Contents

List of Figures

List of Tables

ABBREVIATIONS

Abbreviation	Description
BE	Best Estimate
CCS	Carbon capture and storage
CWC	Concrete Weight Coating
DFF	Design Fatigue Factor
EBN	Energie Beheer Nederland
FEED	Front-end engineering design
GS	(TTE) General Spcifications
KDF	Knock-Down Factor
LAT	Lowest Astronomical Tide
LE	Lower Estimate
MPa	Mega Pascal
NEN	Royal Netherlands Standardization Institute
SCF	Stress concentration factor
TEPNL	TotalEnergies E&P Nederland B.V.
TTE	TotalEnergies
UE	Upper Estimate
VM	Von Mises equivalent stress

DEFINITIONS

Terminology	Definition

HOLDS

No.	Section	Hold

1 INTRODUCTION

1.1 Purpose of Document

The purpose of this document is to describe the lateral buckling assessment of the 16” D-HUBN and L4A platforms, present the results and demonstrate conformance to the design code.

1.2 Project and Code Requirements

The lateral buckling assessment is performed within the requirements of NEN 3656 [1], Company General Specification GS EP PLR 100 [2] and DNV codes [3], [4].

2 SUMMARY AND CONCLUSIONS

Lateral buckling is a phenomenon associated with pipelines which are not buried and therefore applies to L4A spurline.

As a first step, the susceptibility to lateral buckling is checked based on the analytical methods specified in the codes. The pipeline is found to be susceptible to lateral buckling along its entire length as per DNV methodology [4] which includes 0.65 factor on the critical axial force. Using hydrodynamic loads, the results show that the pipeline is not absolutely stable. This is aligned with the on-bottom stability assessment [5], which predicts lateral movement under wave and current actions along the whole pipeline. This implies that the pipeline will move laterally up to 10D (7m) on the seabed during storms, creating many lateral out of straightness features which may then initiate lateral buckles.

In the second step, a worst-case location lateral buckle is simulated by running finite element software Abaqus. Half-buckle models for each of the 3 concrete coating thicknesses along the pipeline (100mm for first 11km from D-HUBN, 140mm for the next 7km and 60mm for the last 11km) are developed. An initial out-of-straightness is created by applying a lateral displacement to the buckle crown node and then releasing it to let the pipe find equilibrium with the seabed friction. A combination of various lower estimate, best estimate and upper estimate values of axial and lateral friction are used as per GS EP PLR 100 [2] . These result in 5 load cases. Each load case is checked against a series of initial imperfections (out-of-straightness) to study the lateral buckle formation. The analysis considers minimum installation temperature (associated with pipelay in winter which is unlikely), together with the maximum fluid inlet temperature (associated with summer conditions). If the pipeline is installed in summer, lateral buckles will be less severe or eliminated completely.

The results show that;

i. Less than 1m of lateral movement/buckling takes place if the axial breakout friction is taken as the drained condition. This is the most likely condition for lateral buckling assessment as drained conditions develop in a rather short time, as supported by field observations [6], [7].

ii. To encourage the pipeline buckle/expansion at the artificially created lateral imperfection, lower values of axial friction (undrained) are also assessed.

iii. With undrained axial friction, the pipeline does not move laterally for imperfection values of 0.5m or less.

iv. 2m of imperfection amplitude is found to create the worst stress in the 100mm and 140mm CWC sections. For 140mm CWC section, 3m imperfection gives the maximum stress in the laterally displaced (buckled) pipe.

A summary of results is given in Table 2-1.

Table 2-1 – Summary of Results

	Drained	Undrained (axial friction)		
	100mm	100mm	140mm	60mm
From KP - to KP	0-11	0-11	11-18	18-29
Buckle Amplitude (m)	0.87	1.85	0.44	1.27
Buckle Length (m)	160	140	160	180
Maximum Von-Mises Stress (MPa)	303	400	280	316
Total Strain	0.001298	0.00188	0.00105	0.001303
Plastic Strain	0	0	0	0

The resulting stresses and strains in all cases are within the elastic limit and do not exceed the code criteria.

The stress range during shut-down & start-up cycles at the buckle crown is checked for fatigue damage. Using SN curve methodology, the number of cycles that the spurline can survive is calculated as 5301 in 30 years (or 176 per year). This includes agreed DFF and DFF, in accordance with TTE GS requirements.

The discontinuity in concrete coating at a field joint will increase the stress. A stress concentration factor of 1.435 is applied and the resulting maximum stress is found to remain within the elastic limit.

It is concluded that lateral buckling may occur under extreme maximum operating conditions but will form small buckles/lateral displacements resulting in acceptable stresses. Buckling will be reduced or avoided if the pipeline is installed in summer, as expected. No mitigation is required.

3 DESIGN DATA

All data used in this report is obtained from the pipeline design basis [6]. Where data is not available in the design basis, then it is documented here.

3.1 Linepipe Data

The 16inch spurline wall thickness is 16.66mm [7] giving an ID of 373.08mm. The 500m zone around each platform has thicker wall of 21.44mm [7], but the ID is kept constant.

3.2 Pipe Coatings

The entire spurline has a 4.2mm 3LPE coating with a density of 900kg/m^3. A concrete weight coating is added to keep the pipeline movement under hydrodynamic loadings under code specified limits. The CWC thicknesses shown in Table 3-1 with density of 3450kg/m^3 are used for the spurline. Ref. [5].

Table 3-1 – Concrete Coating Thickness

Section	Thickness (mm)
KP 0 to 11.1	100
KP 11.1 to 17.8	140
KP 17.8 to 28.7	60

3.3 Temperatures and Pressures

The data is given in the table below.

Table 3-2 – Temperature and Pressure Data

	Value
Temperature at installation, °C	5 [Note 1]
Design Pressure, barg	200 [Note 2]
Hydrotest Pressure, barg	250 [Note 2]
Maximum operating pressure, barg	170
Maximum Operating Temperature, °C	26
Ambient Temperature in Operation, °C	16

Notes:

1. The lowest mean monthly seabed temperature [8]. This is also used as the minimum system temperature for calculation purposes.
2. The pressure is defined at 6.03m above LAT.

Note the hydrotest temperature is assumed to be equal to the installation temperature.

The maximum temperature, pressure and density profiles used in the FEA [9] are given in the following figures. These conditions are associated with the maximum expected summer seabed temperature of 16°C.

Figure 3.1 – Pressure Profile

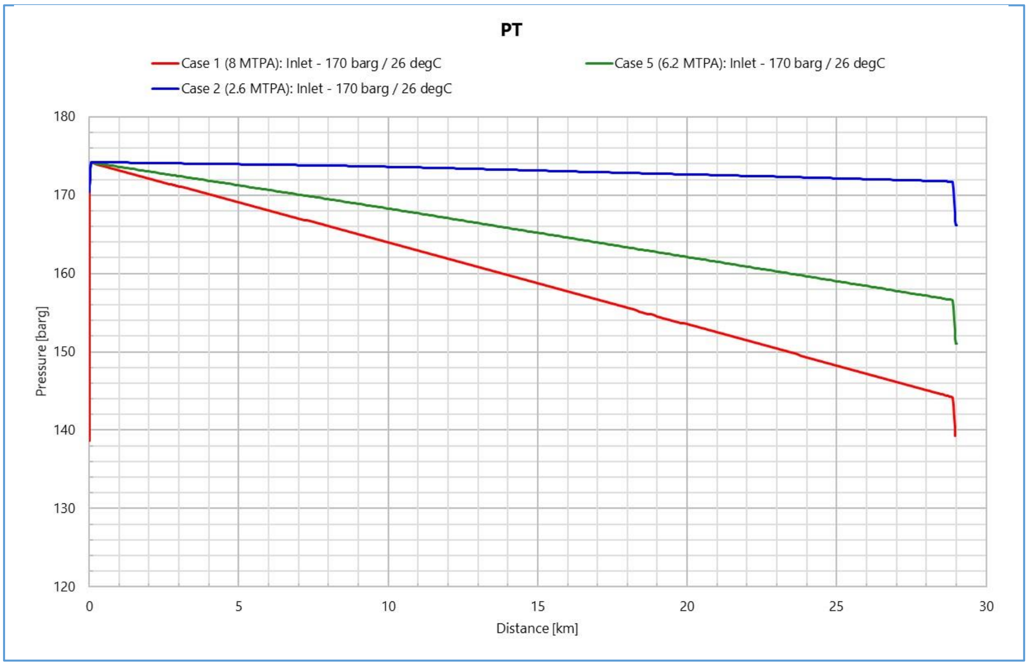


Figure 3.2 – Temperature Profile

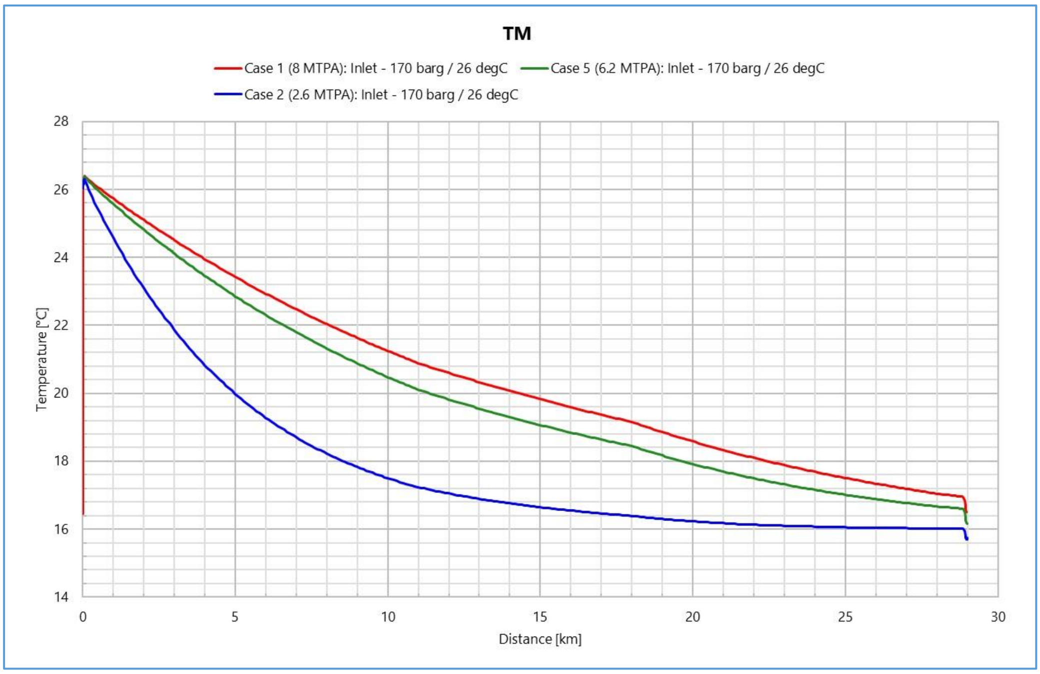
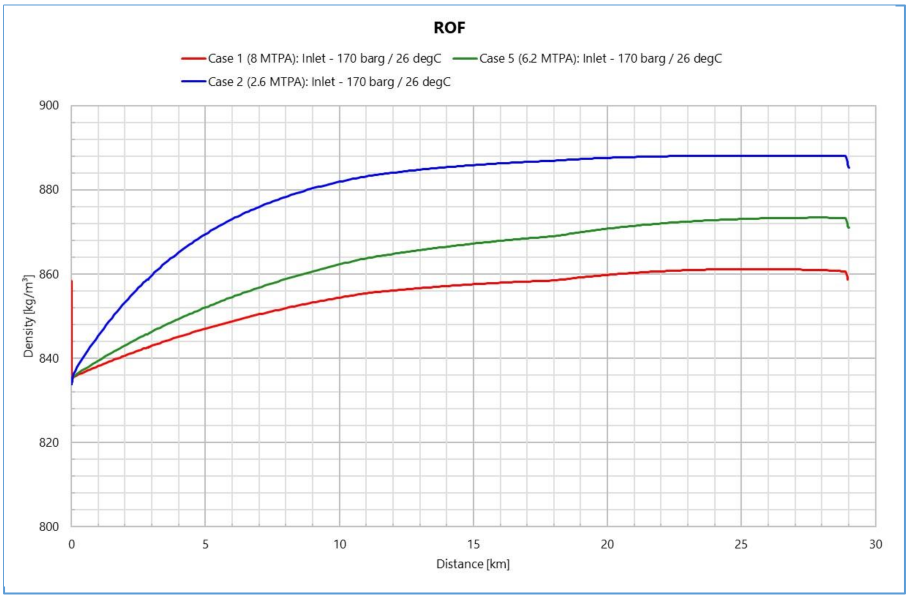


Figure 3.3 – Density Profile



Case 2 is selected for analysis as this results in the highest effective axial force along the length of the line. Corresponding pressures and temperatures for each of the three CWC zones are summarized below.

Table 3-3 - Selected Temperatures and Pressures for Analysis

CWC Thickness, mm	100	140	60
Temperature, C	26.3	17.7	16.5
Pressure, barg	174.2	173.6	172.9

3.4 Pipe-Soil Data

The pipe-soil friction data is taken from the PSI report [10]. The Abaqus analysis considers a simplified pipe-soil friction model, using the built-in anisotropic Coulomb friction model, considering break-out lateral and axial friction only. A mobilization displacement of 1mm is considered This approach is considered adequate for FEED, where relatively benign buckles are expected.

A more sophisticated analysis with non-linear friction and un-coupled axial and lateral behaviour should be considered during detailed design.

3.5 Pipe Material Stress-Strain Curve

The X65 line pipe material is modelled as an elastic-perfectly plastic material, with yield stress of 450 MPa.

3.6 Fatigue Parameters

For the estimate of fatigue damage using Miner's rule, the following parameters are used.

Table 3-4 – Fatigue Assessment Parameters

	Value	Reference
SN Curve	F1 (air)	[2]
DFF	10	[2]
KDF	9	[2], [4]
SCF at weld cap	1.286	[13] & See Appendix A.2

4 METHODOLOGY

4.1 Lateral Buckling

A pipeline tends to expand due to increase in temperature and pressure from the conditions when it was installed. The resistance from pipe-soil interaction (friction) restrains this expansion and thus generates axial compressive forces in the pipeline. This compressive force can result in global (Euler's) buckling of the pipeline in which the pipeline expands in a shape of a wave (buckle) and releases the compressive axial force. A single or multiple buckles form on a plane of least resistance. On a surface-laid pipeline like the L4A spurline, this is the seabed surface i.e. the pipeline will undergo lateral buckling.

4.2 Assessment

Lateral buckling assessment is carried out in the following stages or steps;

i. Analytical screening to determine the potential for lateral buckling. If the results show susceptibility to lateral buckling then proceed to step ii below.

ii. Run finite element simulation to predict the final buckle shape and the resulting stress/strain. Check these against the code limits. If code limits are exceeded, then uncontrolled (rogue) buckling cannot be allowed. Move on to step iii for design of mitigation measures.

iii. If uncontrolled buckling is not acceptable, define and evaluate mitigation measures to ensure buckles are avoided, or remain within acceptable limits.

Details of the above criteria are given in the design premise [6]. The 5 load cases combining axial and lateral frictions as per GS EP PLR 100 [2] are shown in Table 4-1 below. The appropriate soil friction values are taken from PSI report [10].

Table 4-1 – Load Cases

	LE Axial	BE Axial	UE Axial
LE Lateral	1	2	-
BE Lateral	-	3	-
UE Lateral	-	4	5

4.3 Acceptance Criteria

A full nonlinear elastic-plastic strain-based assessment is performed. From NEN 3656 [1], the LC4 is applicable.

Total strain limit (K.3.2) = 0.5%

The Abaqus stresses and strains are calculated around the pipe circumference at 32 positions, with output extracted at the following 4 positions on the outside of the steel pipe;

Position 1 = Maximum tension (9'o clock)

Position 2 = Top of pipe (12’o clock)

Position 3 = Maximum compression (3’o clock)

Position 4 = Bottom of pipe (6’o clock)

The 3D stress components at each location are extracted from Abaqus and combined to give von-mises stress.

5 RESULTS AND CONCLUSION

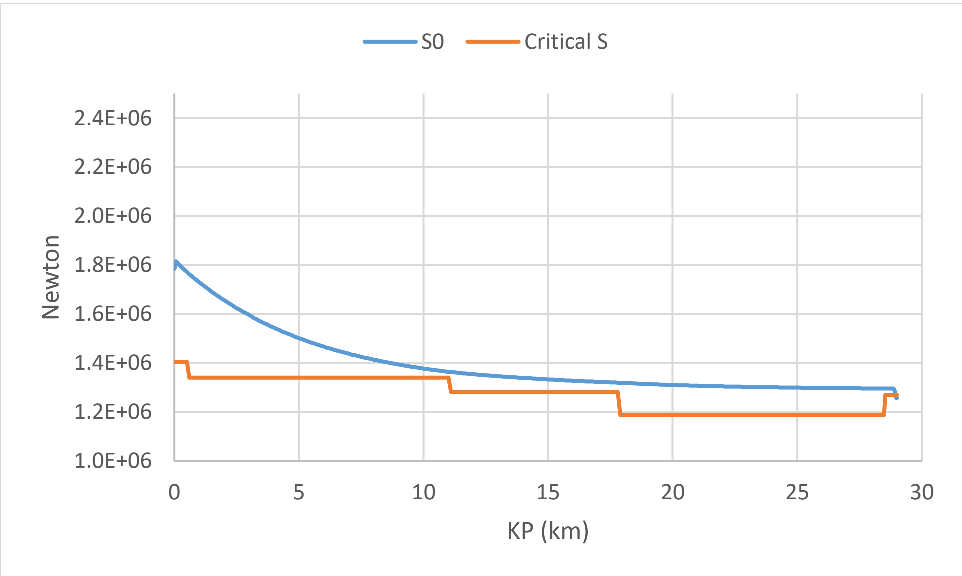
5.1 Screening Results

The effective axial force due to temperature and pressure is calculated and is compared with the critical axial force. However, in order to trigger a lateral buckle, there must be some initial out-of-straightness (imperfection) in the pipeline. Alternatively, an external force such has wave/current or anchor/fishing gear can provide the initial push necessary to trigger a lateral buckle.

The on-bottom stability design of spurline [5] allows for 10D lateral displacement along its whole route. In the screening check [4], for the pipe to be not susceptible to lateral buckling, it needs to be absolutely stable under the hydrodynamic loads i.e. zero lateral movement. From the on-bottom stability checks, it has already been established that even with high density concrete thickness of 140mm, the pipeline is not absolutely stable. It is predicted to move up to 10 times the pipe diameter. It is therefore concluded that even if the pipeline is perfectly straight after pipelay, significant lateral out of straightness features will develop after exposure to storm conditions. These features will act as buckle triggers, where lateral movement is initiated as the compressive axial force increases. See A.1 for calculations including the hydrodynamic loads.

Without hydrodynamic loads, Figure 5.1 below shows that the whole spurline length is still susceptible to lateral buckling as the effective axial force S_o exceeds the critical level of the effective axial force for the infinite buckling mode [4]. The critical force includes a factor of 0.65 as per DNV-RP-F110 [4].

Figure 5.1 – Susceptibility to Lateral Buckling Without Hydrodynamic Loads



5.2 Abaqus Simulation

As the pipeline is susceptible to lateral movement due to wave & current actions, step ii assessment i.e. a finite element analysis is necessary to study the release of axial compressive force in the pipeline. In a lateral buckling scenario, the axial compressive force can cause a rapid (snap) lateral movement also known as Euler's buckling. In this case the movement can result in a large displacement and high stresses/strains at the tip (crown) of the buckle. These high stress/strain values can exceed the local buckling limits.

The Abaqus model represents a single isolated buckle centred within a 5km length of pipe. This is selected to be sufficiently long to generate a virtual anchor point from feed-in to the buckle within the modelled length. This ensures that the maximum possible buckle strains are simulated.

The Abaqus model represents a single isolated buckle centred within a 5km straight length of pipe. This is selected to be sufficiently long to generate a virtual anchor point from feed-in to the buckle within the modelled length. This ensures that the maximum possible buckle strains are simulated.

The Abaqus modelling simulates the following sequence;

- A lateral imperfection is created by pulling the end node (buckle crown or tip) under fictitious pipe-soil friction. The displacement is then released, and actual friction values are applied.
- After, flooding and hydrotesting, the pressure is applied.
- In the last step, the temperature is added
- For the fatigue check, additional steps are included in which pressure is reduce followed by temperature dropping to ambient. The operating pressure and then temperature are applied again to model the next start-up.

A full step list is given below. Steps 11 to 20 cover the shut-down start-up cycles.

Step Name	Description
Step-1	Dummy weight and 1000.0N Residual lay tension
Step-2	Apply empty submerged weight -4045.49709797 N/m
Step-3	Impose 2.0m lateral displacement at trigger location
Step-4	Activate real seabed friction
Step-5	Release lateral displacement at trigger node & lock ends
Step-6	Apply Pipe : -5144.72233388 N/m flooded weight and 352620.45 Pa internal pressu
Step-7	Apply 25000000.0 Pa hydrotest pressure
Step-8	Remove hydrotest pressure
Step-9	Apply 17420000.0 Pa operating pressure and Pipe: -4973.13595559 N/m submerged w
Step-10	Apply 26.3 degC operating temperature
Step-11	Apply 8000000.0 Pa shut-down pressure
Step-12	Apply 16 degC shut-down temperature
Step-13	Apply 17420000.0 Pa operating pressure and Pipe: -4973.13595559 N/m submerged w
Step-14	Apply 26.3 degC operating temperature
Step-15	Apply 8000000.0 Pa shut-down pressure
Step-16	Apply 16 degC shut-down temperature
Step-17	Apply 17420000.0 Pa operating pressure and Pipe: -4973.13595559 N/m submerged w
Step-18	Apply 26.3 degC operating temperature
Step-19	Apply 8000000.0 Pa shut-down pressure
Step-20	Apply 16 degC shut-down temperature

The results as shown in a typical plot in Figure 5.2 are extracted and post-processed to check against the code limits. A half-buckle is modelled to improve computational efficiency, with a symmetry boundary condition applied at the crown of the buckle. This enforces Mode 3 buckling response, which generates the highest strains in the buckle. The buckle shape with symmetry mirror applied for visualisation is shown in Figure 5.3.

Figure 5.2 – Abaqus Lateral Buckle Model

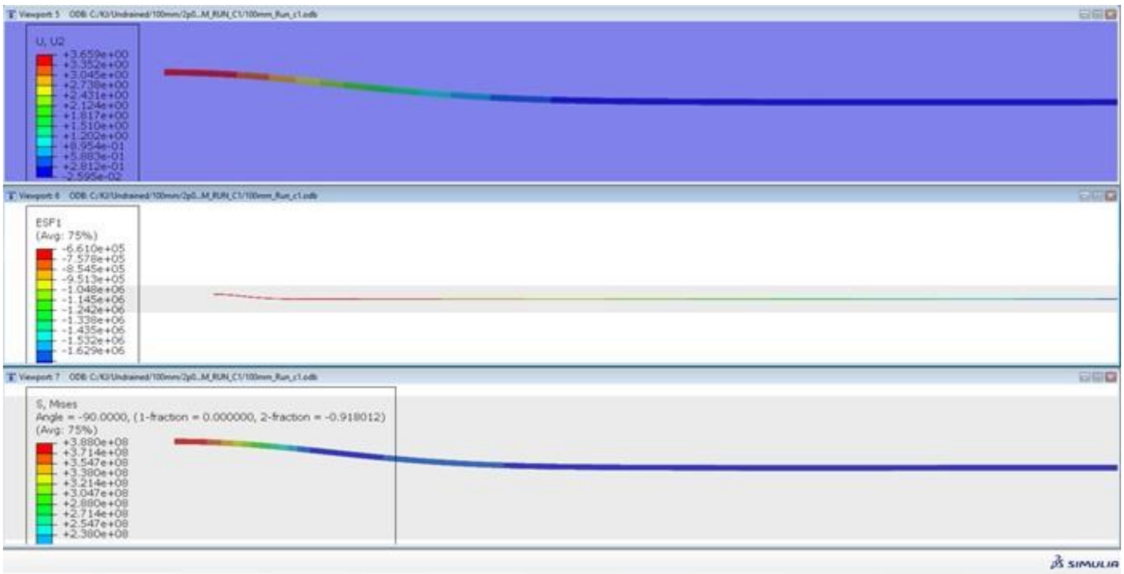
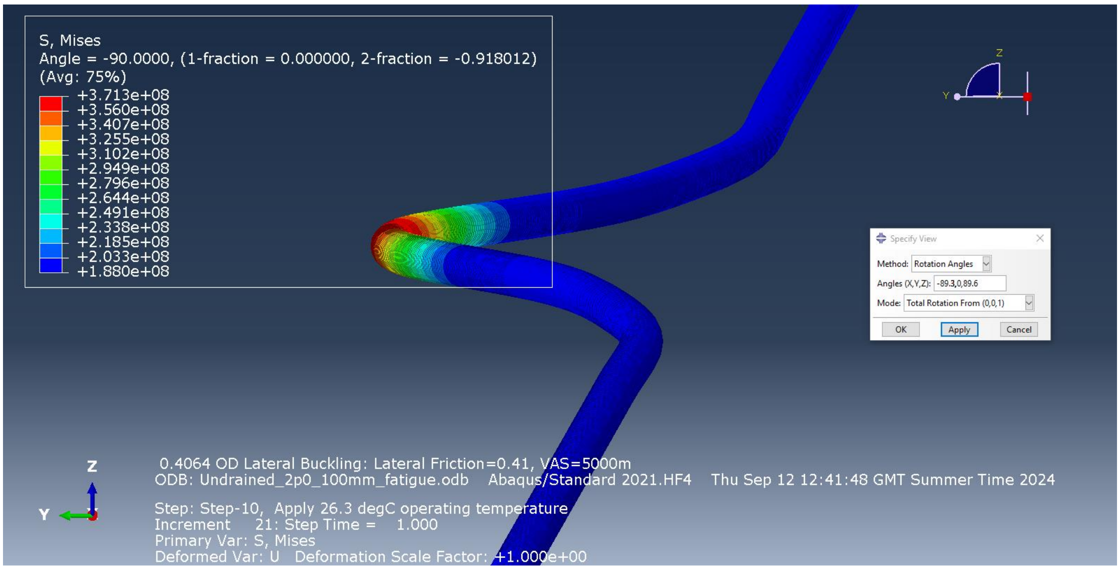


Figure 5.3 - Abaqus buckle shape with symmetry mirror applied to show full buckle



There are 3 concrete coating thickness sections along the spurline. These are analysed separately with their appropriate temperature, pressure and soil friction properties.

The drained axial friction results in minimal (less than 1m) lateral movement at the imperfection. Therefore, the case of undrained axial friction is studied in more detail in the sections below for various concrete thicknesses. A drained case is also added at the end for comparison.

5.3 Undrained Condition

5.3.1 100mm Concrete

A series of simulation are run in order to find the worst case imperfection size. The results are given in Table 5-1.

Table 5-1 – Sensitivity to Initial Imperfection Size (0.5m to 2.5m)

LC#	Ax	La	Buckle Amplitude (m)					Maximum VM (MPa)				
			0.5m	1.0m	1.5m	2.0m	2.5m	0.5m	1.0m	1.5m	2.0m	2.5m
1	LE	LE	0.00	1.31	1.81	1.85	1.77	200	367	403	400	396
2	BE	LE	0.00	1.42	1.45	1.49	1.42	200	370	371	366	362
3	BE	BE	0.00	0.00	0.06	1.06	1.14	200	208	238	379	376
4	BE	UE	0.00	0.00	0.00	0.87	1.04	200	208	217	374	373
5	UE	UE	0.00	0.00	0.00	0.68	0.84	200	208	217	345	350

As shown in Table 5-1, there is no lateral movement (buckle) for imperfection size 0.5m or less. At 1.0m & 1.5m imperfections, only Lower Estimate (L) of lateral friction allows a buckle to form. Lateral buckle reaches it's maximum amplitude if the imperfection size is 2.0m. Using a higher value of imperfection size reduces the amplitude and the maximum stress in the buckle. Therefore 2.0m imperfection size is the worst case for 100mm CWC pipe at the hot end of spurline.

The results for 2m imperfection are given in the following figures. The largest buckle in load case 1 friction is shown in the plots below.

Figure 5.4 – Lateral Displacement (U2)

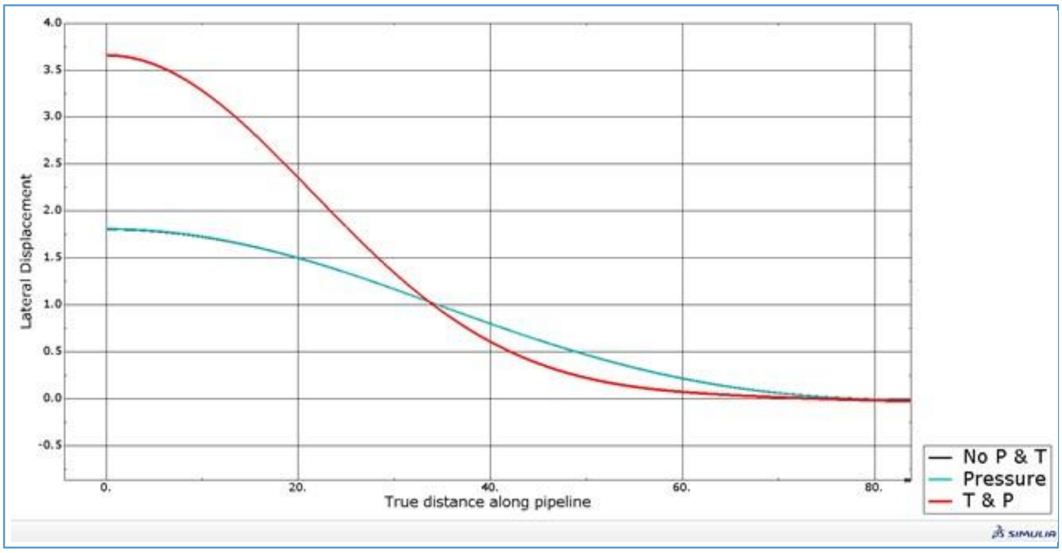


Figure 5.4 shows that after releasing the initial displacement of 2m, the pipe settles at approximately 1.8m amplitude in equilibrium with the axial and lateral soil frictions.

The application of the hydrotest or maximum operating pressure barely moves the pipe. In the final step of the simulation, temperature is added. The T & P step pushes the pipeline laterally by a further 1.85m (total lateral displacement = 1.8+1.85=3.65m) as shown in Figure 5.4.

The buckle wave length from the half-buckle model can be estimated from Figure 5.4 as 2 x 70m=140m.

Figure 5.5 – Effective Axial Force - ESF1

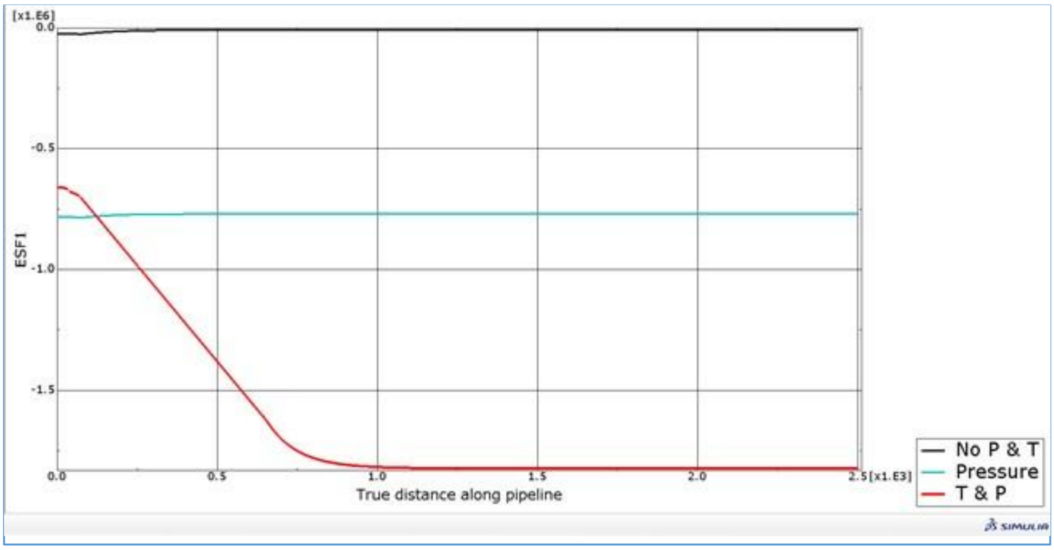


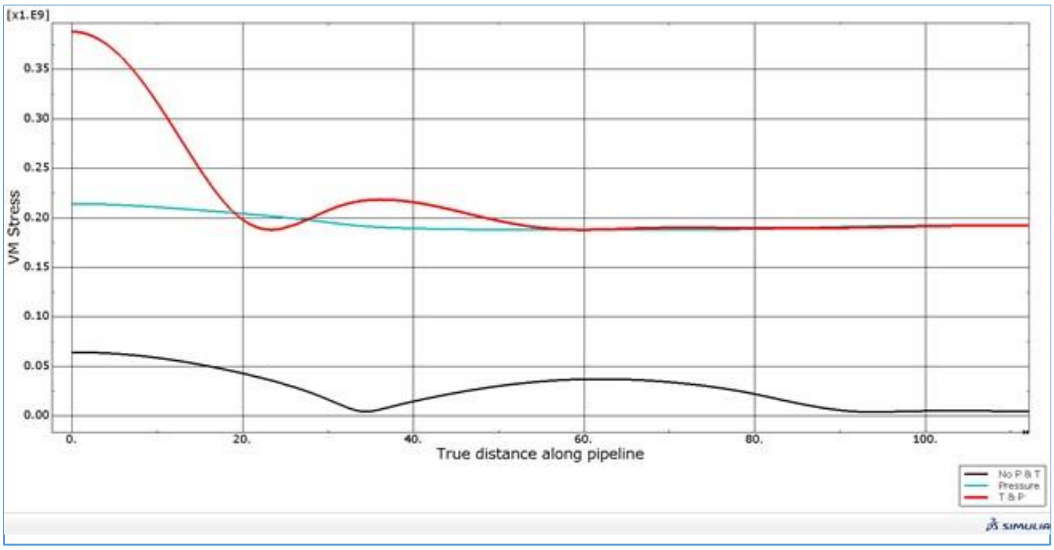
Figure 5.5 shows the effective axial froce along the pipeline during different loading stages.

- Before any temperature and pressure, the force is zero (except for a small amount in the atrificially created imperfection).
- With the application of pressure, since there is no lateral movement, the whole pipeline model sees a constant increase in effective axial force.
- In the final step with the addition of temperature, the effective axial force in the pipeline reaches the ‘fully restrained’ value of 1.8MN. However due to lateral movement (buckle formation), this force is releases in the buckle and adajacent area. The maximum release is at the buckle crown where the force reduces to approxiamtely 0.7MN. The pipeline length where the axial force is released is the ‘feed-in’ length or VAS length. From Figure 5.5, it can be estimated as 2 x 800=1600m. Most of the feed-in length (1600m-140m=1460m) sees only axial movement as there is no lateral movement outside the buckle (see Figure 5.4).
- Figure 5.6 shows the axial displacement plot which illustrates the feed-in length of approximately 800m on each side of the buckle. The feed-in displacement is indicated as 0.11m from each side of the buckle.

Figure 5.6 – Axial Displacement

The maximum bending takes place at the buckle crown and results in the highest stress as illustrated in Figure 5.7.

Figure 5.7 – von Mises Stress



5.3.2 140mm Concrete

Similar to 100mm CWC model, a separate Abaqus model is prepared with the following data;

i. CWC = 140mm and corresponding pipe-soil friction values

ii. Temperature, pressure and density values at KP 11.1, see section 3.3.

An imperfection size of 3m is found to give maximum buckle size and the results are given in this section. The plots below are for load case 1 friction values.

Figure 5.8 – Lateral Displacement - U2

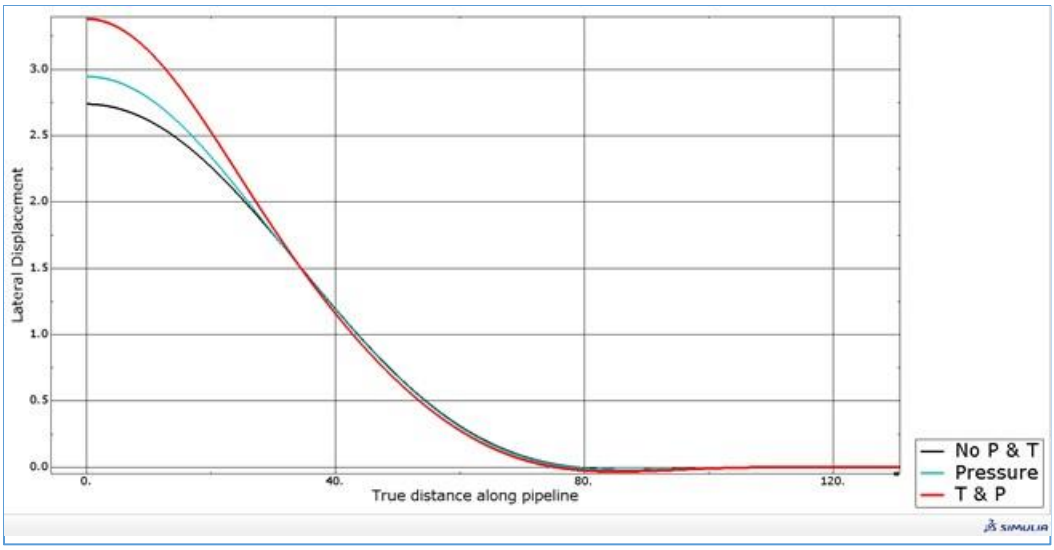


Figure 5.9 – Effective Axial Force - ESF1

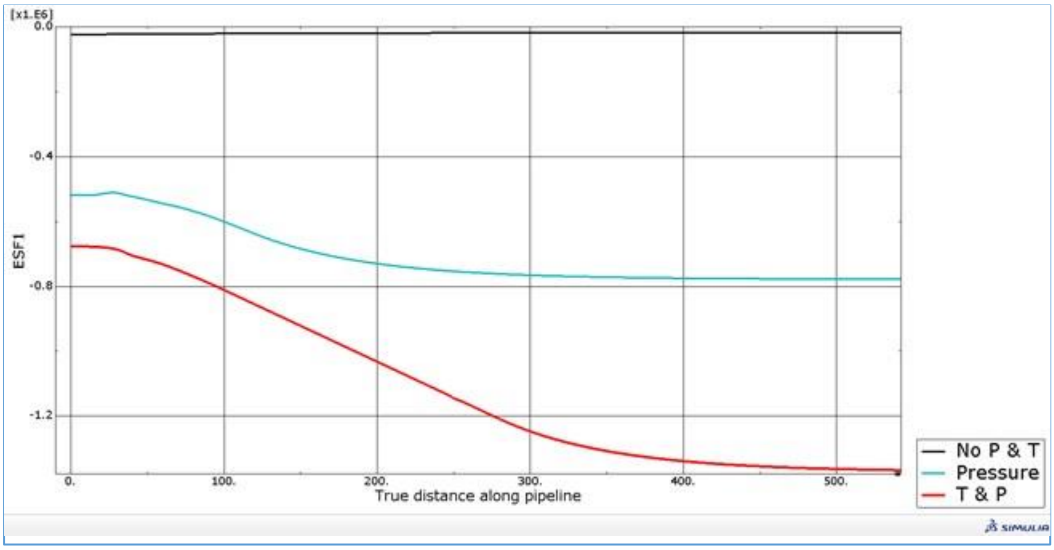


Table 5-2 – Results for 140mm

Load Case	Axial	Lateral	Buckle Amplitude (m)	VM (MPa)
1	LE	LE	0.43	291
2	BE	LE	0.31	273
3	BE	BE	0.01	238
4	BE	UE	0.02	241
5	UE	UE	0.02	241

Comparing the results of 140mm CWC with the 100mm CWC section results, it can be seen that due to heavier pipe and less temperature increase, the lateral buckle is smaller in size in 140mm CWC section. The VAS length reduces to 700m.

5.3.3 60mm Concrete

Similar to 100mm CWC model, a separate Abaqus model is prepared with the following data;

iii. CWC = 60mm and corresponding pipe-soil friction values

iv. Temperature, pressure and density values at KP 17.8, see section 3.3.

The result plots below are for load case 1 frictions and 2m imperfection size.

Figure 5.10 – Lateral Displacement

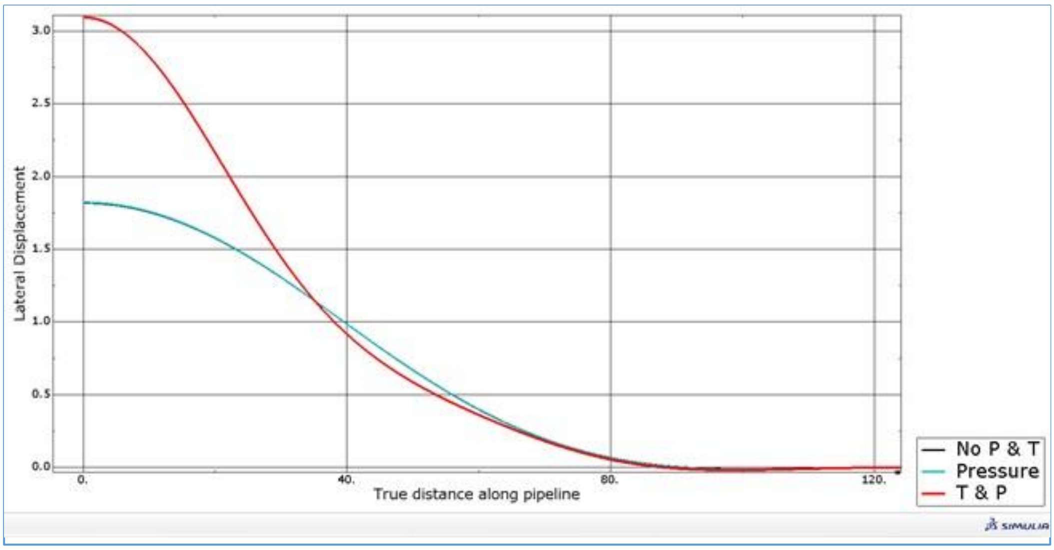


Figure 5.11 – Effective Axial Force

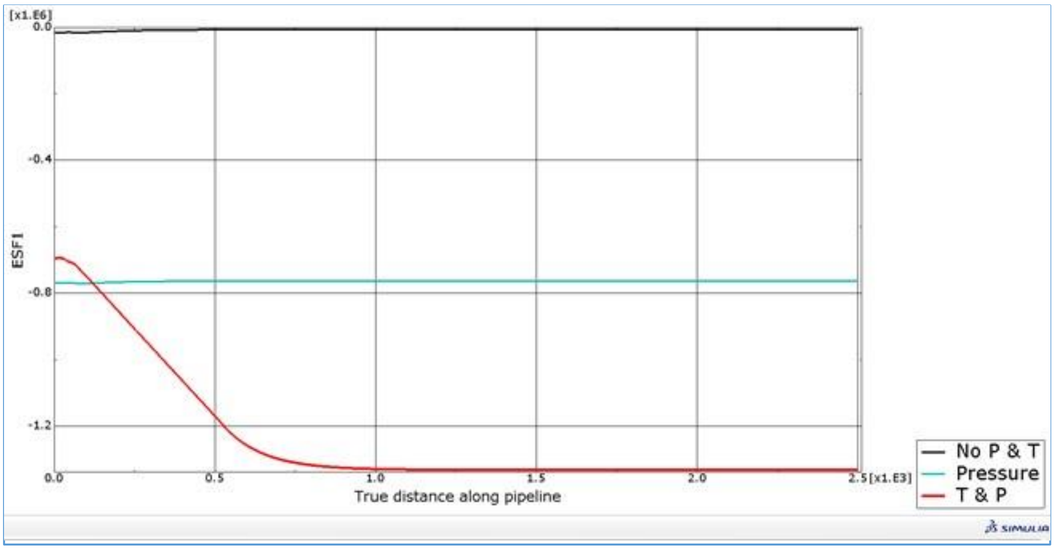


Table 5-3 – Results for 60mm CWC

Load Case	Axial	Lateral	Buckle Amplitude (m)	VM (MPa)
1	LE	LE	1.27	316
2	BE	LE	1.00	293
3	BE	BE	1.00	293
4	BE	UE	0.01	200
5	UE	UE	0.01	200

Due to lighter weight of 60mm CWC section, the buckle amplitude is higher that with 140mm adjacent section. The drop in temperature at this section keeps the buckle size smaller than the 100mm section.

The 3 CWC section results with undrained axial friction are summarised in Table 5-4 below for load case 1.

Table 5-4 – Undrained Results Summary

	100mm CWC	140mm CWC	60mm CWC
From KP - to KP	0-11	11-18	18-29
Fully Restrained ESF (MN)	1.82	1.37	1.33
ESF at Buckle (MN)	0.66	0.68	0.69
Buckle Amplitude (m)	1.85	0.44	1.27
Buckle Length (m)	140	160	180
VAS (m)	1600	700	1400
Maximum Von-Mises Stress (MPa)	400	280	316
Total Strain	0.00188	0.00105	0.00130
Plastic Strain	0	0	0

5.4 Drained Axial Friction

The result plots are presented for 2m imperfection and 100mm concrete section with load case 1 frictions. The results show that size of lateral displacement/buckle and the resulting stress is significantly less than the undrained axial friction case.

Figure 5.12 – Lateral Displacement

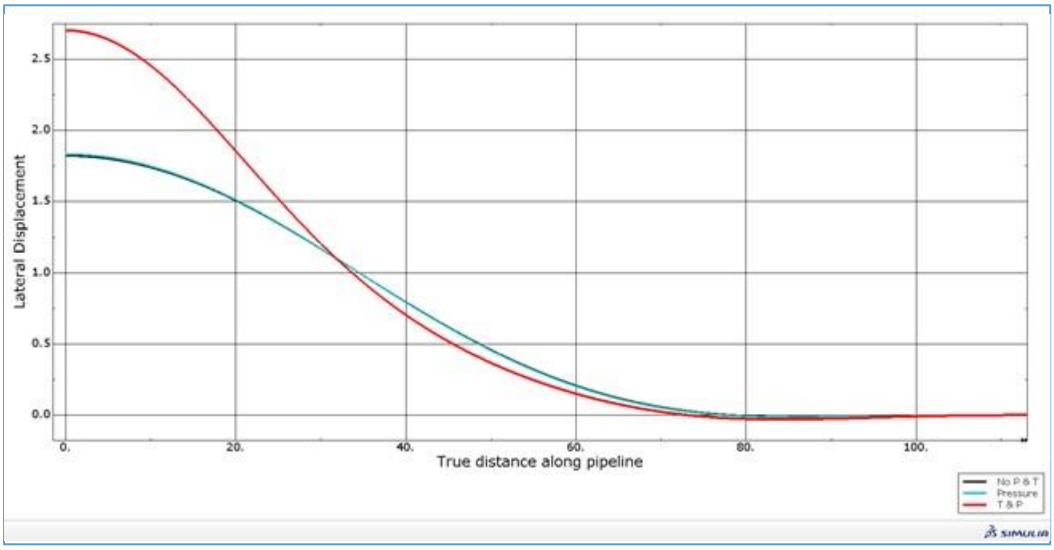


Figure 5.13 – Effective Axial Force

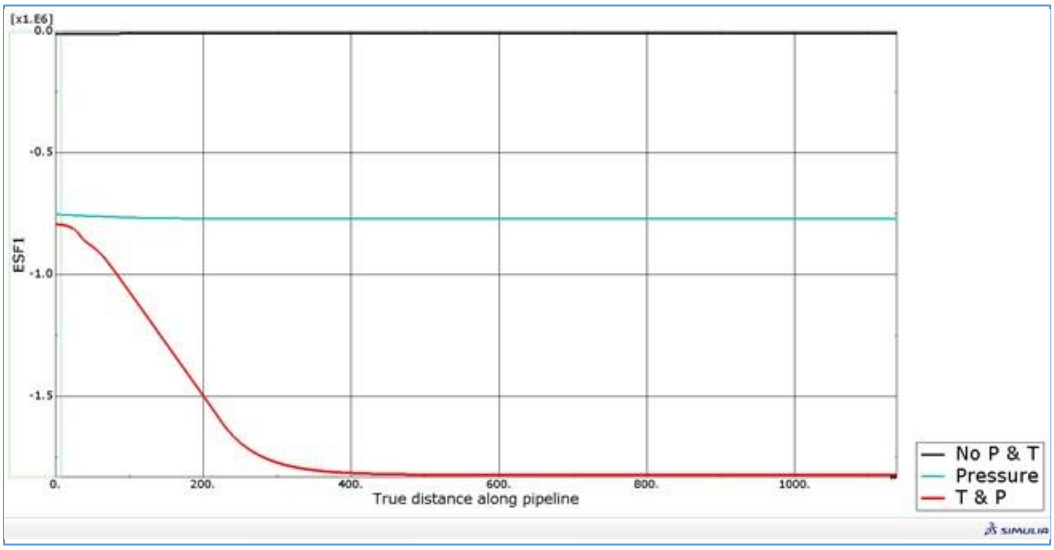


Table 5-5 – Results for 100mm Drained

Load Case	Axial	Lateral	Buckle Amplitude (m)	VM (MPa)
1	LE	LE	0.87	303
2	BE	LE	0.86	301
3	BE	BE	0.54	302
4	BE	UE	0.46	296
5	UE	UE	0.45	296

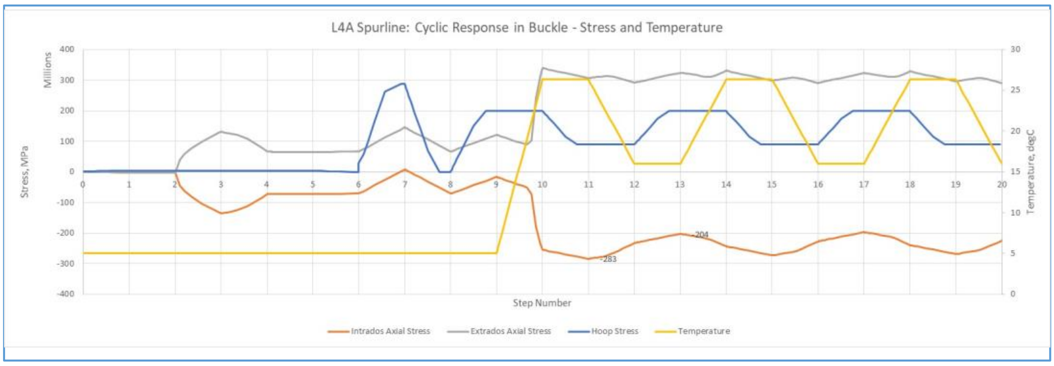
5.5 Fatigue Assessment

100mm CWC load case 3, i.e. with BE friction is run to include 3 shut-down & start-up cycles. The results are shown in Figure 5.14. The stress changes in each cycle from -283MPa to -204MPa=79MPa. This range is used with an in-air F1 SN curve and an SCF to calculate the number of cycles to failure.

An SCF taking into account misalignment at a weld due to out of roundness and wall thickness tolerance is calculated as 1.286. This SCF is used with the stress range in the F1 (in air) SN curve to calculate the number of cycles to failure. DFF and KDF are then applied to get the allowable fatigue cycles. Dividing these by the design life gives 176.7 cycles of shut-down & start up allowed per year.

See Appendix A.2 for the calculation sheet.

Figure 5.14 – Stress Range Results for Cyclic Operation



5.6 Stress/strain Concentration at Field Joint

The discontinuity in concrete coating at a field joint can result in concentration of stress/strain specially if there is plastic strain. No plastic strain is calculated in the cases analysed in this report.

A stress concentration factor of 1.435 is calculated using DNV [11] method (see Appendix A.3). The BE friction load case 3 in undrained condition is used to include this SCF. The resulting von-Mises stress is calculated as 425MPa which is below the steel yield strength or the code limit. Note that the stress concentration factor is applied to only longitudinal stress as shown in Appendix A.3.

5.7 Conclusion

The worst-case lateral buckles in each of the 3 CWC thickness sections are simulated and are shown to result in acceptable stress and strain in the pipe.

The number of pressure and temperature cycles are calculated to allow for fatigue damage using SN curve method. The result (176.7 per year) is well above the expected cycles during the spurline design life.

To account for the possibility of a field joint at the maximum stress location (the buckle crown), an SCF due to concrete coating stiffness change is also checked. The factored stress remains within elastic limit and therefore not a cause for concern.

The lateral buckling is expected to occur but would result in buckles of acceptable size/maximum stress. Due to high hydrodynamic loads, it is likely that the spurline will assume a snake-shaped configuration as soon as the first storm loads are applied. This will ensure multiple strong buckle initiation features along the pipeline, which are expected to trigger formation of several benign buckles under maximum operating temperature conditions. Where these buckles form at spacing closer than 1.6km, the buckles will interact, leading to lower strains than estimated in this assessment.

The detailed design should include the following refinements to this FEED assessment, to fully demonstrate robustness of the surface-laid design, without mitigation of lateral buckling:

1. When the installation schedule is confirmed, the analysis should be checked with the expected installation temperature, instead of the worst-case winter temperature assumed in this analysis.
2. When the pre-commissioning schedule is confirmed, the hydrotest check should be repeated to take account of any thermal effects for changing seabed temperature between pipelay and hydrotest, as the FEED assessment assumes installation and hydrotest are performed at the same temperature.
3. A non-linear uncoupled lateral/axial friction model should be used instead of the standard Abaqus anisotropic friction model.
4. A more detailed assessment of CWC SCF effects and corresponding strain localisation potential should be included within the FEA.
5. If deterministic VAS analysis does not confirm sufficient design margin, probabilistic assessment in accordance with [4], including TTE-developed enhancements described in [13], should be applied.

6 REFERENCES

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[7] L4A Wall Thickness Calculation, 2024.

[8] Offshore Metocean Design Basis, 2023.

[9] Steady State Report.

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[13] Ripoll, I, Sicilia, C, and Bonnet, E (2023). "Lateral Buckling Design using the Friction Distributions at the Expected Buckles," SPT Congress, September 2023, London.