatigue failure
  - Initiation
    - Welded vs cast/machined/forged
    - $S-N / \varepsilon-N$
  - Propagation/brittle fracture
    - Crack growth laws e.g. Paris, Forman
    - Linear elastic fracture mechanics
    - Ductile brittle transition
Fatigue Failure

• Accurate analysis requires accurate inputs:
  • Loads/stresses
    • Strain gauges
    • Pressure transducers for hydraulics
  • Numerical analysis
  • Material properties
    • MDR’s
    • Hardness testing
    • Metallurgical analysis
  • Fracture parameters
    • Stress intensity factors
Fatigue Failure

• Fracture parameters are difficult to determine
  • AS 3788 - Pressure equipment - In-service inspection
    • Simplified fracture mechanics and corrosion assessments
  • BS 7910 - Guide to Methods For Assessing the Acceptability of Flaws in Metallic Structures
    • Failure analysis, acceptance criteria, life extension, justification of deviations from a design code
• Numerical analysis
Numerical Analysis

• Unlike codes, not restricted by:
  • Simplistic geometric assumptions
    • e.g. flat plates, tubes/pipes
    • Crack propagation always straight/planar
  • Simplistic assumptions regarding the loads
    • Changing stress fields during crack propagation
    • Rotating principal stress directions

• Numerical analysis avoids the conservatism required by the assumptions made using hand calculations
Numerical Analysis

• Mechsafe staff have been using BEASY for 20+ years
• Boundary element based – DBEM crack modelling
• Non-linear contact and crack face loads
• Automatic crack growth
  • As the crack grows, K values along the crack front and the fatigue growth law determine the new crack front shape
  • Cracks can grow round corners and change shape as determined by the geometry and loading
• Any crack shapes can be added to a crack library
Model Configuration
Flaw Definition - Library
Flaw Definition - User Defined

- User defined cracks can be added to the crack library if required.
- This process uses a mesh of the required crack along with some additional crack front & breakout edge data.
Material Properties

- NASGRO material property database is in software
- User defined values can be added to the model
- Tabulated $da/dN$ (crack growth rate) data can be used
Non-planar Flaw Fracture Assessment

Images courtesy BEASY UK
Automatic Crack Propagation

Images courtesy BEASY UK
Fretting Fatigue – Contact with Crack Growth

Images courtesy BEASY UK
Post Processing Tools

Images courtesy BEASY UK
BEASY Defect Scanner

- Produces a map of critical crack sizes
  - Threshold for crack growth
  - Critical size for fracture

Images courtesy BEASY UK
Damage Tolerance & Design of Repairs

• All techniques discussed here can provide the following information
  • growth rates of cracks
  • time to reach the critical size
  • a new value of operational load to slow crack growth to an allowable rate
  • a new value of operational load to stop any crack growth at all
  • the effectiveness of repair methods that don’t completely eliminate the presence of the cracks
  • a sensitivity study of the effect of errors in the measurement of the crack size using NDT, if different NDT methods are giving different results
  • inspection intervals and locations
Summary

• Equipment failure, unnecessary maintenance shuts and badly designed repairs can cost operators large sums.
• These costs can be avoided by the application of predictive assessments.
• Modern numerical techniques and software enhances fracture mechanics assessments, and makes them more affordable.
• The information that these assessments provide is essential for critical asset management and maintenance strategy considerations, resulting in cost savings, less equipment downtime and accident prevention.