introduction to

DNV-RP-F105 Free Spanning Pipelines

Introduction

presented by

Olav Fyrileiv
Principal Engineer
Det Norske Veritas

Historical Perspective - VIV

- **Maximum allowable span length**

  Implicitly assumes natural frequency f_0 controlled by free span length.

  Do not account for free span scenario, loading phenomenon or environment

70ties

- **Fatigue Criteria for In-line**

  True ULS accounting for stress amplitude and number of cycles (η=0.1)

  Arbitrary models and SN-curves applied. Effect of waves?

80ties

- **Onset criteria for Cross-flow**

  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 FLS accounting for stress amplitude and number of cycles

  Provides robust decision criteria.

  Other failure modes may be governing (in-line fatigue, over-stress)

Historical Perspective - VIV

1998

• DNV Guideline (GL14)
'Free Spanning Pipelines

Updated and released as

2002

• DNV Recommended Practice (RP-F105)
'Free Spanning Pipelines'

Free Span Assessment - Multidiscipline

- 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
- Structural Response
  - Soil-pipe interaction
  - Non-linearities (geometrical, static/dynamic properties)
- Acceptance criteria
  - SN-approach (weld, defects, …)

Basis for GL14/DNV-RP-F105

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-flow
  - Reliability based calibration
- GUDESP PROJECT (1989-1994)
  - Cross-flow Response model
  - Effect of Waves
- Research projects
  - SVS full scale test
  - MASPUS lab test
- DHI/Statoil study

- Allows for state-of-the-art fatigue analyses
- Links in-line VIV and wave loads
- Allows cross-flow vibrations
- Safety philosophy in compliance with DNV-OS-F101
- Introduces consistent link between analysis models and safety factor(s)

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

DNV GL 14 → DNV-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

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)

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
- DNV-RP-F105 still complex (and difficult?) to use
- Need for a calculation tool to:
  - make it easier to apply the RP
  - enable a cost-efficient span assessment


Welcome to FatFree
FATFREE ™
FATIGUE ANALYSIS OF FREE SPANNING PIPELINES
DNV
Offshore Classification and Technical Services
fatfree@dnv.com
Version: 6.00 Released: 26/08/98
Program by: Kim Mørk, Olav Fyrileiv & Angus Reid
Please Note. FatFree has been thoroughly validated and verified. However no warranty, expressed or implied, is made by Det Norske Veritas, as to the accuracy or functionality of the program, and no responsibility is assumed in connection therewith.

LEVEL 1 SPANS	OPTIONS
LEVEL 2 SPANS	USER HELP
LEVEL 3 SPANS	PRINT RESULTS

FATFREE Current Vers. 9.0

FATIGUE ANALYSIS OF FREE SPANNING PIPELINES

DNV version *Expiry date: 2002-12-31* *Release Note*

Program by:
Kim Mørk (Kim.Mork@dnv.com)
Olav Fyrileiv (Olav.Fyrileiv@dnv.com)
Deep Water Technology

FATFREE COMPLETED
No Wave Case

Project:		**Date:**	2002-06-10	**Calculations by**	
References:				**Verified by**	

Calculation Options	Current Modelling	Free Span Scenario	Response Data	Damping	SN-Curves	Safety Factors
Analysis Level 3	Uc Histogram	Flat sea-bed	User Defined	User Defined	F2 (CN 30.4)	NORMAL

Code	Wave Modelling
RP-F105	
Return Period Values	**Directionality**
Automatic Generated	Discrete - C dir.
UPDATE SHEET	Environmental Data
CALCULATE	Current

Free Span Scenario		Response Data		Damping		SN-Curves		Safety Factors	
h [m]	200	f_o(in-line)	0.722	ζ_{struc}	0.000	m_1	3	η	0.50
L [m]	50	f_o(cr-flow)	2.000	ζ_{soil} (in-line)	0.000	m_2	3	γ_k	1.30
e [m]	3.00	A_{in} (in-line)	186	ζ_{soil} (cr-flow)	0.000	Log(C_1)	11.630	γ_f	1.20
d [m]	0	A_{cr} (cr-flow)	186	$\zeta_{h,RM}$	0.000	Log(C2)	11.630	γ_S	1.05
θ_{pipe}	0.0	λ_{max}	484			$\log N_{sw}$	8.00	γ_{on}	1.10
D [m]	0.500	δ/D	1.52	K_S(in-line)	0.00	S_0 [MPa]	0.00		
L/D	100	S_{eff}/P_E	0.13	K_S(cr-flow)	0.00	SCF	1.00		
		$L_{eff,vs}$/L		**Soil stiffness**				Ψ_R	1.00
		$L_{eff,v}$/L		Sand - Medium					
				K_V	1.907E+07			☐ Well Defined Span	
				K_L	1.430E+07				
				$K_{V,S}$	5.300E+05				

FATIGUE LIFE

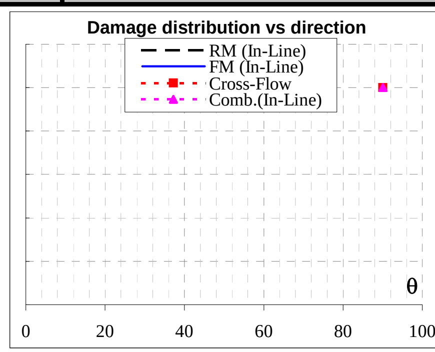
In-line (Response Model)	2.10E+00	yrs
In-line (Force Model)	-	yrs
In-line (Combined)	-	yrs
Cross-Flow	8.33E+05	yrs

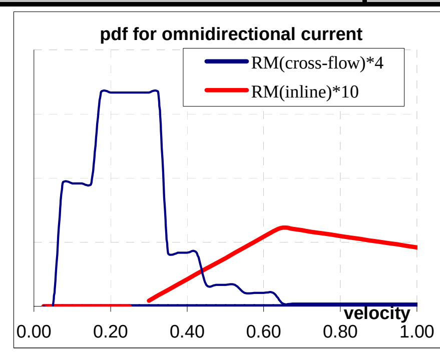
DYNAMIC STRESS [MPa]

cross-flow direction	Peak Stress	V. Mises Stress	in-line direction	Peak Stress	V. Mises Stress
σ_x(1 year)	0.0	319.8	σ_x(1 year)	22.0	113.7
σ_x(10 year)	0.0	319.8	σ_x(10 year)	22.0	113.7
σ_x(100 year)	0.0	319.8	σ_x(100 year)	22.0	113.7

EXTREME CONDITIONS

Current		Waves	
U_C(1 year)	0.76	U_S(1 year)	0.00
U_C(10 year)	0.76	U_S(10 year)	0.00
U_C(100 year)	0.76	U_S(100 year)	0.00





STRUCTURAL MODELLING

Static Stress [MPa]		Transfer values		Areas [m²]		Functional Loads		Pipe Dimensions [m]		Constants		Densities [kg/m³]	
σ_h	48.0	EI_{steel}	1.80E+08	A_i	0.16619	H_{eff} [N]	0.00E+00	D_s	0.5000	ν	0.30	ρ_{steel}	7850
σ_N	6.8	m_e	472	A_{steel}	0.03016	p [bar]	60	t_{steel}	0.0200	α [°C⁻¹]	1.17E-05	$\rho_{concrete}$	0
$\sigma_{M,cr}$	299.9	q	670	$A_{coating}$	0.00000	ΔT [°C]	0	$t_{concrete}$	0.0000	E [N/m²]	2.07E+11	$\rho_{coating}$	0
$\sigma_{M,in}$ (100y)	66.6	S_{eff}	-3.99E+05	$A_{concrete}$	0.00000	**Coating data**		$t_{coating}$	0.0000	C_D(current)	1.00	ρ_{cont}	200
		C_a	1.00	A_e	0.19635	k_c	0.00					ρ_{water}	1027
		CSF	0.00			f_{cn} (MPa)	45						
		ρ_s/ρ	1.34										

Experience with DNV-RP-F105

- Slight relaxation compared to Guideline 14.
- Pipe-in-trench effect significant, relevant for free spans due to scouring.
- Effect of thick concrete coating significant.
- Updated boundary condition coefficients provides good estimates for the structural response of single free spans.
- DNV-RP-F105 allows significantly longer spans than older codes.

DNV-RP-F105 represents state-of-art in free span design and minimise the costs related to seabed correction and span intervention work.

API RP 1111 (1999)

4.4.3 Spans

The length of unsupported spans on an offshore pipeline should be controlled to avoid excessive loads or deformations in the pipeline.

4.4.3.1 Span Limitation Due to Weight, Pressure, and Temperature

Refer to 4.1.4 and 4.6.3 for the static loads and limits on combined loads in determining the span limitation due to its own weight, pressures, temperature, and primary longitudinal loading.

4.4.3.2 Span Limitation Due to Vortex Shedding

4.4.3.2.1 Spans exposed to transverse flow of seawater due to currents and waves are subject to a phenomenon commonly referred to as *vortex shedding*. This can cause the pipeline to oscillate as vortices alternately change the pressure above it and the pressure below it as they form and detach. Large amplitude oscillations may occur unless the natural frequency of the span is sufficiently greater than the frequency of vortex shedding.

M = approximate mass of pipe plus mass of water displaced by pipe, in kg/m (slugs/ft).

4.4.3.2.3 Comparison of frequencies obtained from these calculations should indicate the tendency of a span to oscillate because of vortex shedding. As with other stability calculations, determination of may be complex.

4.4.3.2.4 Both tension and axial stiffness affect the natural frequency. The tension and axial stiffness of the pipe may increase the natural frequency above that calculated by using equation 11. Span limitation due to vortex shedding should be based on the increased natural frequency due to the combined effect of tension and axial stiffness. Alternative methods such as finite element analysis can be employed to estimate structural response to the vortex shedding. More discussion on this subject can be found in the MIT thesis[8] and the DNV Guideline No. 14.[5]

4.5 FATIGUE ANALYSIS

4.5.1 All pipeline components such as risers, unsupported free spans, welds, J-lay collars, buckle arrestors, and flex-joints, should be assessed for fatigue. Potential cyclic loading that can cause fatigue damage includes vortex-induced-

DNV GL14→ Updated and released as DNV-RP-F105

DNV