RP- F105 Free Spanning Pipelines

- ✓Introduction/Concepts
- ✓DNV Guideline no 14
- ✓RP-F105 - Why Update
- ✓ FatFree Calculation Tool
- ✓ Project References
- ✓ Concluding remarks

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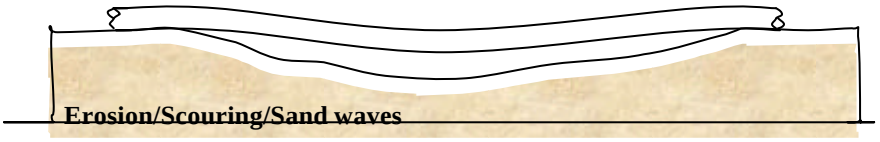
Free Spans



Potential Failure Modes?

Uneven seabed

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Failure Modes

Fatigue Limit State

.. accumulated damage from stress cycles caused by:

✓**Vortex Induced Vibrations** (in-line & cross-flow) (RP-F105)
✓ **Direct Wave Loads** (RP-F105)

Ultimate Limit State

.. over-stress (local buckling) due to:

✓ **Static Bending (weight & current)** (DNV OS-F101)
✓**VIV & Wave Loads** (RP-F105)
✓ **Pressure Effects** (DNV OS-F101)
✓**Axial Force** (DNV OS-F101)
✓ **Trawl interference** (GL 13)

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Historical Perspective - Acceptance Criteria

1977

- **Maximum allowable span length - no vibrations allowed**
  Implicitly assumes natural frequency f_0 controlled by free span length.
  Do not account for free span scenario, loading phenomenon or environment

1994

- **Fatigue Criteria for In-line & Onset criteria for Cross-flow**
  True ULS accounting for stress amplitude and number of cycles (η=0.1)
  Arbitrary models and SN-curves applied. Effect of waves?
  Cross-flow VIV not allowed. OK for "short" spans and current conditions
  Do not account for stress ranges and time to failure if exceeded.

1998

- **Fatigue Criteria for Cross-flow**
  True ULS accounting for stress amplitude and number of cycles.
  Other failure modes may be governing (in-line fatigue, over-stress)

2002

- **Screening Criteria (on-set)**
- **Fatigue Criteria & Collapse Criteria (local buckling)**

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Free Span Assessment - defining the problem

Substantial prevailing uncertainties:

- ✓ Environmental conditions
  - ➔ Flow conditions from combined wave and current
  - ➔ Local topography
- ✓ Loading Mechanism
  - ➔ Vortex Induced Vibration (in-line & cross-flow)
  - ➔ Direct wave loads & Proximity Effects
- ✓ Response Analyses
  - ➔ Soil-pipe interaction
  - ➔ Non-linearities (geometrical, static/dynamic properties)
- ✓ Acceptance criteria
  - ➔ SN-approach (weld, defects, …)

Objective to approach the problem from the conservative side

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DNV GL 14: Free Spanning Pipelines (1998)

VIV Models based on experience from R&D projects & pipeline design

- ✓ MULTISPAN Project (1994-1996)
  - ➔ Response Model for In-line VIV
  - ➔ On-set criteria for cross-low
  - ➔ Reliability based calibration
- ✓ GUDESP PROJECT (1989-1994)
  - ➔ Cross-flow Response model
  - ➔ Effect of Waves
- ✓ Research projects
  - ➔ SVS full scale test
  - ➔ MASPUS lab test

- ✓ Allows for state-of-the-art fatigue analyses
- ✓ Links in-line VIV and wave loads
- ✓ Allows cross-flow vibration
- ✓ Safety philosophy in compliance with DNV'96
- ✓ Introduces consistent link between analysis model and safety factor(s)

- ✓ Applied in numerous projects in
  - ☛ North Sea
  - ☛ Persian Gulf
  - ☛ South East Asia
  - ☛ GOM

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RP-F105 - why update

- **Include experience feed-back from projects**
- **Include recent R&D effort:**
  - Pipe in trench
  - VIV response model updates
  - Hydrodynamical coefficients
  - Structural response estimates
  - Soil stiffness
  - Force model (frequency domain)
  - Recommended SN curves
- **Make it more user-friendly:**
  - screening (on-set) criterion
  - make criteria and calculation methods more complete
  - restructure document

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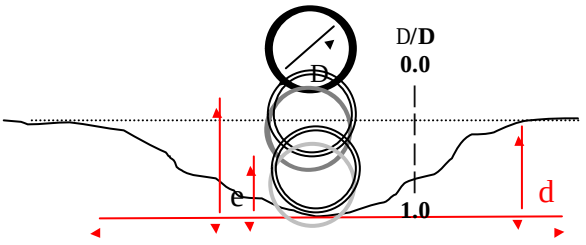
Recent Developments - Pipe in a Trench

- CFD runs with fixed and flexible 2D pipes
- Corrections to GL14 on relative basis
- Verifications against available lab test



Trench factor

$$\frac{D}{D} = \frac{1.25d - e}{D}$$

$$\frac{D}{D} \in [0;1]$$

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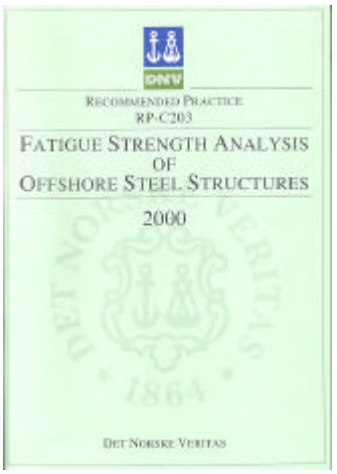
Link to RP-C203 : Fatigue Strength

- C-Mn steel SMYS < 500 MPa
- Crack growth at girth welds
- Environment at crack initiation
  - In air
  - Seawater w/cathodic protection
  - Seawater (free corrosion)
- Stress concentration factors due to misalignment accounted for in some curves
- Membrane stresses not extreme outer fibre stresses



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Recent Developments - Structural Response Models

- Simple and good estimate of structural response
- Natural frequency, dynamic stress, static moment and deflection
- Boundary coefficients based on FE-analyses
- Accounting for soil stiffness and axial force

$$f_0 \approx C_1 \cdot \sqrt{1+CSF} \sqrt{\frac{EI}{m_e L^4} \cdot \left(1 + C_2 \cdot \frac{S_{eff}}{P_E} + C_3 \left(\frac{\delta}{D}\right)^2\right)}$$

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Calculation Tool

- Free span assessment complex
- Require detailed knowledge in several disciplines:
  - hydrodynamics, VIV and load models
  - environmental conditions, long-term statistics
  - fatigue calculations
  - structural response incl. geotechnical aspects
- Guidelines/RPs complex and difficult to use
- Need for a calculation tool to:
  - make it easier to apply the RP
  - enable a cost-efficient span assessment

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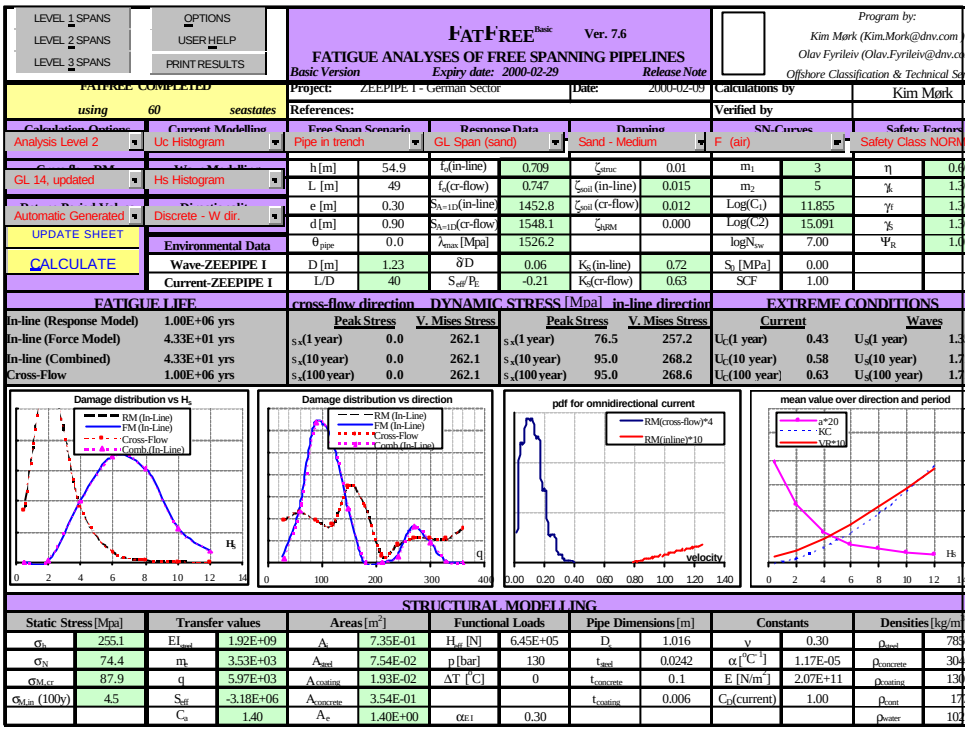

Selected Project References (DNV projects)

- Zeepipe I & II (NS/Statoil)
  - Large number of free spans observed during operation
  - Scouring, pipe in trench
  - Avoided rock dumping/trenching
- Åsgard Transport (NS/Statoil)
  - Large number of free spans
  - Uneven, rocky seabed
  - Minimised intervention work
  - Time schedule for intervention
- Ormen Lange (NS/N. Hydro)
  - Large number of long spans
  - Uneven seabed
  - Assess very long spans
  - RP update?

- Sirri pipelines (PG/Total)
  - Large number of free spans
  - Spans exceeding max length during as-laid phase
  - Higher current than expected
  - Necessary span corrections
  - Avoid pipe replacement/repair
- West Natuna pipelines (SEA/Connoco)
  - A few free spans
  - Hydrogen cracking in repair welds
  - Avoid pipe replacement/repair
  - Probabilistic inspection optimisation of free spans

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Concluding Remarks - RP-F105

- Recommended Practice based on experience from:
  - **MULTISPAN & GUDESP R&D project**
  - **Recent R&D & design projects**
- Allows for state-of-the-art fatigue analyses:
  - **consistent model and safety factors**
- Covers potential failure modes of free spans due to:
  - **Fatigue**
  - **Collapse (local buckling)**
- Safety philosophy in compliance with DNV-OS-F101
- Provides cost-effective solutions
  - Minimise seabed correction and span intervention costs
  - Allow planning of such work (schedule)
  - Assessment of observed free spans exceeding allowable length

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