Agenda

Introduction

What is Fatigue and Why is it important

Approaches for Fatigue Analysis

ANSYS nCode DesignLife overview

Questions
ANSYS® nCode DesignLife™

Integrated within ANSYS Workbench to provide a leading solution for advanced fatigue analysis.
What is Fatigue?

Fatigue is:

Failure under a repeated or otherwise varying load which never reaches a level sufficient to cause failure in a single application.

The initiation and growth of a crack, or growth of a pre-existing defect, until it reaches a critical size.

The progressive and localized structural damage that occurs when a material is subjected to cyclic loading.
Why is it Important?

Why do we need to do Fatigue Analysis?

• “...Between 80 - 90% of all structural failures occur through a fatigue mechanism...”

• “…The estimated annual cost of fracture and fatigue to the US was 4.4% of GDP…”

Fatigue is a statistical, not deterministic, phenomenon.

- Stress-life
- Strain-life
- Crack growth

Fatigue is a statistical, not deterministic, phenomenon.
Fatigue Analysis: Stress-Life (SN)

SN is also known as “High Cycle Fatigue” or “Nominal Stress Approach”

Elastic stress history used to determine life

Used extensively for welded joints and non-metallic materials

Suitable for design lives greater than 10,000 cycles

Well established, familiar, large amount of material data available

Simple loadings can be analyzed as a hand calculation

Wöhler circa 1850

[Graph showing cyclic stress vs. number of cycles with data points for smooth and sharp shoulders]
Fatigue Analysis: Strain-Life (EN)

EN is also known as “Low Cycle Fatigue”, “Crack Initiation” or “Local Strain Approach”

Elastic-plastic strain history used to determine life

Local plasticity can be estimated from fully elastic FE analysis or computed directly in ANSYS

Suitable for low and high cycle fatigue

Cycle counting and plasticity corrections difficult to do by hand.
Fatigue Analysis: Crack Growth

Crack growth known as crack propagation, or fracture mechanics

Predicts cycle by cycle crack growth

Used in aerospace Damage Tolerance analysis

Determine impact of known or suspected flaws
Combined loading scenarios accumulate damage
- Stresses must be combined
- Cycles associated with each combination must be counted
- Cumulative effect of the combinations must be determined

Rainflow counting is the most common cycle counting algorithm
- Applicable to both SN and EN
- Automated in ANSYS nCode DesignLife

Miner’s Linear Damage Rule is the most common damage accumulation algorithm
- Applicable to both SN and EN
- Automated in ANSYS nCode DesignLife

\[ \sum_{i=1}^{I} \frac{n_i}{N_i} \geq 1 \]
ANSYS® nCode DesignLife

ANSYS™ Workbench®

Engineering Data → Materials → Stresses → DesignLife

Mechanical

Loads
ANSYS® nCode DesignLife™

- nCode OEM Partnership
- nCode DesignLife
  - Advanced Fatigue Analysis
  - Process Orientation
  - Ease of Use
- Workbench Integration
- DesignLife Systems
- Design Parameters
- Material library
ANSYS® nCode DesignLife™ - Features
Streamlining the Virtual Engineering Process

- Powerful Fatigue Analysis Technology
- Integrated Reporting and Process Encapsulation
- Fast, Expandable, and Scalable
Intuitive and easy to use software for performing fatigue analysis of finite element models.

Efficiently analyze large finite element models and complete usage schedules.

Wide range of fatigue analysis capabilities including stress-life, strain-life, multi-axial, weld analysis, virtual shaker table, and more.

Single environment for both Test and CAE data.

Extensive material database
Predefined ANSYS nCode DesignLife processes can be accessed by dropping them onto the Workbench Project Schematic.

**Stress-Life (SN)** – uses time based FE stresses
- constant amplitude loading
- time step loading
- time series loading

**Strain-Life (EN)** – uses time based FE strains
- constant amplitude loading
- time step loading
- time series loading

**Vibration** – uses frequency based FE stresses
- swept sine and random vibration
Case Study – Thermal/Structural loading

- Project schematic shows:
  - Steady-state thermal analysis
  - Static structural analysis
  - Strain life constant amplitude analysis with thermal correction
Case Study – ANSYS Results
Case Study – DesignLife Results

Temperature & Stress results from Workbench

Fatigue solver

Export to ANSYS Design Optimizer

Preconfigured report output

Bill of Materials from Workbench

hotspot detection
ANSYS nCode DesignLife™ - Capabilities

ANSYS nCode DesignLife has an extensive scope of fatigue capabilities...

- Strain-Life (automated multi-axial corrections)
- Stress-Life (single, multi-curve, Haigh diagrams)
- Crack Growth (LEFM)
- Seam welds and spot welds
- High temperature fatigue
- Vibration fatigue (shaker simulation)
- Virtual Strain gage
- Complete duty cycles / flight spectrums
- Multiple runs in a single analysis
- Multi-processor enabled for fast results

Finite Element results supported
  - Static (linear superposition)
  - Transient
  - Modal
  - Frequency Response
  - Linear & Non-linear

Finite Element solvers supported
  - ANSYS
  - Abaqus
  - Nastran
  - LS-Dyna
ANSYS® nCode DesignLife™ - Benefits

- Perform virtual durability assessment up front to reduce reliance on physical test and avoid costly design and tooling changes
- Perform smarter and quicker physical tests by simulating first
- Design durability into your products and reduce warranty claims
- Standardize analysis processes to improve consistency and quality
- Automate processes to better utilize engineers’ time and workload
- Assess more design options, consider more realistic loading conditions and more confidently reduce cost and weight
Questions

THANK YOU!
Appendix
# ANSYS® nCode DesignLife™
## Product Packages

<table>
<thead>
<tr>
<th>Package/Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANSYS nCode DesignLife Standard</strong></td>
<td>Base package including Stress-Life, Strain-Life and Dang Van analyzers</td>
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<table>
<thead>
<tr>
<th><strong>ANSYS nCode DesignLife Modules/add-ons</strong></th>
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<tbody>
<tr>
<td><strong>ANSYS nCode DesignLife Vibration</strong></td>
<td>Adds ability to do vibration fatigue analysis. Simulate swept sine and PSD loadings</td>
</tr>
<tr>
<td><strong>ANSYS nCode DesignLife Accelerated Testing</strong></td>
<td>Signal processing package complementary to vibration option. Design accelerated virtual and physical vibration tests.</td>
</tr>
<tr>
<td><strong>ANSYS nCode DesignLife Welds</strong></td>
<td>Fatigue life prediction for seam welds and spot welds.</td>
</tr>
<tr>
<td><strong>ANSYS nCode DesignLife Parallelization</strong></td>
<td>DesignLife is multi-threaded and licensed per core with one core included in the base package.</td>
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</table>
# ANSYS® nCode DesignLife™
## ANSYS nCode DesignLife Standard

<table>
<thead>
<tr>
<th>Standard Package includes:</th>
<th>Description</th>
<th>Applications</th>
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<tbody>
<tr>
<td><strong>Stress-Life</strong></td>
<td>Enables fatigue life calculations to be made using the stress-life approach. Includes the ability to interpolate between material curves depending on the temperature. Python scripting can also be used to add new or proprietary SN methods.</td>
<td>High-cycle fatigue (long lives) where nominal stress controls the fatigue life.</td>
</tr>
<tr>
<td><strong>Strain-Life</strong></td>
<td>Enables fatigue life predictions to be made using the local strain approach. Includes the ability to interpolate between material curves depending on the temperature at each location.</td>
<td>Wide range of problems including low-cycle fatigue with the local elastic-plastic strain controls the fatigue life.</td>
</tr>
<tr>
<td><strong>Dang Van analyzers</strong></td>
<td>Enables Dang Van safety factor calculations. The Dang Van criterion is a method of predicting the endurance limit under complex loading situations. The output from the analysis is always expressed as a safety factor not a fatigue life. Specific material parameters are calculated from tensile and torsion tests.</td>
<td>Engine and powertrain-type applications where there are very large numbers of loading cycles.</td>
</tr>
</tbody>
</table>
## ANSYS® nCode DesignLife™
### Product Packages

### Availability and Compatibility

<table>
<thead>
<tr>
<th>Platform</th>
<th>Processor</th>
<th>Operating System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows (64-bit)</td>
<td>x64</td>
<td>Windows 7 64-bit, Vista 64, XP 64</td>
</tr>
<tr>
<td>Windows (32-bit)</td>
<td>x86</td>
<td>Windows 7, Vista, XP</td>
</tr>
</tbody>
</table>
ANSYS® 13 nCode DesignLife™ SP1

- Support for Named Selections
- New state engine to manage DesignLife system updates
- DesignLife processes saved with results
- FKM mean stress with multicurve SN
- Material map import deactivate
- Seam weld enhancements
- BS7608 and Eurocode 3 weld analysis
Q. What is the difference between ANSYS nCode DesignLife and the ANSYS Fatigue module?

A. The ANSYS Fatigue module is very limited in what it can do. No critical plane capability and therefore no non-proportional non-constant amplitude loading. Loading is limited to a single time history or a specific 2 load case option. ANSYS Fatigue cannot analyze multiple events (It has no “duty cycle” capabilities). Also, it does not support vibration, spot-weld, or seam-weld...
Q. Are there any Fatigue capabilities that ANSYS customers use that are not available in nCode DesignLife or its modules?

A. Currently, ANSYS nCode DesignLife does not perform the ASME Boiler and Pressure Vessel fatigue calculations as specified by this code. This will be in the R14 release.

Notably:
- Through thickness integration of stresses
- Linearize stresses to determine equivalent membrane and bending stresses
- Consistent method of stress recovery for solid models
THANK YOU!
Summary Flowchart of CAE Durability Analysis

CAE Durability

Fatigue Approach

Stress-Life (EN)

Rainflow cycle counting
Miner’s rule damage accumulation

Total number of cycles to failure (life)

Crack Life Approach

Paris Law

Crack growth rate

Strain-Life (SN)
Many DesignLife processes are built around five basic Glyphs
• so called “5 box trick”