Fatigue Design Rules Used in European Countries

« uncertainties »
in Life Evaluation of Components

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ENSMA Poitiers

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Content

✓ Fatigue Rules for Pressure Equipment why ?
✓ Example of field experience: OCDE data bank
✓ What are fatigue Essential Parameters ?
✓ General overviews of Codified Rules
✓ Uncertainties
✓ On-going work, Gaps and Needs
Fatigue Rules for Pressure Equipment why?

- Pressure Equipment Directive requirement ➔ Fatigue has to be considered
  - For Hazard Analyses
  - For Design Justification ➔ need of "realistic", "validated" and "not too much conservative rule"
  - For Instruction Notice ➔ In Service Inspection consequences

- Different type of fatigue of metallic Pressure Equipment in Energy Industries
  - Low cycle / high cycle
  - Mechanical / thermal / combination of cyclic loads / "residual strain"
  - Mono / Multi axial
  - Base Metal / Weld / Dissimilar Weld
  - Extremely high cyclic loads, like seismic… (outside of EN Standard Scope)

- From PED: “In choosing the most appropriate solutions, the manufacturer must apply the principles set out below in the following order:
  - eliminate or reduce hazards as far as is reasonably practicable,
  - apply appropriate protection measures against hazards which cannot be eliminated,
  - where appropriate, inform users of residual hazards and indicate whether it is necessary to take appropriate special measures to reduce the risks at the time of installation and/or use”

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Accelerated Corrosion</td>
<td>21.4%</td>
</tr>
<tr>
<td>Stress Corrosion Cracking</td>
<td>6.5%</td>
</tr>
<tr>
<td>Vibration Fatigue (incl. Fretting)</td>
<td>14.8%</td>
</tr>
<tr>
<td>Corrosion (Crevice, MIC, Pitting)</td>
<td>14.7%</td>
</tr>
<tr>
<td>Design &amp; Construction</td>
<td>14.8%</td>
</tr>
<tr>
<td>Thermal Fatigue</td>
<td>14.8%</td>
</tr>
<tr>
<td>Erosion-Cavitation</td>
<td>14.8%</td>
</tr>
<tr>
<td>Over-stressed / Over-pressurized</td>
<td>14.8%</td>
</tr>
<tr>
<td>Water Hammer</td>
<td>14.8%</td>
</tr>
<tr>
<td>Human Error</td>
<td>14.8%</td>
</tr>
<tr>
<td>Unreported</td>
<td>14.8%</td>
</tr>
<tr>
<td>Corrosion Fatigue</td>
<td>14.8%</td>
</tr>
<tr>
<td>Severe Weather (Freezing)</td>
<td>14.8%</td>
</tr>
</tbody>
</table>

5164 reported failures

Why a so limited field experience in thermal fatigue???
What are fatigue Essential Parameters?

✓ Phenomenon
  o Crack initiation followed by progressively growing crack until the final catastrophic failure that can appear in normal operation with no visible large distortion
  o technical understanding of fatigue requires a comprehensive knowledge of metallurgy, physics, and phenomena like plastic deformation, slip planes and dislocation theory…
  o fatigue usually – not always – initiates at a location that acts as a stress concentration, or focal point, to the stress location imposed on a component. Stress concentrations take a wide variety of forms. They include geometric features (such as holes, slots, corners, radii…), rough areas of surface finish, welds, corrosion pits, and microstructural defects such as inclusions

✓ Classical prediction rules:
  o Shear stress amplitude on the surface, converts in mono-axial “strain” range versus fatigue curve (Δω/2,N) ➔ Codified curves generally: (S=E,Δω/2,N) N cycles to specimen failure ➔ consequently Plastic Shakedown has to be checked
  o Mainly in stress concentration location, but with different gradient close to the surface…

✓ Cumulative Usage Factor of 1 ➔ Criteria has to be clear:
  o through wall crack
  o limited crack growth (around 1 to 3 mm)
  o number of cycle from 50µm crack to 3mm crack depth
General overviews of Codified Rules

**Type I**

- Define strain amplitude for each transient \( \Delta \epsilon / 2 \)
- Material mean S-N curve
- Transferability and Reduction Factors
- Design S-N curve

Load / Temperature history for all transients
Number of cycles (\( N_{\text{applied}} \))

\[
CUF = \sum f_{ui}
\]

**Type II**

- Use a data bank of component tests with similar characteristics
- BM, Welds, local geometry...
- Define similar fatigue behavior through different parameters as structural stress...
- Define interpolation/extrapolation rules...

\[
f_{ui} = \frac{N_{\text{applied}}}{N_{\text{allowable}}}
\]

**Step by Step Method Type I**

**Fatigue Analysis Procedure**

- **Cyclic loading**
  - Elastic Strain History
  - Temperature History
  - Plastic Shakedown
    - Elastic / Non linear analysis
  - Cycle combination
    - Design transients: shock/step
    - Spectrum / Sub cycles/Monitoring
    - Strain rate of combined cycles
  - Damage Cumulation
    - Miner Rule / "Rainflow" / other
  - Cumulative Usage Factor
  - Crack Growth
    - Not for Design!
    - Possible in operation for LTO
    - Crack size for CUF = 1

**Transferability & criteria**

Material Properties:
- Cyclic S - S Curves
- -(S,N) da/dN / AK curves
- Plasticity
  - \( K_e, K_n \) or Non-linear Analysis
- Detrimental factors (FSRF)
  - temperature, cold work, bi-axiality, mean stress, surface
  - finished, welds, residual stress...
- Damage Cumulation
  - Miner Rule / "Rainflow" / other

**Tests on Mock-ups and Components**

**Benchmarking**

**Codified Rules**

- RCC-M, RCC-MRx, RSE-M
- ASME III - VIII
- EN 13445 - 13480

**Scope**

- Vessels-Pipes-Valves
- Or other components
- Class 1-2-3-NC
- Base metal / Cast
- Welds / Crack like defects
- * HCF + Seismic loads

**Small specimen tests**

- Material Properties:
  - Cyclic S - S Curves
  - -(S,N) da/dN / AK curves
  - Plasticity
    - \( K_e, K_n \) or Non-linear Analysis
  - Detrimental factors (FSRF)
    - temperature, cold work, bi-axiality, mean stress, surface
    - finished, welds, residual stress...
  - Damage Cumulation
    - Miner Rule / "Rainflow" / other

**December 08, 2016**

ASME-Section France - Fatigue Rules - ENISA, Poitiers France
Material mean fatigue S-N curve

"mean": \( \Delta u/2 \% = \frac{32.093}{(N^{0.5})} + 0.112 \)
Mainly 304L-316L tests

Fatigue Code curves versus test results SS (air)

- EDF test results
- EDF fitting proposal

Données américaines et japonaises NUREG 6909 + PVP 2009 -77115
Donnees francaises

Similar mean curve, but less scatter of the French data than international data
French versus International Fatigue data

Comparison of air mean fatigue S-N curve
Design Fatigue curve

- Detrimental effects: RF
  - RF\textsubscript{sct} scatter on N\textsubscript{c}
  - RF\textsubscript{scl} scale/thickness on N\textsubscript{c}
  - RF\textsubscript{temp} temperature on N\textsubscript{c}
  - RF\textsubscript{cwo} cold work on N\textsubscript{c}
  - RF\textsubscript{biax} bi-axiality on N\textsubscript{c}
  - RF\textsubscript{en} environment on N\textsubscript{c}
  - RF\textsubscript{ht} hold time on N\textsubscript{c}
  - RF\textsubscript{sha} transient shape on N\textsubscript{c}
  - RF\textsubscript{rou} roughness on N\textsubscript{c}
  - RF\textsubscript{mast} mean stress on N\textsubscript{c}
  - RF\textsubscript{inter} interaction on N\textsubscript{c}
  - RF\textsubscript{*} weld on Δε
  - RF\textsuperscript{**} high cycle on Δε
  - RF\textsubscript{plast} plasticity on Δε

- CUF is proportional to: De power 3 to 5 (!!!)
  - N cycles

Evolution of Design Fatigue Curves

- S\textsubscript{a} = S\textsubscript{y} \left( \frac{\sigma\textsubscript{u} - \sigma\textsubscript{s}}{\sigma\textsubscript{u} - S\textsubscript{a}} \right) \text{ For: } S\textsubscript{a} < \sigma\textsubscript{y}
- S\textsuperscript{'}\textsubscript{a} = S\textsubscript{y} \text{ For: } S\textsubscript{a} > \sigma\textsubscript{y}
Historical Reduction Factors from ASME (1970's)

Mean curve ➔ 20 on cycles or 2 on strain
2 on material variability
2.5 on size effects
4 on surface finish
0 on loading history

To-day
material variability 2.1 – 2.8
size effects 1.0 – 1.4
surface finish 1.5 – 3.5
loading history 1-2
Total: 4.7 – 27.4

ASME 2015
Mean curve ➔ 12 on cycles or 2 on strain

RCCM 2015
Mean curve ➔ 10 on cycles or 1.4 on strain

SS Environmental Effects (PWR & BWR water)

\[ F_{en} = \exp(-T' \varepsilon' O') \]

\[
\begin{array}{c|c|c}
T' & \text{T<100°C} & \text{T>325} \\
\hline
0 & \text{T=0} & \text{T'=(T-100)/250} \\
0.9 & \text{T'=0.9} & \text{T>325} \\
\hline
\varepsilon' & \varepsilon<10 \%/s & \varepsilon<10 \%/s \\
\hline
\varepsilon' & \ln(\varepsilon/10) & 0.0004<\varepsilon<10 \%/s \\
\hline
\varepsilon' & \ln(0,0004/10) & \varepsilon<0.0004 \%/s \\
\hline
O' & 0.29 & \text{Wrought & cast SS} \\
\hline
\end{array}
\]

\[ F_{en} = \frac{N_{cycles \ in \ air}}{N_{cycles \ in \ water}} \]
ASME III Fen factor for SS

Modified rate approach for no constant strain rate

\[ F_{en} = \frac{N_{air}}{N_{water}} \]

strain rate in % / s

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Fen</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 °C</td>
<td>16</td>
</tr>
<tr>
<td>150 °C</td>
<td>14</td>
</tr>
<tr>
<td>200 °C</td>
<td>12</td>
</tr>
<tr>
<td>250 °C</td>
<td>10</td>
</tr>
<tr>
<td>300 °C</td>
<td>8</td>
</tr>
<tr>
<td>325 °C</td>
<td>6</td>
</tr>
</tbody>
</table>

???
- What is the background of modified rate approach?
- What temperature to consider for thermal transient?
- Do we have a De threshold?
- How to combine Fen with other RFs?

FINAL STEP by STEP PROCEDURE

Elastic analysis of the strain cycle associated to the transient

Plasticity effects \( K_e, K_v \)

\( \Delta \varepsilon / 2 \) and \( \varepsilon^\prime \)

Stainless steel air mean curve

PWR water design curve through reduction of air fatigue mean curve:

\[ RF = RF_e * RF_{sc} * RF_{ro} * F_{en} * RF_{sh} * RF_{inter} \]

and 1.4 reduction factor on the \( \Delta \varepsilon / 2 \)

\[ Fu = \text{Ncycles} / \text{Nallowable} \]

on the reduced fatigue curve

New RCCM 2016RPP rules:
- New air curve for RCCM SS
- Environmental effects
- Without roughness and environment cumulation
EN 13445 - Fatigue Rules and Comparison

EN13445-Fatigue Design Curves versus weld category

- Constant amplitude
- Variable amplitude
CF Integrity 21

EN 13445-Fatigue Design Curves for Weld

<table>
<thead>
<tr>
<th>Class</th>
<th>Constants of $\Delta \varepsilon \cdot N$ curve*</th>
<th>Stress range at $N$ cycles, MPa</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$m_1$ $C_1$</td>
<td>$m_2$ $C_2$</td>
<td>$\Delta \varepsilon_{\text{min}}$</td>
</tr>
<tr>
<td>100</td>
<td>3.0 $2.00 \times 10^{10}$</td>
<td>5.0</td>
<td>$1.09 \times 10^{11}$</td>
</tr>
<tr>
<td>90</td>
<td>3.0 $1.49 \times 10^{10}$</td>
<td>5.0</td>
<td>$6.41 \times 10^{11}$</td>
</tr>
<tr>
<td>80</td>
<td>3.0 $1.02 \times 10^{10}$</td>
<td>5.0</td>
<td>$3.56 \times 10^{11}$</td>
</tr>
<tr>
<td>71</td>
<td>3.0 $7.16 \times 10^{9}$</td>
<td>5.0</td>
<td>$1.96 \times 10^{11}$</td>
</tr>
<tr>
<td>63</td>
<td>3.0 $5.00 \times 10^{9}$</td>
<td>5.0</td>
<td>$1.08 \times 10^{11}$</td>
</tr>
<tr>
<td>56</td>
<td>3.0 $3.51 \times 10^{9}$</td>
<td>5.0</td>
<td>$5.98 \times 10^{10}$</td>
</tr>
<tr>
<td>50</td>
<td>3.0 $2.30 \times 10^{9}$</td>
<td>5.0</td>
<td>$3.39 \times 10^{10}$</td>
</tr>
<tr>
<td>45</td>
<td>3.0 $1.82 \times 10^{9}$</td>
<td>5.0</td>
<td>$2.00 \times 10^{10}$</td>
</tr>
<tr>
<td>40</td>
<td>3.0 $1.28 \times 10^{9}$</td>
<td>5.0</td>
<td>$1.11 \times 10^{10}$</td>
</tr>
<tr>
<td>32</td>
<td>3.0 $6.55 \times 10^{8}$</td>
<td>5.0</td>
<td>$3.64 \times 10^{9}$</td>
</tr>
</tbody>
</table>

*For $E = 2.09 \times 10^{11}$ MPa

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ASME-Section France - Fatigue Rules - ENSMA, Poitiers France

CF Integrity 22

Comparison of Fatigue Design Rules

**ASME – RCCM Meth. I**
- Exemption rules: yes, in class 2
- Simplified rules mechanical load: no
- Base Metal
  - Curve based on standard Tests on small specimen
  - 1 curve by group of similar material
  - Transfer to structure:
    - ASME Nc/12 - RCCM Nc/10
    - ASME S/2 - RCCM S/1/4
  - Corresponding to a crack < 2 to 3 mm
  - Reduction Factors: generally no
  - Plasticity: $K_N$
  - Use of Tresca
  - Cycle Combination
  - Miner rule to cumulate fatigue damage

**EN 13445 – Cl. 18 Meth. 2**
- Exemption rules: no
- Simplified rules: yes Clause 17
- Base metal
  - Curve based on standard Tests on small specimen
  - 1 curve by $R_m$ independent of material
  - Transfer to structure: Nc/10 or S/1.5
    Consider as Safety Factor (!)
  - Corresponding to through wall crack
  - Reduction Factors (0.4 à 1)
  - Plasticity: $K_N$ or $K_s$
  - Use of Tresca or Von Mises
  - "Original" cycle combination
  - Miner rule to cumulate fatigue damage

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ASME-Section France - Fatigue Rules - ENSMA, Poitiers France
### Plasticity Corrections

**ASME - RCCM**

- **Mechanical Load (ASME)**
  \[ K_e = 1 + \frac{(1-n)}{m(n-1)}(\frac{S_n}{3S_m} - 1) \]
  for \(3S_m < S_n < 3mS_m\)

- **Thermal Shocks (RCCM)**
  \[ K_e = 1.86 \left( \frac{1}{1-1.66\frac{S_n}{S_m}} \right) \]

**EN 13445 – Cl. 18**

- **Mechanical Load**
  \[ K_e = 1 + A_0 \left( \frac{\Delta\sigma}{R_{p0.2t}} - 1 \right) \]
  where: \( A_0 = 0.4 \)
  - for austenitic
  - and ferritic \( R_m < 500 \text{MPa} \)
  and: \( A_0 = 0.4 + \frac{(R_m - 500)}{3000} \)

- **Thermal Shocks**
  \[ K_v = 0.7 / \left( 0.5 + \frac{0.4}{D_s/R_{p0.2t}} \right) \]

### Material mean fatigue S-N curve

**ASME – RCCM Meth. I**

- **Welded Joins**
  - Base tests on small specimen
  - No reduction factor for production welds manufactured/examined with ASME-RCCM specifications class 1 & 2
  - A specific rule for crack like defects in RCCM (notch model as a crack)

**EN 13445 – Cl. 18 Meth. 2**

- **Welded Joins**
  - Base: test on typical joins
  - One fatigue curve by class of join connected to control
  - A dedicated calculation for specific joins

---

1. Nominal stress
2. Structural stress
3. Notch stress
4. Extrapolation to give structural stress at potential crack initiation site.
Structural Stress VS Hot-Spot Stress
- SS: linearization of stress distributed across the section thickness
- HSS: Extrapolation to give structural stress at potential crack initiation site
- Similar when the stress gradient through the thickness is linear
- Could be different when the distribution of the stress/strain is non-linear through the thickness

\[ \Delta S_{\text{ess},k} = \Delta \sigma_k \left( \frac{t_{\text{max}}}{t_{\text{ess}}} \right)^{1/m_{\text{ess}}} f_{\text{MK}} \]

with \( m_{\text{ess}} = 3.6 \)
\( t_{\text{max}} = t \) between \( t=16 \) and \( 150 \) mm
\( t_{\text{ess}} = \frac{1.23 \cdot 0.36R - 0.17R^2}{1.007 - 0.306R - 0.17R^2} \)
\( f_{\text{MK}} = (1-R)^{1/m_{\text{ess}}} \) and \( R = \sigma_{\text{init}}/\sigma_{\text{max}} \)

Angular or Crack Like Defects
- Distance \( d \) characteristic stress (RCCM-RCCMRx)
  - For very small \( \rho \) up to crack-like-defects
  - Same procedure as basic fatigue analysis methods
  - 2 options
    - With specific fatigue curves and associated \( d \) value for each material
    - With basic (S,N) curves after 1.5 reduction factor on stress amplitude and \( d=50\mu m \)
### Weld category – Testing Groups (1/3)

<table>
<thead>
<tr>
<th>Detail No.</th>
<th>Joint type</th>
<th>Sketch of detail</th>
<th>Comments</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Full penetration butt weld flush ground, including weld repairs</td>
<td><img src="image1" alt="Sketch of detail" /></td>
<td>Weld to be proved free from surface-breaking flaws and significant sub-surface flaws (see EN 13445:2014) by non-destructive testing. Use $f_s$ instead of $f_u$.</td>
<td>Testing group 1 or 2: 90 71</td>
</tr>
<tr>
<td>1.2</td>
<td>Full penetration butt weld made from both sides or from one side onto consumable insert or temporary non-fusible backing</td>
<td><img src="image2" alt="Sketch of detail" /></td>
<td>Weld to be proved free from significant flaws (see EN 13445:2014) by non-destructive testing and, for welds made from one side, full penetration*.</td>
<td>Testing group 1 or 2: 90 63</td>
</tr>
</tbody>
</table>
| 1.4        |                      | ![Sketch of detail](image3) | Weld to be proved free from significant flaws (see EN 13445:2014) by non-destructive testing. 

- $\alpha \leq 30^\circ$
- $\alpha > 30^\circ$ | Testing group 1 or 2: 80 63 71 56 |

### Weld category – Testing Groups (2/3)

<table>
<thead>
<tr>
<th>Detail No.</th>
<th>Joint type</th>
<th>Sketch of detail</th>
<th>Comments</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>Full penetration butt welds made from one side onto permanent backing.</td>
<td><img src="image4" alt="Sketch of detail" /></td>
<td>Circumferential seams only (see 5.7 Minimum throat = shell thickness) Weld not pass inspected to ensure full fusion to backing. Single pass weld.</td>
<td>Testing group 1 or 2: 56 40</td>
</tr>
</tbody>
</table>
| 1.8        | Full penetration welds made from both sides (detail a): | ![Sketch of detail](image5) | - as-welded 
- weld toes dressed (see 18.10.2.2). Partial penetration welds made from both sides (detail b): 
- fatigue cracking in weld* - fatigue cracking in shell from weld toe. Full penetration welds made from one side without back-up weld (detail c): 
- if the inside weld can be visually inspected and is proved to be free from overlap or root concavity. 
- if the inside cannot be visually inspected and full penetration cannot be assured. | Testing group 1 or 2: 71 60 63 32 32 63 63 60 60 40 40 |

*...
### Reduction Factors

\[ f_U = f_s \cdot f_e \cdot f_m \cdot f_t \]

- **\( f_s \):** Surface finish effects through rugosity \( RZ \)
- **\( f_e \):** Thickness effects, between 25 and 150 mm
- **\( f_m \):** Mean stress effects
- **\( f_t \):** Temperature effects over 100°C
Mean Stress Effects: $f_m$

Surface Finish Effects: $f_s$
Mean Temperature Effects: $f_T$

**Aciers ferritiques**

**Aciers austénitiques**

- $t^*$, Cycle Mean Temperature

Thickness Effect, $f_e$

Facteur de correction fonction épaisseur, $f_e$

- $e$ 50 mm
- $e$ 100 mm
- $e$ 150 mm

- $f_e$ vs. Nombre de cycles
### Mean Stress

\[ 0.9 < f_m < 1.1 \]

### Thickness

\[ 0.9 \leq f_e \leq 10^4 \text{ et } 0.8 \leq 10^6 \]

### Temperature

\[ 0.8 \text{ ferritic et } 0.9 \text{ austenitic} \]

### Roughness

\[ f_s = 0.85 \leq 10^4 \text{ et } 0.7 \leq 10^6 \text{ cycles} \]

\[ f_u = f_s \cdot f_e \cdot f_m \cdot f_t \]

<table>
<thead>
<tr>
<th></th>
<th>ferritic</th>
<th>austenitic</th>
</tr>
</thead>
<tbody>
<tr>
<td>10^4 cycles</td>
<td>0.76</td>
<td>0.67</td>
</tr>
<tr>
<td>10^6 cycles</td>
<td>0.45</td>
<td>0.41</td>
</tr>
</tbody>
</table>

### Base Metal Fatigue Curves

**Comparaison RCCM-ASME / EN13445 pour le métal de base : aciers ferritiques / austénitiques**

- ASME-RCCM Design - Inox E=179000MPa
- EN 13445 Rm=600MPa
- EN 13445 Rm=400MPa
- RCCM Design-Ferritique E=207000MPa

![Fatigue Curves Diagram](image)
Comparison Conclusions

- **Major uncertainties:**
  - Geometry and tolerances
  - Thermal Mechanical material properties
  - Different reduction factors
  - Plasticity factors and nonlinear analyses
  - Fatigue curve
  - Cycle combination
  - Welds “crack like defects” and “angle”

- **Similar results have to be obtain with different codified rules, or clearly explain**

- **More detailed comparisons are needed**
  - A project on detailed comparison of nuclear and non-nuclear fatigue rules is on-going in WNA-CORDEL-CSTF (international organization)

- **Well selected practical cases have to be benchmarked with different codified methods and Results Consistency has to be checked**
WNA CORDEL CSTF projects

✓ 2 on-going projects
- Non linear design rules
  - **Nuclear and non-nuclear Code** comparison ➔ released
  - Recommended practice ➔ for end of 2016
  - Benchmarking on 2 typical cases ➔ for 2017
  - For fatigue
    - *Direct evaluation of Ke by non linear analyses and cyclic stress-strain curve*
    - *Cycle by cycle non linear analyses (exceptional cases…)*
- Fatigue design rules
  - **Nuclear and non-nuclear Code** comparison ➔ before end of 2016
  - Environment effects ➔ 2017
  - Fatigue crack growth ➔ end of 2017

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ASME-Section France - Fatigue Rules - ENSMA, Poitiers France
Long and Diverse experimental support

- Many experimental tests on pressure cycling of vessels and piping, with many different local design, with and without welds
- More specific tests on welds

Thermal cycling fatigue tests
Gaps, Needs, Proposed actions

- Many different situation: large scope of EN 13445 compared to Nuclear industry
- All the Factors used in the standard have to be justified
- Residual stresses effects need clarification
- Environmental effects (difficult, high number of environments…)
- Mechanism understanding for different materials and environments
- Fatigue Curves: background and comparison
- Nonlinear strain evaluation
- Fatigue crack growth

Proposal
- A dedicated Road Map for “Fatigue Design Rules”: vessels and piping ➔ ASME International Fatigue Working Groups and EPRI
- Revised parts of EN 13445 or confirm through justification, proposed a complete alternative root consistent with ASME BPVC ➔ EPERC
- Piping Systems EN 13480: different methods (stress indices) ➔ EPERC
- INCLUDE CONTINUOUSLY INTERNATIONAL R&D RESULTS
Thanks for your Attention !!!

Open for questions and/or comments...

???