SUT

October Evening Technical Meeting

A Case Study on Optimising Flexible Riser Fatigue Design

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Introduction

Context

- Assess a manufactured flexible for suitability
- Preliminary assessment indicates that fatigue life may be a concern

Objectives

1. Confirm that the intact riser can sustain the full design life
2. Assess the impact of an outer sheath breach on fatigue life
3. If failure is a risk, recommend measures to optimise fatigue performance

Constraints

- Do not change the cross section (existing flexible)
- Do not change the proposed configuration
- API 17J Safety Factor would not be reduced

Introduction

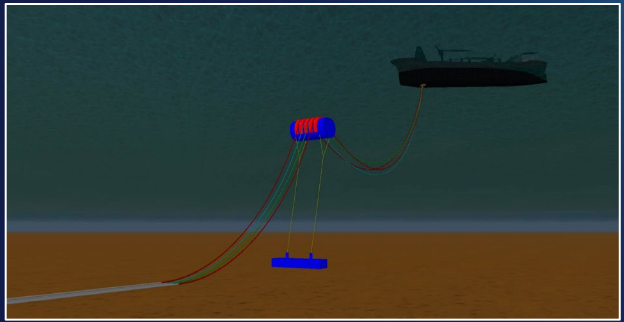
<u>Problem:</u> Fast turn around required

Fatigue life calculation for dynamic risers:

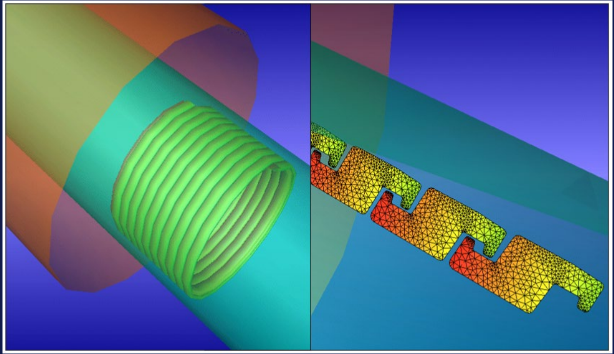
- Global analysis (Orcaflex)
- Local cross section analysis (BFLEX)

Change one parameter = Re-run both models

Can we automate the process to run multiple load cases and sensitivities with better efficiency?



Orcaflex Software (Orcina)



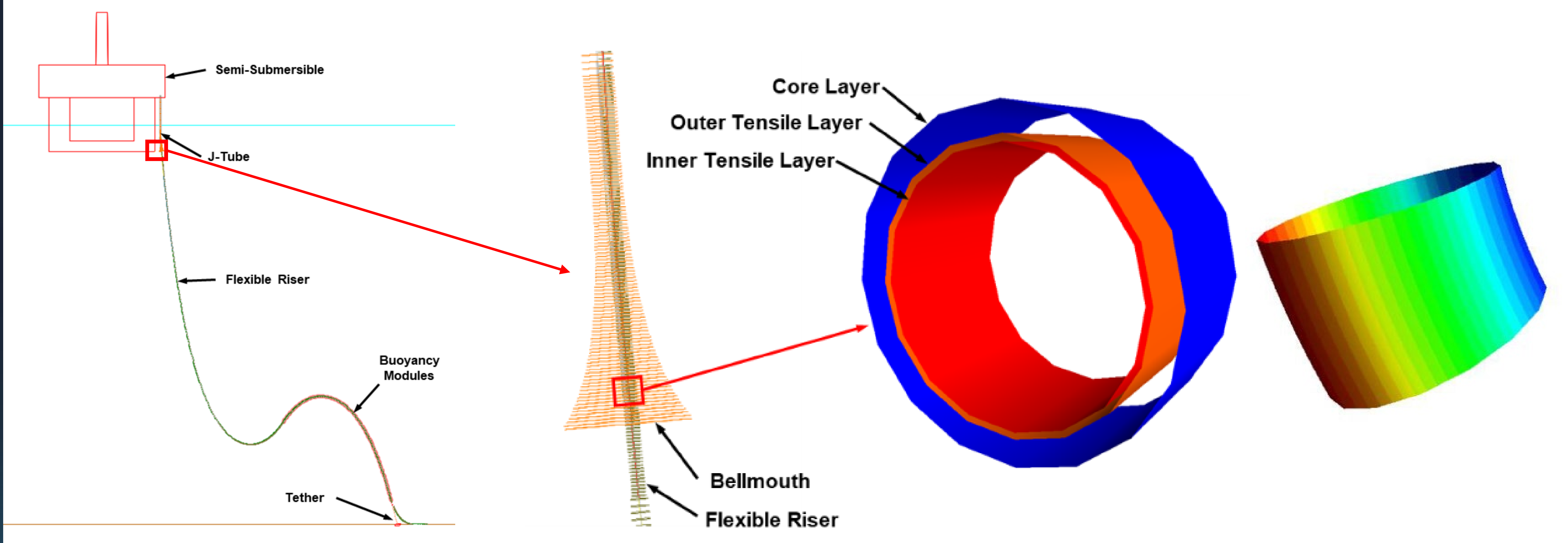
BFLEX Software (Sintef)

Analysis Toolchain

1. BFLEX for hysteresis (P, T, µ)
2. Orcaflex for tensions and curvatures (metocean)
3. BFLEX for local stresses
4. Python for fatigue damage

Model Description

- Riser in Pliant Wave configuration
- Focus on fatigue critical zone within the bellmouth



Global Model

Local (Stub) Model

Model Description

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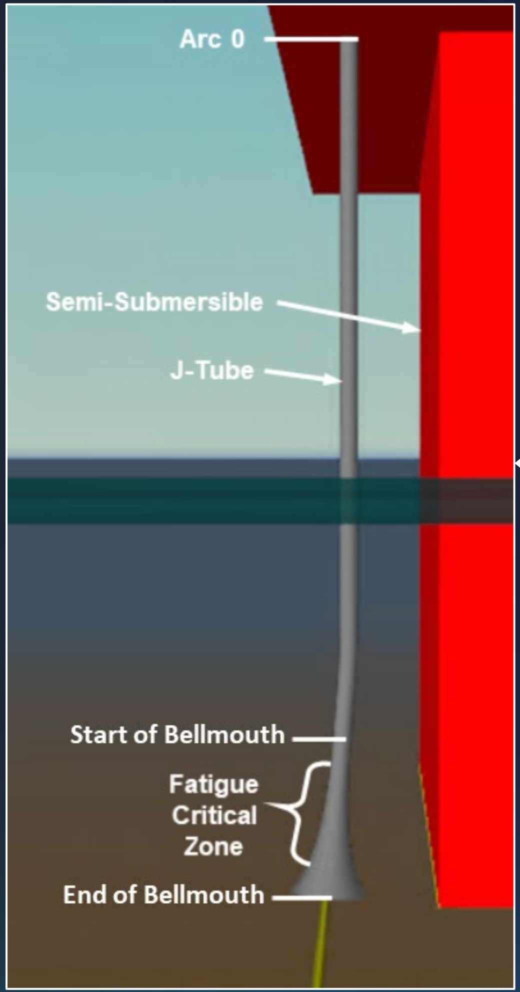
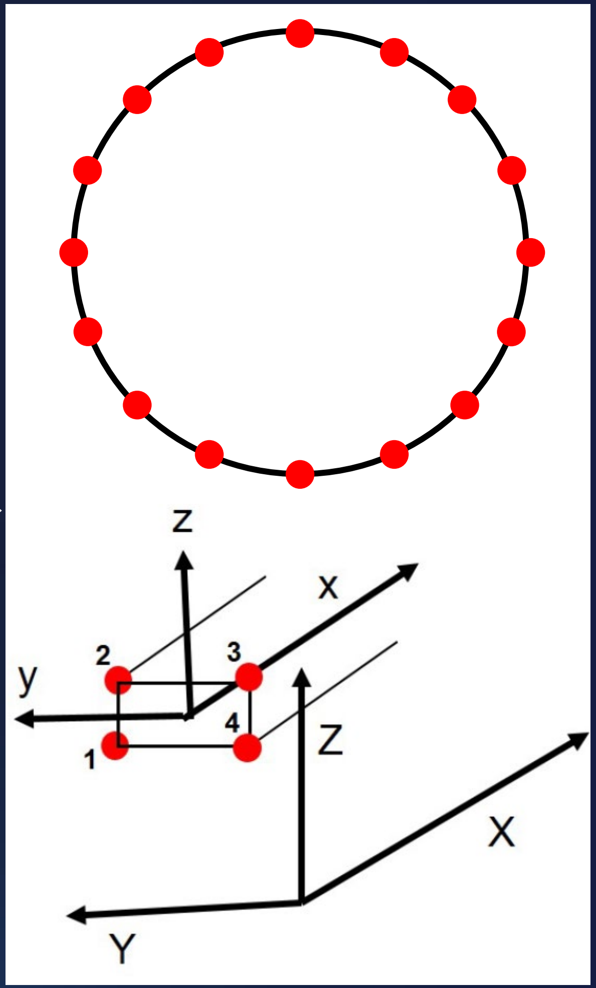


Global Model



Local Model

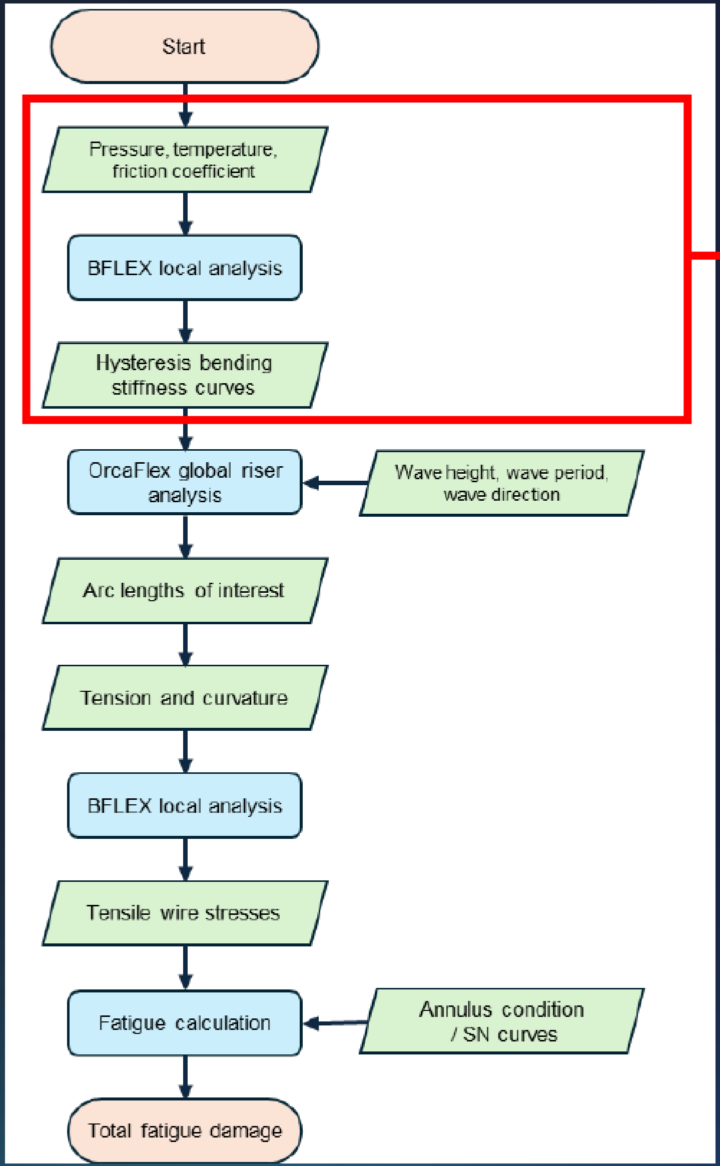
GLOBAL MODEL

- Extract loads along 8.4 metres of pipeline
- 200 mm pipe elements

LOCAL MODEL

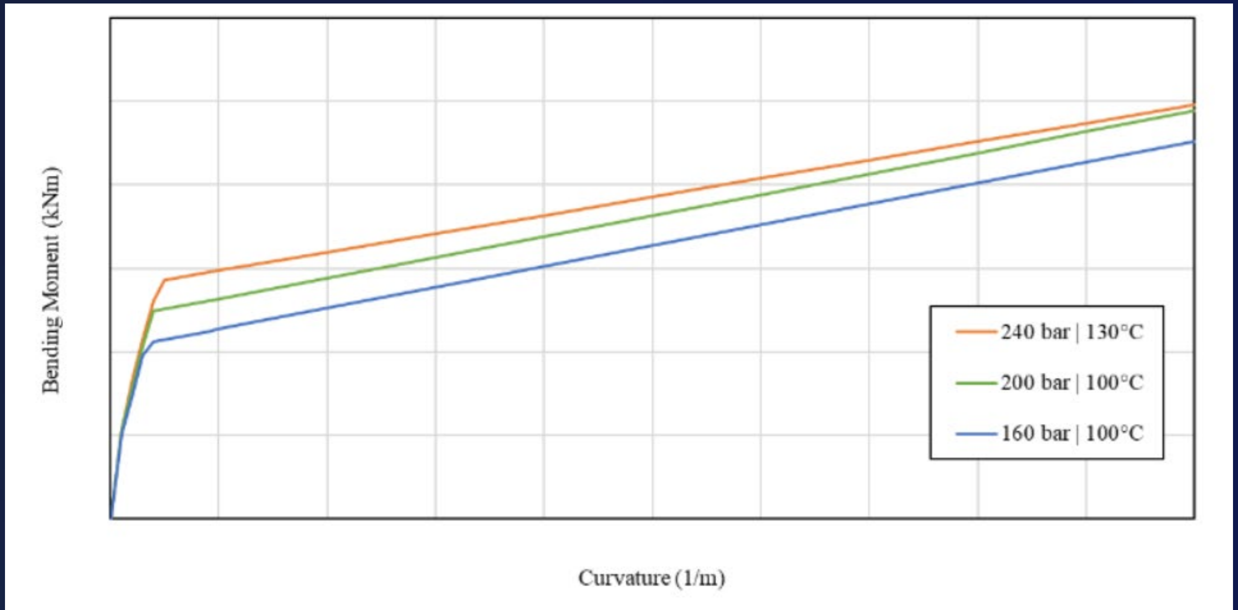
- One element of the global model
- 16 points around the circumference
- Inner armour / Outer armour
- Extraction of stresses and fatigue damage calculation at all 4 corners of the wire

Step 0 - Calibration



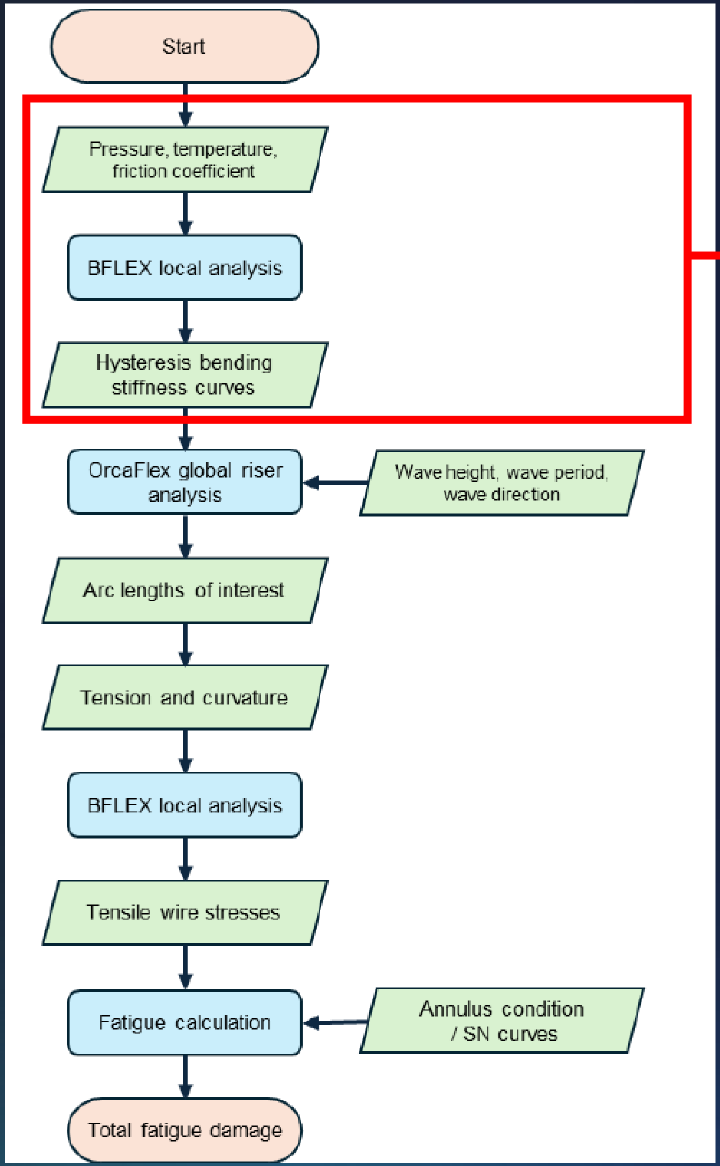
LOCAL MODEL

- Calibration based on manufacturer's data



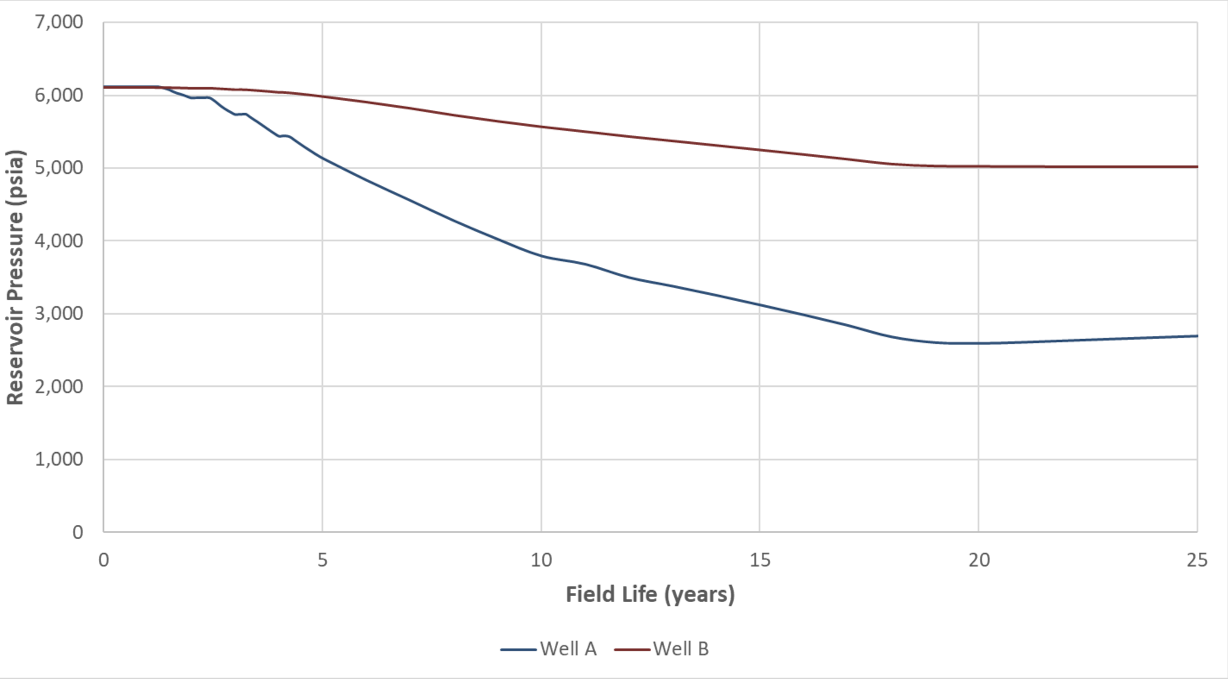
Stiffness Curves

Step 1 - Stiffness Curves

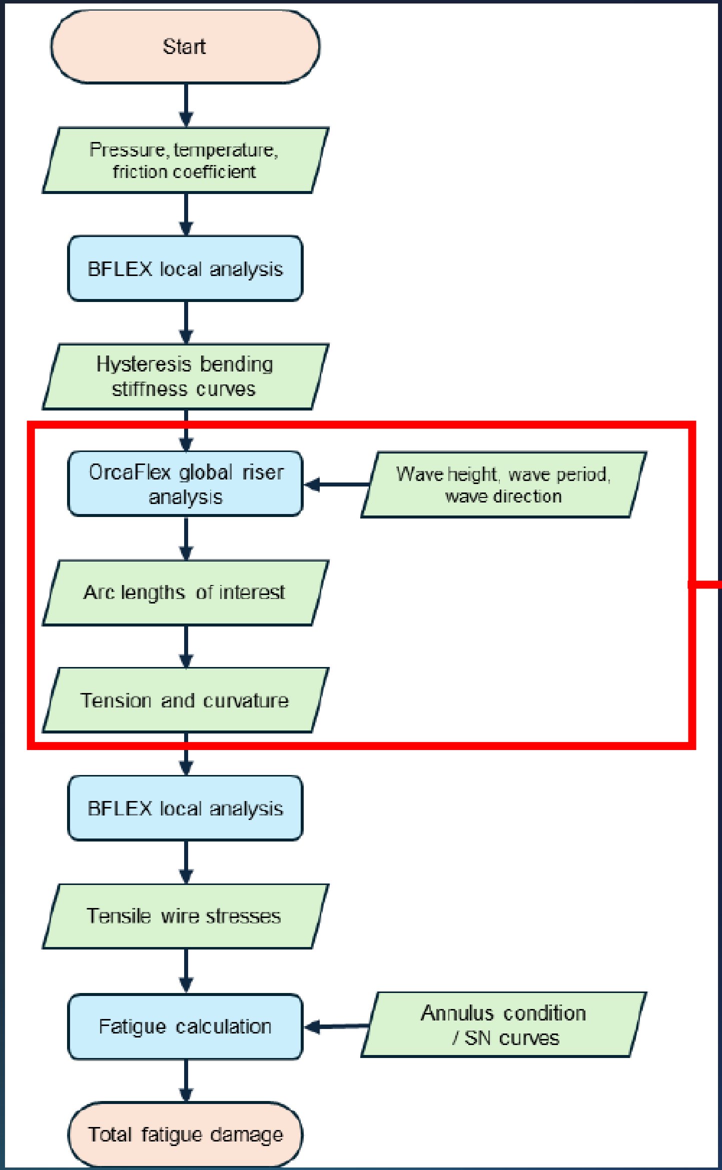


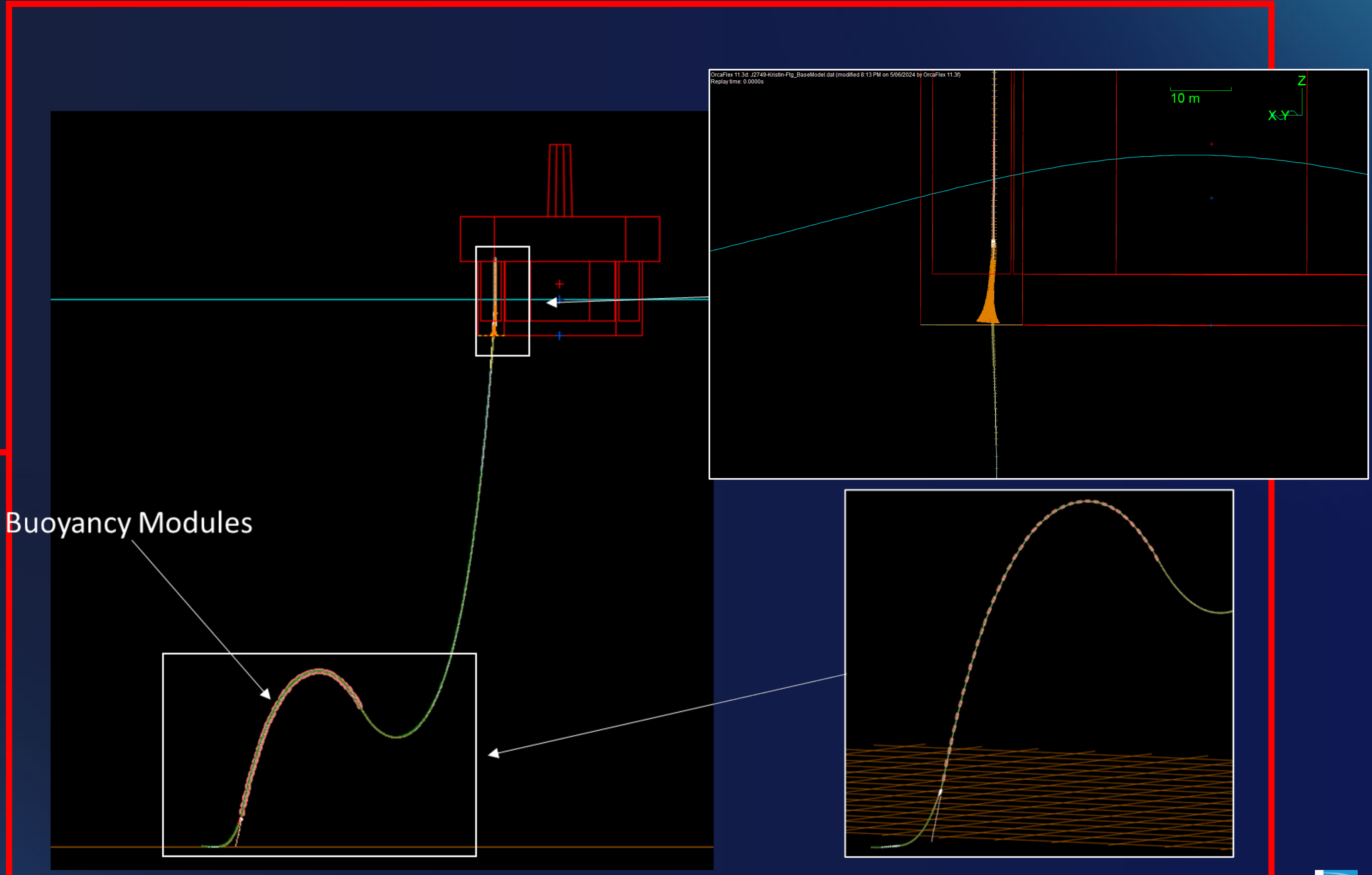
LOCAL MODEL

- Determine hysteretic stiffness curves for 12 combinations:
  - Pressure: 24 / 20 / 16 MPa
  - Temperature: 130 / 100°C
  - Friction interlayers: 0.14 / 0.12



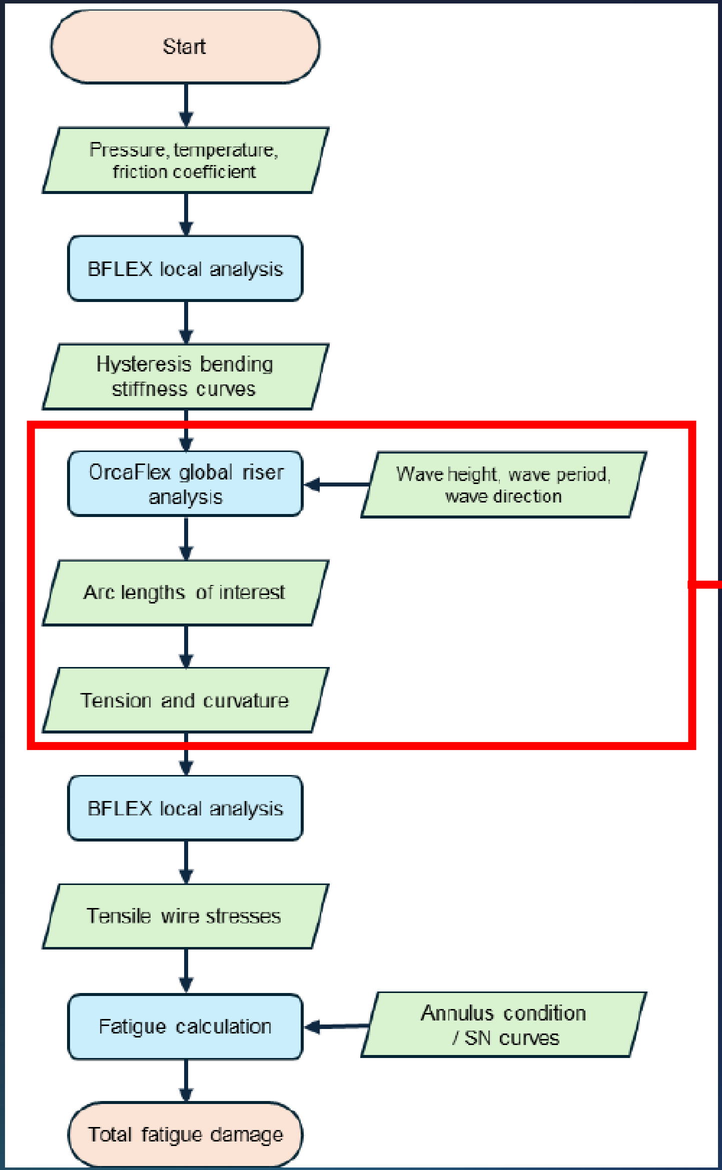
Step 2 – Global Dynamic Analysis





Global Model

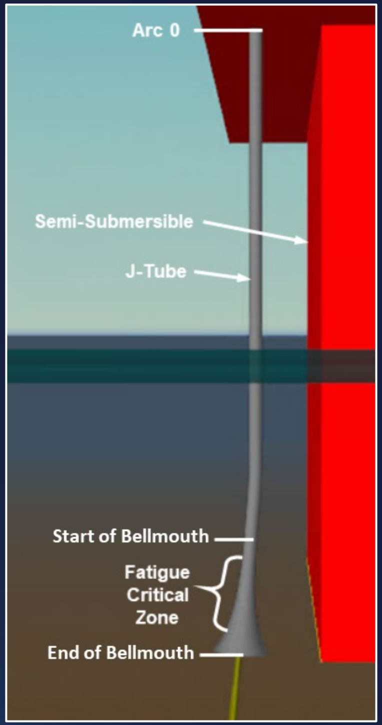
Step 2 – Global Dynamic Analysis



FOR EACH STIFFNESS CURVE

- All relevant H_s/T_p combinations
- 12 directions (30° increments)
- With and without steady current

➢**10,896 runs**



Fatigue Critical Zone

	Number of Cycles (log10)																										
H (m) \ T (s)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	>28
1	7.4	7.5	7.5	7.5	7.4	7.2	7.0	6.8	6.5	6.3	6.0	5.7	5.4	5.1	4.8	4.5	4.2	3.9	3.6	3.3	3.0	2.7	2.4	2.0	1.6	1.2	1.0
2		6.6	7.0	7.3	7.5	7.5	7.3	7.2	7.0	6.7	6.5	6.2	5.9	5.6	5.3	5.0	4.7	4.4	4.0	3.7	3.4	3.0	2.7	2.3	1.9	1.5	1.2
3		5.4	6.1	6.6	6.9	7.1	7.1	7.0	6.8	6.6	6.4	6.1	5.9	5.6	5.2	4.9	4.6	4.2	3.9	3.5	3.1	2.8	2.4	2.0	1.6	1.1	0.9
4			5.2	5.9	6.3	6.6	6.7	6.7	6.6	6.4	6.2	6.0	5.7	5.4	5.1	4.8	4.4	4.1	3.7	3.3	2.9	2.5	2.1	1.7	1.2	0.8	0.5
5				5.1	5.7	6.1	6.3	6.3	6.3	6.1	6.0	5.7	5.5	5.2	4.9	4.6	4.2	3.9	3.5	3.1	2.7	2.3	1.9	1.5	1.0	0.5	0.0
6				4.4	5.1	5.5	5.8	5.9	6.0	5.9	5.7	5.5	5.2	5.0	4.7	4.4	4.0	3.7	3.3	2.9	2.5	2.1	1.7	1.3	0.8	0.5	0.0
7				3.6	4.4	5.0	5.4	5.6	5.6	5.6	5.5	5.3	5.0	4.7	4.4	4.1	3.8	3.4	3.1	2.7	2.3	1.9	1.5	1.1	0.7	0.3	0.0
8					3.8	4.5	4.9	5.2	5.3	5.3	5.2	5.0	4.8	4.5	4.2	3.9	3.5	3.2	2.8	2.4	2.0	1.7	1.3	0.8	0.5	0.0	
9					3.1	3.9	4.5	4.8	5.0	5.0	4.9	4.8	4.6	4.3	4.0	3.7	3.3	2.9	2.5	2.2	1.8	1.4	1.0	0.6	0.3	0.0	
10						3.4	4.0	4.4	4.6	4.7	4.7	4.5	4.3	4.1	3.8	3.4	3.1	2.7	2.3	1.9	1.5	1.1	0.7	0.3	0.0		
11						2.9	3.5	4.0	4.3	4.4	4.4	4.3	4.1	3.9	3.5	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.3	0.0			
12						2.3	3.1	3.6	3.9	4.1	4.1	4.1	3.9	3.6	3.3	3.0	2.6	2.2	1.8	1.4	1.0	0.5	0.0				
13							2.6	3.2	3.6	3.8	3.9	3.8	3.6	3.4	3.1	2.8	2.4	2.0	1.6	1.1	0.7	0.3	0.0				
14							2.1	2.8	3.2	3.5	3.6	3.5	3.4	3.2	2.9	2.6	2.2	1.8	1.4	0.9	0.5	0.0					
15							1.6	2.3	2.8	3.1	3.3	3.3	3.2	3.0	2.7	2.4	2.0	1.6	1.1	0.7	0.3	0.0					
16							1.1	1.9	2.5	2.8	3.0	3.0	2.9	2.7	2.5	2.2	1.8	1.4	1.0	0.5	0.0						
17								1.5	2.1	2.5	2.7	2.7	2.7	2.5	2.3	2.0	1.6	1.2	0.7	0.3	0.0						
18								1.0	1.7	2.1	2.4	2.5	2.4	2.3	2.0	1.7	1.4	1.0	0.5	0.0							
19								0.6	1.3	1.8	2.1	2.2	2.2	2.1	1.8	1.5	1.2	0.8	0.3	0.0							
20								0.0	0.8	1.4	1.8	1.9	1.9	1.8	1.6	1.3	1.0	0.6	0.0								
21									0.5	1.0	1.4	1.6	1.7	1.6	1.4	1.1	0.8	0.3	0.0								
22									0.0	0.7	1.1	1.3	1.4	1.3	1.2	0.9	0.6	0.0									
23										0.3	0.8	1.0	1.1	1.1	1.0	0.7	0.3	0.0									
24										0.0	0.5	0.8	0.9	0.8	0.7	0.5	0.0	0.0									
25											0.0	0.5	0.6	0.6	0.5	0.3	0.0										
26											0.0	0.0	0.3	0.3	0.3	0.0	0.0										
27												0.0	0.0	0.0	0.0	0.0											
28													0.0	0.0	0.0												

Yearly Metocean Data

Step 3 – Stress and Fatigue Damage

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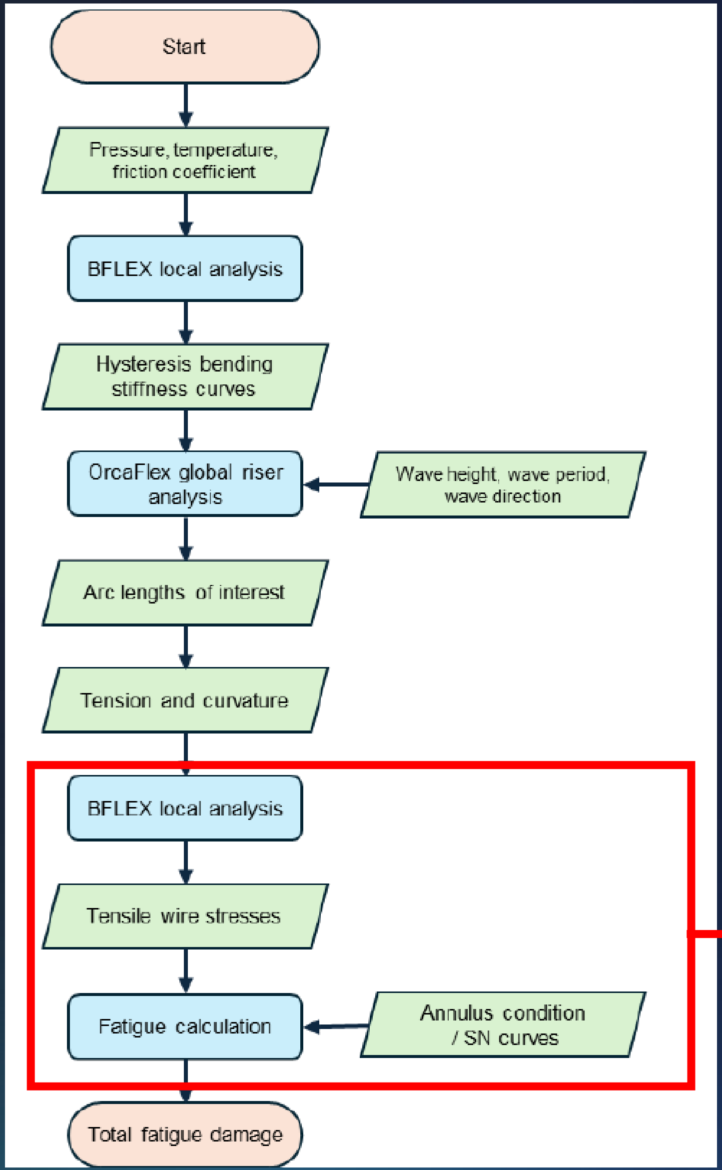
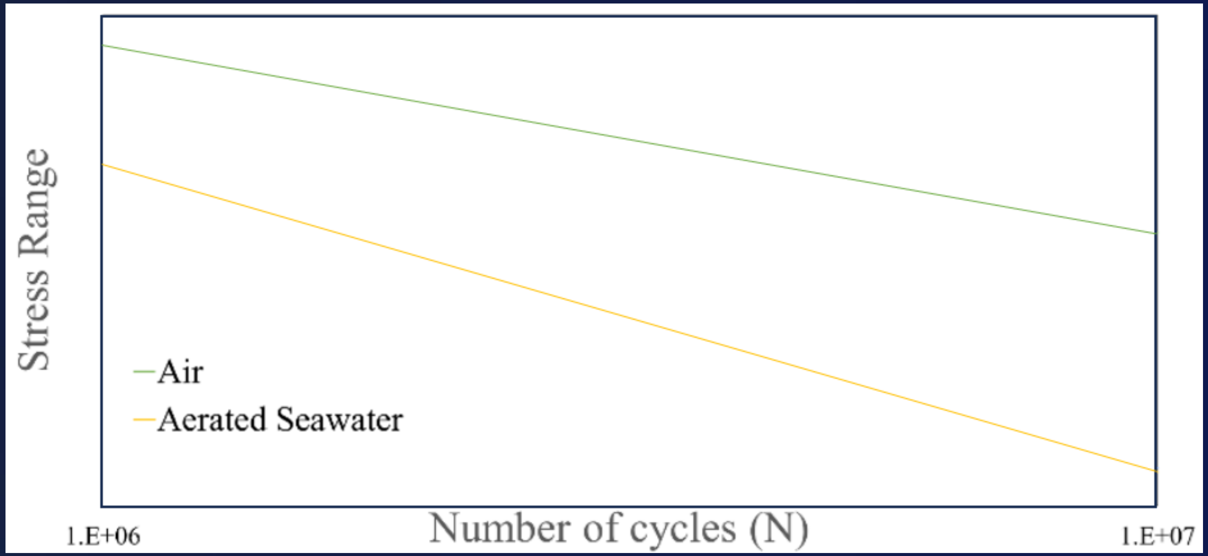


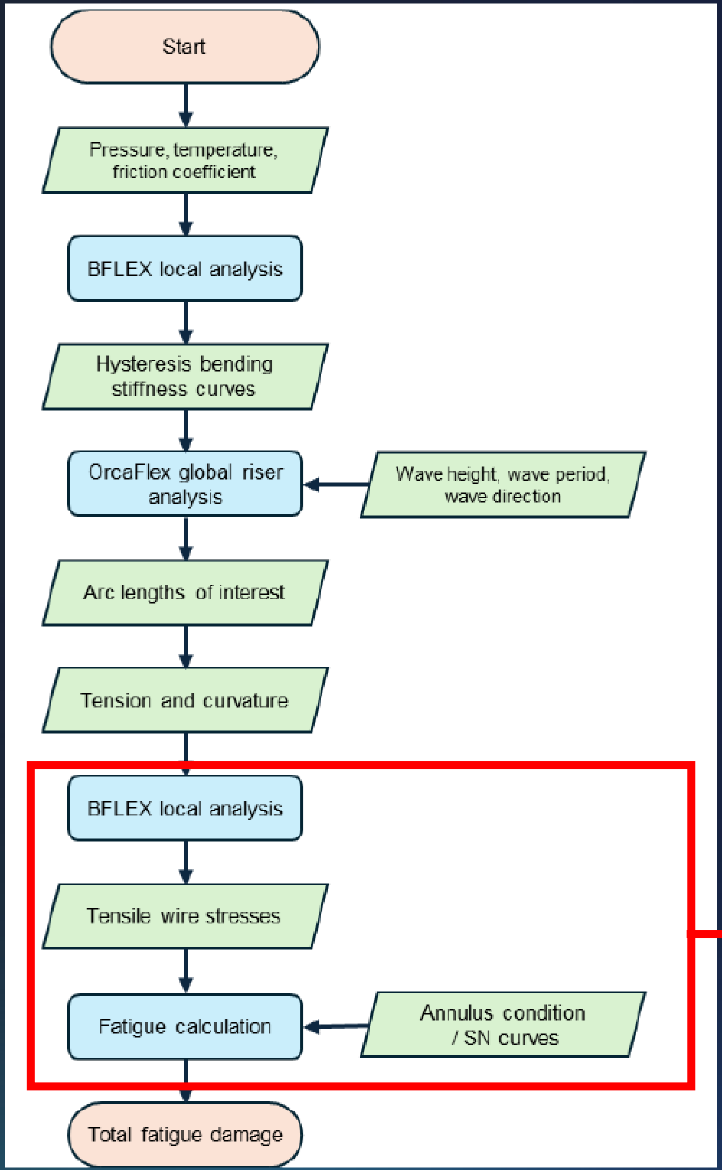
LOCAL MODEL

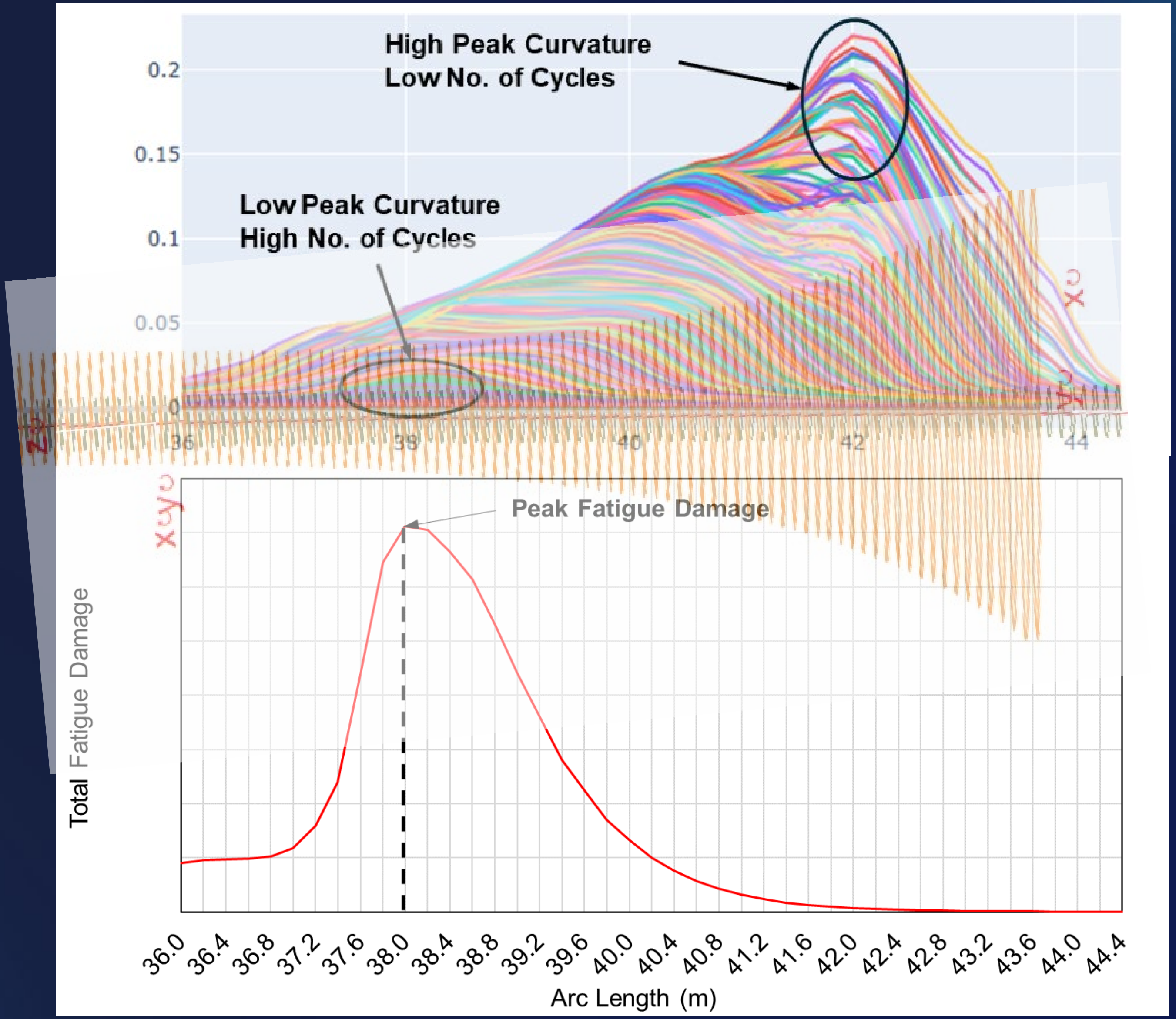
- Stresses calculated in the fatigue critical zone (457,632 runs)
- Fatigue damage from stress ranges using Miner's summation (59 million)
- Varying annulus conditions (before / after breach)
- Consider corrosion (cross section reduction)



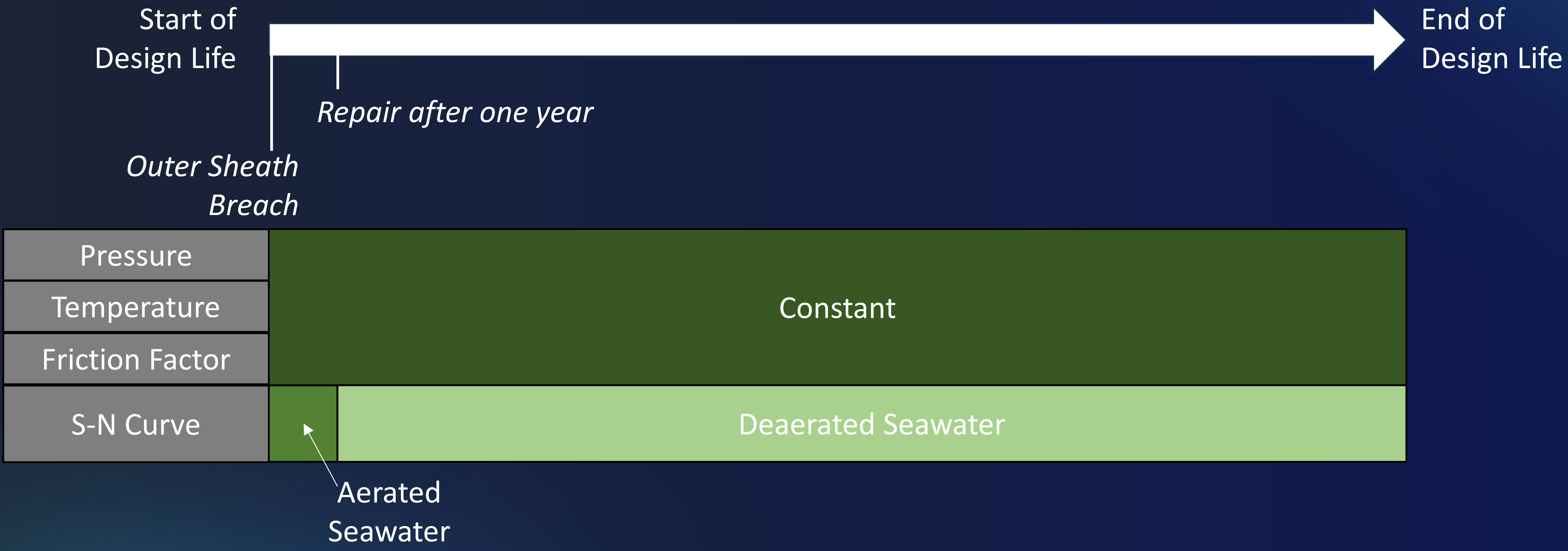
S-N Curves

Step 3 – Stress and Fatigue Damage





Results – Breach on Year 1



Results – Breach on Year 1

Operating Year	Cumulative Damage
1 (breach)	0.01400
2	0.02488
3	0.03598
4	0.04729
5	0.05882
6	0.07057
7	0.08256
8	0.09477
9	**0.10723**
10	0.11993
11	0.13288
12	0.14608
13	0.15955
14	0.17328
15	0.18728
16	0.20157
17	0.21614
18	0.23100
19	0.24616
20	0.26162
21	0.27740
22	0.29349
23	0.30991
24	0.32667
25	0.34377

Fail Fatigue Criterion

Design Operating Conditions

Design Operating Conditions:

- Fatigue damage > 0.1 during the 9th operating year (safety factor of 10 as per API 17J)

Sensitivities:

- Friction factor (dry to wet): ~ 3 years improvement
- Steady current (mean): ~ 1 year improvement
- Internal pressure reduction: > 4 years improvement

Friction Factor	Current	Pressure (bar)	Operating Year 0.1 Damage Exceeded
0.14	None	240	9
0.12	None	240	12
0.14	**Mean**	240	10
0.14	None	**200**	13
0.14	None	**160**	19
0.12	**Mean**	**200**	19
0.12	**Mean**	**160**	>25

Effect of Sensitivity Parameters on Fatigue Life

Results – Year of Failure vs Internal Pressure

Pressure	Design	Reduced	
Temperature	Design	Reduced	
Friction Factor	Dry	Wet	
S-N Curve	Air	Aerated Seawater	Deaerated Seawater

Results – Year of Failure vs Internal Pressure

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Pressure reduces overtime

Breach Occurrence	Operating Year 0.1 Damage Exceeded		
	240 Bar Post Breach	200 Bar Post Breach	160 Bar Post Breach
Year 1	12	18	>25
Year 2	13	19	>25
Year 3	14	20	>25
Year 4	15	21	>25
Year 5	16	22	>25
Year 6	17	23	>25
Year 7	18	24	>25
Year 8	19	>25	>25
Year 9	20	>25	>25
Year 10	21	>25	>25
Year 11	22	>25	>25
Year 12	23	>25	>25
Year 13	24	>25	>25
Year 14	>25	>25	>25

Conclusions

- Efficient way to assess fatigue performance of the riser and address client's concerns
- Method can be replicated for different configurations / cross-sections / locations

Key Success:

- Maximised study value by executing and post-processing a very large number of cases in a minimum time
- Enables rapid sensitivity assessments (turnaround < 1 day once setup)

Insights:

- The method presented allows for better understanding of the damage buildup in a riser.
- It can be used to estimate the actual service life compared to the design life
  - Fatigue Optimisation
  - System changes
- The manufacturer's recommended design envelope is typically conservative and method like the ones presented here allows to better understand how you are tracking compared to the "design" scenario

Thank You

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