Advanced Fatigue from nCode

Robert Cawte

Principal Applications Engineer
HBM-nCode
Contents

• Introducing **nCode ANSYS DesignLife** for **ANSYS™ Workbench 13**

• Case Study 1 – Lever Assembly Example
  ‣ How to do Lifing analysis in Workbench
  ‣ Design optimisation based on Life

• Case Study 2 – Wind Turbine Gearbox
  ‣ What makes a good fatigue analysis?
  ‣ Element types, mesh quality, stress convergence, support for shells and solids in DesignLife

• Case Study 3 – Wind Turbine Main Shaft
  ‣ Duty cycle loading in DesignLife
  ‣ Multiaxial fatigue considerations
  ‣ Selection of critical areas by damage criteria
What is nCode DesignLife?

• A fatigue analysis solver & interface for FE users
  ‣ Part of nCode GlyphWorks (signal processing)
    • To encourage test-FE collaboration
      ‣ Customised for Ansys users (DesignLife only)

• DesignLife is both flexible and rigid!
  ‣ Flexibility to set up the required analysis options
  ‣ Rigid – options are saved in a locked process flow
    • Re-used to give consistent process results

• DesignLife works from Ansys RST files
  ‣ and/or sits inside Workbench
Fatigue Life Prediction Process

3 Main Approaches:
• Stress-Life (SN Analysis)
• Strain-Life (EN or Crack Initiation Analysis)
• Crack Growth (LEFM)

Material Properties

Geometry (FEA)

Damage Analysis

Fatigue Life

Load History
Fatigue loading is not just cycling a static loadcase
   ‣ Most realistic loading is variable amplitude
   ‣ Many are multi-channel
   ‣ Many are multi-event (and multi-channel) such as ISO/IEC 61400
Fatigue Life Prediction Process

Time Signal  Rainflow Cycle Counting  Rainflow Histogram

LIFE
Palmgren-Miner’s damage summation

Damage Histogram  SN Analysis
Case study 1 – Lever Assembly Example

- Project schematic shows:
  ‣ Steady-state thermal analysis
  ‣ Static structural analysis
  ‣ Strain life constant amplitude analysis with thermal correction
Case study 1 – Lever Assembly Example

• Steady-state Thermal Analysis Results
Case study 1 – Lever Assembly Example

• Static Structural Analysis
  Results
Case study 1 – Lever Assembly Example

- nCode ANSYS DesignLife Fatigue Results

  - Automatic hotspot detection
  - Fatigue solver
  - Export to ANSYS Design Optimizer
  - Preconfigured report output
  - Temperature & Stress results from Workbench
  - Bill of Materials from Workbench

measure and predict with confidence

HBM
**Case study 1 – Lever Assembly Example**

- Full integration with parametric and optimisation capabilities of Workbench

### Outline of All Parameters

<table>
<thead>
<tr>
<th>ID</th>
<th>Parameter Name</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ID</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Input Parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>P2 Convection Film Coefficient</td>
<td>1000</td>
<td>W mm(^2) C(^{-1})</td>
</tr>
<tr>
<td>4</td>
<td>P3 Force Z Component</td>
<td>1000</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>P4 StrainLife_Analysse.ENEngine_1_ScaleFactor</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID</th>
<th>New input parameter</th>
<th>New name</th>
<th>New expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Output Parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>P1 Equivalent Stress Maximum</td>
<td>268.65</td>
<td>MPa</td>
</tr>
<tr>
<td>9</td>
<td>P5 Life</td>
<td>&lt;170</td>
<td></td>
</tr>
</tbody>
</table>

### Table of Design Points

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Name</td>
<td>P2 - Convection Film Coefficient</td>
<td>P3 - Force Z Component</td>
<td>P4 - StrainLife_Analysse.ENEngine_1_ScaleFactor</td>
<td>P5 - Equivalent Stress Maximum</td>
<td>P5 - Life</td>
<td>Exported</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>W mm(^2) C(^{-1})</td>
<td>N</td>
<td>MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Current</td>
<td>1000</td>
<td>1000</td>
<td>1</td>
<td>268.65</td>
<td>&lt;170</td>
<td></td>
</tr>
</tbody>
</table>

### Charts
Case Study 2 – Wind Turbine Gearbox

Generalized Gearbox Schematic

Ref 1. Improving Wind Turbine Gearbox Reliability
W. Musial and S. Butterfield National Renewable Energy Laboratory, B. McNiff McNiff Light Industry
Case Study 2 – Wind Turbine Gearbox Casing

- 1 million nodes
- Linear or quad elements
- Solids or skim with shells
Case Study 2 – Unit loads applied at bearing positions

Typical 2-3MW rated
Gearbox >1m diameter
Max torque ~<1MNm
750kN reaction / side (1kN nominal applied)
Case Study 2 – Linear Static Superposition – unit load results
Case Study 2 – Linear Static Superposition – constant amplitude

- Maximum load, 15 active loadcases (bearing reactions)

### Available FE Load Cases

<table>
<thead>
<tr>
<th>Description</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - ALL BEARING LOADS (1000N) BEARING 1 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 - ALL BEARING LOADS (1000N) BEARING 1 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 - ALL BEARING LOADS (1000N) BEARING 2 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - ALL BEARING LOADS (1000N) BEARING 2 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 - ALL BEARING LOADS (1000N) BEARING 3 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 - ALL BEARING LOADS (1000N) BEARING 3 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 - ALL BEARING LOADS (1000N) BEARING 4 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 - ALL BEARING LOADS (1000N) BEARING 4 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 - ALL BEARING LOADS (1000N) BEARING 5 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 - ALL BEARING LOADS (1000N) BEARING 5 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 - ALL BEARING LOADS (1000N) BEARING 6 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 - ALL BEARING LOADS (1000N) BEARING 6 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 - ALL BEARING LOADS (1000N) BEARING 7 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 - ALL BEARING LOADS (1000N) BEARING 7 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 - ALL BEARING LOADS (1000N) BEARING 8 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 - ALL BEARING LOADS (1000N) BEARING 8 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 - ALL BEARING LOADS (1000N) BEARING 9 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 - ALL BEARING LOADS (1000N) BEARING 9 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 - ALL BEARING LOADS (1000N) BEARING 10 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 - ALL BEARING LOADS (1000N) BEARING 10 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 - ALL BEARING LOADS (1000N) BEARING 11 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 - ALL BEARING LOADS (1000N) BEARING 11 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 - ALL BEARING LOADS (1000N) BEARING 12 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 - ALL BEARING LOADS (1000N) BEARING 12 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 - ALL BEARING LOADS (1000N) BEARING 13 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 - ALL BEARING LOADS (1000N) BEARING 13 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 - ALL BEARING LOADS (1000N) BEARING 14 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 - ALL BEARING LOADS (1000N) BEARING 14 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 - ALL BEARING LOADS (1000N) BEARING 15 1000N X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 - ALL BEARING LOADS (1000N) BEARING 15 1000N Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Selected for combination

- Load Case Description
  - Load Case 1: 1 - ALL BEARING LOADS (1000N) BEARING 1 1000N X
  - Load Case 2: 1 - ALL BEARING LOADS (1000N) BEARING 1 1000N Y
  - Load Case 3: 7 - ALL BEARING LOADS (1000N) BEARING 1 1000N X
  - Load Case 4: 8 - ALL BEARING LOADS (1000N) BEARING 1 1000N Y
  - Load Case 5: 10 - ALL BEARING LOADS (1000N) BEARING 1 1000N X
  - Load Case 6: 11 - ALL BEARING LOADS (1000N) BEARING 1 1000N Y
  - Load Case 7: 9 - ALL BEARING LOADS (1000N) BEARING 1 1000N X
  - Load Case 8: 14 - ALL BEARING LOADS (1000N) BEARING 1 1000N Y
  - Load Case 9: 15 - ALL BEARING LOADS (1000N) BEARING 1 1000N X
  - Load Case 10: 16 - ALL BEARING LOADS (1000N) BEARING 1 1000N Y
  - Load Case 11: 17 - ALL BEARING LOADS (1000N) BEARING 1 1000N X
  - Load Case 12: 18 - ALL BEARING LOADS (1000N) BEARING 1 1000N Y
  - Load Case 13: 19 - ALL BEARING LOADS (1000N) BEARING 1 1000N X
  - Load Case 14: 20 - ALL BEARING LOADS (1000N) BEARING 1 1000N Y
  - Load Case 15: 21 - ALL BEARING LOADS (1000N) BEARING 1 1000N Z

### Scale factors

- Load Case 1: Max Factor = 1.000, Min Factor = 0.000
- Load Case 2: Max Factor = 1.000, Min Factor = 0.000
- Load Case 3: Max Factor = 1.000, Min Factor = 0.000
- Load Case 4: Max Factor = 1.000, Min Factor = 0.000
- Load Case 5: Max Factor = 1.000, Min Factor = 0.000
- Load Case 6: Max Factor = 1.000, Min Factor = 0.000
- Load Case 7: Max Factor = 1.000, Min Factor = 0.000
- Load Case 8: Max Factor = 1.000, Min Factor = 0.000
- Load Case 9: Max Factor = 1.000, Min Factor = 0.000
- Load Case 10: Max Factor = 1.000, Min Factor = 0.000
- Load Case 11: Max Factor = 1.000, Min Factor = 0.000
- Load Case 12: Max Factor = 1.000, Min Factor = 0.000
- Load Case 13: Max Factor = 1.000, Min Factor = 0.000
- Load Case 14: Max Factor = 1.000, Min Factor = 0.000
- Load Case 15: Max Factor = 1.000, Min Factor = 0.000

**Edit Load Map**

- Loading Type: Constant Amplitude
- Load Case Descriptions: All
Case Study 2 – Fatigue results

Life results
Quad elements
Material fatigue properties

- The regression curve represents the life at which 50% of samples have failed.
- Design curve shown with 95% Certainty of Survival and 95% Confidence
- The more samples you test the more confident you are about the scatter
- Compare batch/supplier variability

Case Study 2 – What makes a good FE-fatigue analysis?

nCode Materials Testing / Assurance Service now available to ANSYS users!
Case Study 2 – What makes a good FE-fatigue analysis?

Good Surface Stress Results!!!
- Fatigue cracks usually initiate at free surfaces
- Fatigue damage increases exponentially with stress
  ➢ 10% error in stress ≈ 100% error in life!

Shell models
- Stresses calculated at Gauss points and extrapolated to node
- Node has separate stress result from each element
- Most FEA uses average nodal stress

FE Accuracy/convergence
1. Nodal displacement
2. Nodal forces & moments
3. Element Gauss point stresses
4. Node at element stresses
5. Nodal averaged stresses

Recommendations
- Best choice = Gauss point stresses or Node at element
  • Best stress accuracy & check for convergence
- Use nodal averaged only if you are certain of convergence

Low mesh density
OK for load path & natural modes

High mesh density
Required for Fatigue
Case Study 2 – What makes a good FE-fatigue analysis?

Good Surface Stress Results!!!

- Fatigue cracks usually initiate at free surfaces
- Fatigue damage increases exponentially with stress
  ➢ 10% error in stress ≈ 100% error in life!

Solid models

- Stresses calculated at Gauss points but Gauss points are not on the surface!
- Option 1 – skin surface with membrane or thin shells
  • Shells resolve stresses to surface plane
  • Use element stresses from the shells as before
- Option 2 – Use surface node results
  • Transform stresses to surface plane
  • Use Node at element (or Nodal averaged stresses)
    on surface nodes only
  • Node at element are preferred!

Preferred
Case Study 2 – Fatigue results

<table>
<thead>
<tr>
<th>Node</th>
<th>Node-on-element fatigue life results</th>
<th>Quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Linear</td>
<td>Shell skin 2,676 to 126,000</td>
</tr>
<tr>
<td>204611</td>
<td>Shell skin 18,000 to 100,000</td>
<td>Solid 17,800 to 44,000</td>
</tr>
<tr>
<td></td>
<td>Solid 8,800 to 82,000</td>
<td></td>
</tr>
</tbody>
</table>

- Model not fully refined but demonstrates the importance of:
  - Linear elements converge very slowly (and over-stiff)
  - Shell skins on solid models help resolve surface stresses but do not improve accuracy of stress results
  - Shell skins also prevent stress gradient fatigue techniques
- A well refined quadratic mesh is recommended.
- Node-on-element* fatigue results demonstrate the degree of convergence
Case Study 2 – a good FE-fatigue analysis – refined model fatigue results
Case study 3 – Analysis of main drive shaft
Case Study 3 – Linear Static Superposition
Case Study 3 – Duty cycle load definition

- 20 year target life
- Duty cycle breaks life down into discrete events which are repeated
- Only need to analyse short event histories and multiply damage using Miner’s rule
Case Study 3 – Fatigue results from hot-spot detection runs

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage</td>
<td>Event name</td>
<td>Life</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repeats</td>
</tr>
<tr>
<td>Beyond cutoff</td>
<td>1-hour_100-breeze</td>
<td>Beyond cutoff</td>
</tr>
<tr>
<td>2.103e-11</td>
<td>1-hour_300-inid-rated</td>
<td>4.755e+10</td>
</tr>
<tr>
<td>0.001579</td>
<td>1-hour_600-max-rated</td>
<td>633.4</td>
</tr>
<tr>
<td>0.02607</td>
<td>1-hour_800-above-rated</td>
<td>32.89</td>
</tr>
<tr>
<td>0.01563</td>
<td>shut-down</td>
<td>73.35</td>
</tr>
<tr>
<td>0.04H028</td>
<td>ALL</td>
<td>24.63</td>
</tr>
</tbody>
</table>

Combined Damage

measure and predict with confidence
Case Study 3 – Fatigue using full multiaxial analysis
## Modular structure of ANSYS® nCode DesignLife™

<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>
</tr>
<tr>
<td><strong>ANSYS nCode DesignLife Modules/add-ons</strong></td>
<td></td>
</tr>
<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>
</tr>
</tbody>
</table>
**Capabilities**

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

- Stress-Life (single, multi-curve, Haigh diagrams)
- Strain-Life (automated multi-axial corrections)
- Multi-axial safety factor (Dang Van)
- Seam welds and spot welds
- High temperature fatigue
- Vibration fatigue (shaker simulation)
- Multiple runs in a single analysis
- Complete duty cycles / flight spectrums
- Multi-processor enabled for fast results
- Use Python for proprietary or custom methods

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

• Introducing nCode ANSYS DesignLife for ANSYS™ Workbench 13.0

• Case Study 1 – Lever Assembly Example
  † How to do Lifing analysis in Workbench
  † Design optimisation based on Life

• Case Study 2 – Wind Turbine Gearbox
  † What makes a good fatigue analysis?
  † Element types, mesh quality, stress convergence, support for shells and solids in DesignLife

• Case Study 3 – Wind Turbine Main Shaft
  † Duty cycle loading in DesignLife
  † Multiaxial fatigue considerations
  † Selection of critical areas by damage criteria
Thanks

Robert Cawte
HBM United Kingdom
Tel: +44 (0) 121 733 1837
robert.cawte@hbmncode.com