Z-Subsea is an ISO 9001 and ISO 14001 accredited independent, Subsea Design and Integrity Management consultancy providing full cycle integrated solutions to our oil and gas clients worldwide.

Our full cycle services commence with conceptual definition and continue with detailed design, construction and move into operation up to end of life.

Safe Operation beyond the original design life (life extension) is also of high interest in Z-Subsea. We employ innovative and cost effective approaches in order to maximise our client's safe operation time and to minimise assets shut down and downtime.

Technical personnel of Z-Subsea include 3 directors holding PhD degrees and 20 associates covering various disciplines including Fitness for Service Assessments, Materials and Corrosion, Flow Assurance and Process Engineering, Safety and HSE and Pipeline and Riser Analysis, who are working with the company on an ad-hoc basis.

With offices located in London and Aberdeen, Z-Subsea have the advantage of being close to the operators in the North Sea while its London office acts as an international hub serving global clients.

Z-subsea clients since its establishment in Dec 2011 have been, PetroVietnam Gas (Vietnam), Petro Vietnam Drilling Technology (Vietnam), Bureau Veritas (BV) UK, DNVGL, PDO (Oman), TAQA (UK), Tullow oil (UK), Peritus International (UK), Neptune Marine Services (Australia), Theon Ltd. (UK), Oman Gas Company (Oman) and Fairlead Maritime (UK). Individual personnel of z-subsea have been working for major operators, consultancies and third party verification bodies before establishing Z-Subsea.

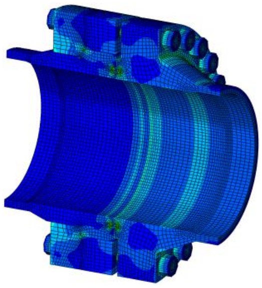
Z-Subsea is specialised in the following technical areas with global projects track records available upon request:

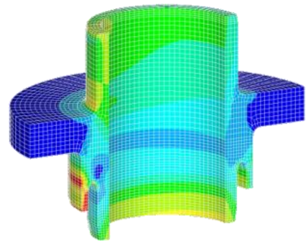
- Subsea Design and Advanced Analysis
- Risk-Based integrity management
- Engineering Critical Assessment (ECA) to BS7910, DNV RP F-108, API 1104 and ASME FFS-1/API 579-1
- Fitness for Assessment (FFS) to ASME FFS-1/API 579-1 and ASME B31G
- Material Selection and Corrosion Assessment and Management

Z-Subsea material and integrity engineering manager is part of the following codes, standards and procedures development committee:

1. BS7910 (fracture, fatigue, material properties chapters and Annex I)
2. European Fitness for Service code (FITNET) - Fracture and fatigue sections
3. Appendix A of DNV OS-F101
4. DNV RP F-108
5. European Structural Integrity Assessment procedure.

Design By Analysis for





Pipeline and Subsea Components

Subsea Component Design

Advanced analysis is a requirement for most oil and gas projects. With increasing computational power of computers, **Nonlinear Finite Element Method** (**NFEM**) has replaced the traditional linear elastic method.

Z-Subsea has successfully delivered Advanced Finite Element Analysis projects since its establishment. Its personnel have worldwide recognition in this area with strong track record on various international, ultra-deep water, and High Pressure-High Temperature (**HPHT**) pipeline component design projects.

Z-Subsea personnel are well established in advanced numerical modeling with many published technical papers in the field.

Design by Analysis (DBA)

Z-Subsea employs **Nonlinear Finite Element Method** (**NFEM**) and **Design by Analysis** (**DBA**) approach to design subsea components such as:

- **Pipe-in-Pipe bulkheads**
- **Pipeline flanges**
- **Pipeline Wye Piece (Y-piece)**
- **Pipeline Tee**
- **Pipeline Reducer**

Design by Analysis using Nonlinear Finite Element Method is an **LRFD** method which can replace the traditional stress linearization and categorization. For components with a complex geometry/loading, the stress categorization process may produce ambiguous result. In contrast, the **DBA** using **NFEM** is applicable to any component with sufficiently ductile material under any given loading.

Commonly used standards for offshore component design are:

- **ASME VIII Division 2**
- **BS EN-13445**
- **PD5500**

The design criteria for **DBA** are generally based on solution convergence, level of strain, and other failure modes such as accumulated plasticity or buckling. This makes the method more efficient than the traditional linear elastic methods.

Design by Analysis Considerations

The Design by Analysis and **NFEM** for component design should be used with complete awareness of the concept of this design method and what consideration each part of the design requires. The application and location of boundary conditions, loadings, and thermal effects are particularly of importance as it can affect the accuracy of the FE model and analysis results during a nonlinear analysis.

a) Elastic-Plastic small Deformation Analysis

One part of the DBA design method requires elastic-perfect plastic material with small deformation theory. Special care needs to be applied while conducting this part of analysis to avoid excessive plastic deformation despite achievement of solution convergence.

b) Elastic-Plastic Large Deformation Analysis

Another part of the **DBA** method requires elastic-plastic material with true stress-strain curve and large deformation theory. The true stress-strain curve is usually provided by the code based on the forging material. This part of analysis is more complicated and requires considering the implications of geometric nonlinearity to avoid erroneous and un-conservative design.

c) Elastic-Plastic Cyclic Analysis and Ratcheting

In this part of a **DBA** method, usually elastic-perfect plastic material with geometric nonlinearity and large deformation theory is required. The load and resistance factors will not be used in this part of analysis. A number of loading/unloading cycles will be applied to the component to ensure plastic shake down. It is usually a requirement of all the **DBA** codes to demonstrate that the plastic deformation stabilizes after a limited number of loading/unloading.

The plastic deformation in a component is usually localized. Therefore, using shape optimization, it must shake down after a few operational cycles.

Similar to section (b) above, care should be practiced for large deformation effects to avoid un-conservative results.

d) **Other Code Check Requirements for DBA**

There are other code checks which might need to be considered in the **DBA,** e.g. buckling check for slender components, and fatigue for components under considerable number of loading cycles.

A successful design shall pass all the applicable code requirements with given load and resistance factors.

e) **Load Safety Factors**

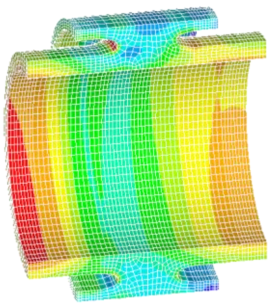
The load factors used in the **DBA** should be chosen carefully to avoid under-design as well as over-design. Some loading conditions might not be explicitly stated in some of the codes (such as installation loading), in which case suitable load factors should be extracted from the code.

From Global to Local FE Model

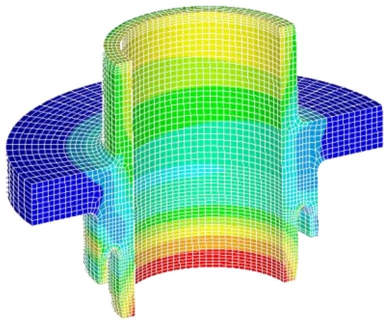
Analysis of the global **FE** model of a system during various loading conditions (Installation, hydrotest, operation, seismic, global buckling, etc.) provides the forces and bending moments acting on a given component in the system. These loads are then used in **DBA** method to perform various code checks using nonlinear **FEA**. Thermal stress analysis is necessary both at global level and local **FE** model to include thermal induced stresses and thermal material de-rating.

Pipeline and Component Code Break

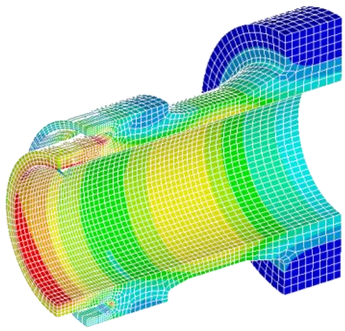
The code break between the component and pipeline is at weld location. However, based on **DNV-OS-F101** it should be demonstrated that the presence of component does not affect the stress in the pipe. If the component introduces concentration of stress/strain in the pipe and disturbs the pipe stress distribution, solutions such as increasing the length of the straight section of forging, or alternatively using pipeline pup piece should be used to remove this effect.



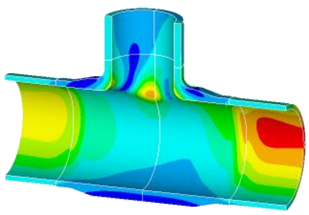
PIP In-Line Bulkhead



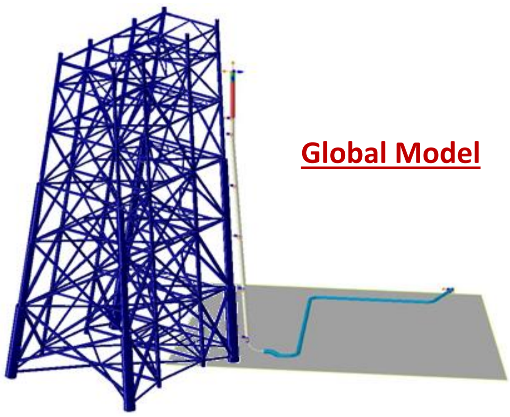
PIP Riser Hang-off Flange



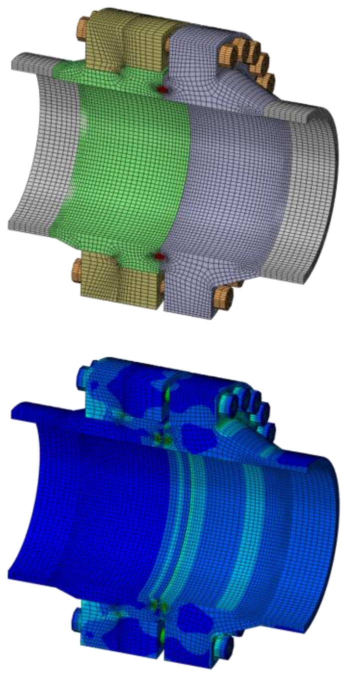
PIP Flange Bulkhead

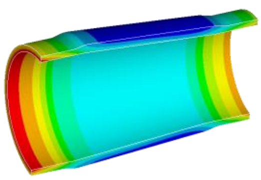


Pipeline Tee

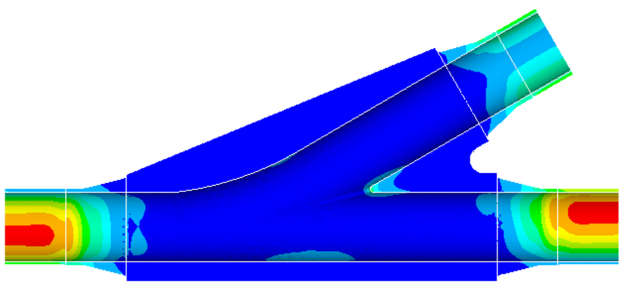


Global Model





Pipeline Reducer



Wye Piece

Pipeline Flange

Z-Subsea Experience on Design by Analysis of Subsea Components

Ship-Jacket Impact Advanced Finite Element Analysis

Overview

Z-Subsea Advanced Analysis team have successfully delivered sophisticated ship-jacket collision analysis to clients.
A Ship-jacket platform collision analysis is used to assess the consequences of impact to an offshore platform to assess the:

- Structural damage to the platform or vessel
- Collision energy loss mechanisms
- Collision forces time-history

Jacket FE Model

The jacket model can be based on beam elements. However, the location of collision can be refined by shell elements to obtain better insight into impact local effects (Figure 1).

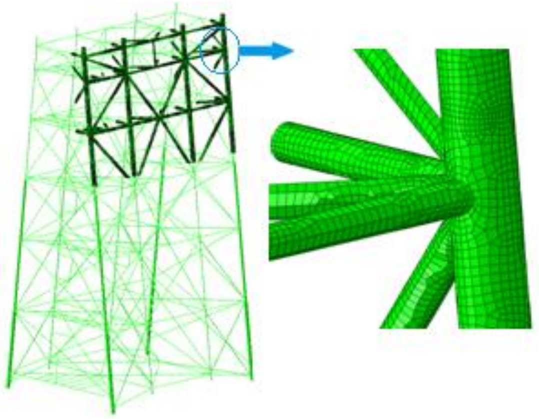


Figure 1. Jacket global beam and local shell elements

The mass/added mass of jacket, gravity, plasticity and other important parameters are considered. To simplify the model, jacket topside can be included as a mass located at its center of gravity.

Ship FE Model

The ship model can be based on beam and shell elements depending on the level of details required (Figure 2).

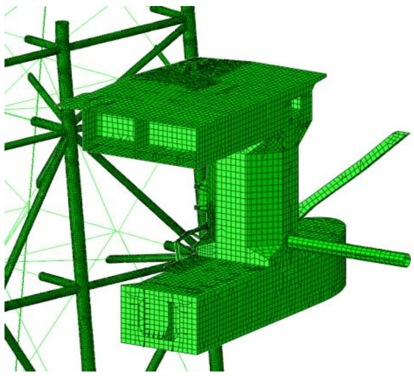


Figure 2. Ship FE model

The structural symmetry or lump mass is usually used to simplify the model. In simplified models, mass-spring-dashpot system can be used as representative of the vessel. Alternatively, rigid surface with concentrated mass, added mass, and rotational inertia located in accurate coordinates can be used.

Dynamic Analysis Method and Achieving Solution Convergence

Choosing between explicit and implicit dynamics requires considerations to have computationally economic analysis while maintaining accuracy and solution convergence. For example, mass scaling, time steps, plasticity or failure models, and contact modeling algorithm are important parameters that can affect the accuracy, solution time and analysis convergence. It is good practice to run both methods for comparison (Figure 3).

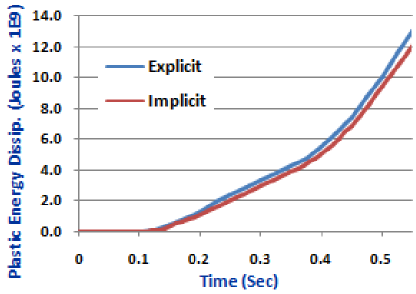


Figure 3. Comparison of Explicit and Implicit dynamics

The difference between explicit and implicit dynamic analysis results depends on e.g. analysis settings, material models, impact energy etc. and can be reduced if more accuracy is required.

Collision Analysis Results

Analysis results provide an assessment of structural damage level upon a ship impact with various ship velocities and impact energies and locations (Figure 4). The jacket overall status, dent size, damage to jacket or vessel, impact energy dissipation mechanisms etc. can be extracted.

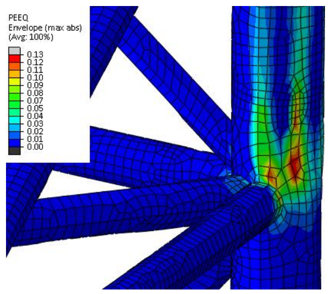


Figure 4. Local damage to jacket structure

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"Design by Analysis" for Subsea Flanges and Bulkheads

Subsea Component Design

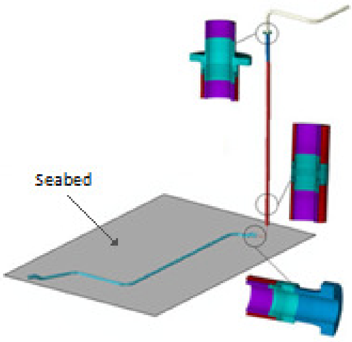
Advanced analysis is a requirement for most oil and gas projects. With increasing computational power of personal computers, more complicated Nonlinear Finite Element Analysis (**NFEA**) is replacing the traditional linear elastic methods.

Z-Subsea has successfully delivered Advanced Finite Element Analysis projects since its establishment. Its personnel have worldwide recognition in this area with strong track record on various international projects and published technical papers in this field, with authorization from international organizations such as Lloyd's Register.

Design by Analysis (DBA)

Z-Subsea employs Nonlinear Finite Element Method (**NFEM**) and "Design by Analysis" (**DBA**) approach to design subsea components such as pipeline inline and end-flange bulkheads , riser and conductor bulkheads, flanges, Y-pieces and T-pieces. This method replaces the traditional stress linearization and categorization which is not applicable to components with complicated geometry.

The global model of a complex system is necessary to be initially built. As an example, analysis carried out on a HPHT pipe-in-pipe (**PIP**) riser and spool system is shown below.



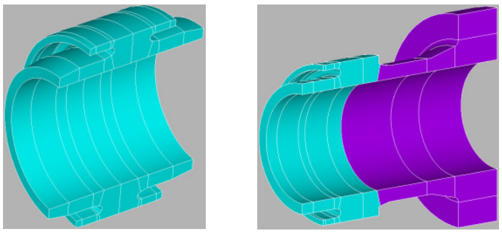
FE Global Model of Pipe-in-Pipe Riser & Spool System

The Components of the system such as bulkheads and flanges are included in the global model.

For sufficiently ductile materials, Design-by-Analysis provides rules for the design of these subsea components under design loads.

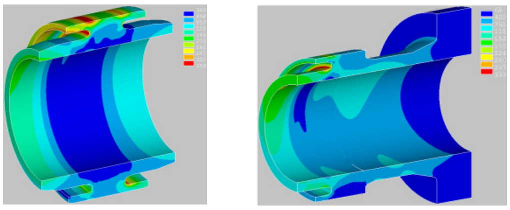
The applicable design codes are ASME VIII Div. 2, BS EN-13445, and PD5500.

These components are subsequently locally modeled and designed based on the forces extracted from the global model.



Pipe-in-Pipe Bulkhead and Flange Component FE Models

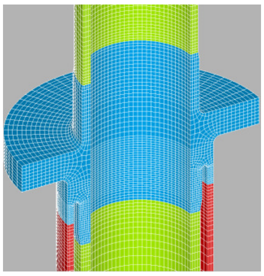
Application of a good mesh and avoiding sharp angles and slopes are some of the key factors in a successful design.



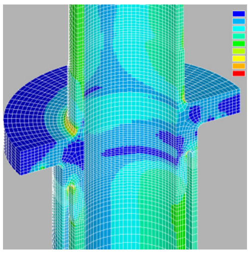
Results of Design by Analysis for Bulkhead & Flange Design

The design criteria for DBA are generally based on solution convergence, level of strain, and other failure modes such as accumulated plasticity. This makes the method more efficient than the traditional linear elastic methods.

Another application of NFEM and DBA is the PIP riser dead weight support flange/bulkhead design as shown below.



FEA of PIP Riser Weight Support Flange/Bulkhead



PIP Riser Weight Support FE Design Result

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Free Span Assessment of Pipelines & Risers

Free Span Assessment

In-service pipelines could potentially suffer from fatigue damage (FLS) and local buckling failure (ULS) due to the free spans.

Pipeline vibration due to vortex shedding (in-line and cross-flow VIV) and direct wave actions causes accumulative fatigue in a free span. Pipeline static bending, vortex induced vibration, direct wave and current effects and trawl gear interaction are the main contributors of a local buckling failure in a free span.

Z-Subsea possesses comprehensive experience in assessment of free spans of in-service pipelines. Z-Subsea's approach is in full in compliance with "DNV-RP-F105 – Free Spanning Pipelines" recommended practice.

Allowable free span length need to fulfill the integrity of the pipeline against fatigue damage, local buckling failure and trawl gear interaction.

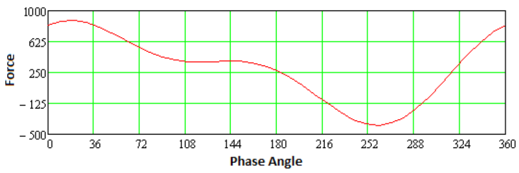
Pipeline Single Or Multi-Span VIV

To calculate allowable free span length against fatigue damage, Z-Subsea employs following levels of assessment:

Screening

This method is a simplified method and provides a very conservative allowable free span length based on a fatigue life in excess of 50 years based on DNV-RP-F105. In this method, the VIV in in-line and cross-flow directions is avoided.

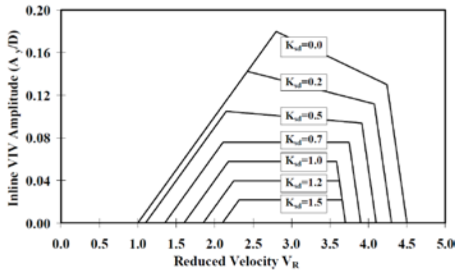
Z-Subsea has detailed in-house calculation sheets to address maximum allowable length of pipeline or riser span under design conditions.



Calculation Sheets for Screening Method

Response Model

This approach evaluates the pipeline span fatigue damage in each seastate independently. Water particle kinematics at pipeline level are established for each cell of scatter diagram, DNV-RP-F105 response model is utilized to calculate the vibration amplitude and frequency, appropriate S-N carves are applied to calculated the fatigue damage of that specific seastate and then the total fatigue damage over the expected time is obtained. This approach is yet conservative however, provides more realistic results compared to screening level assessment.

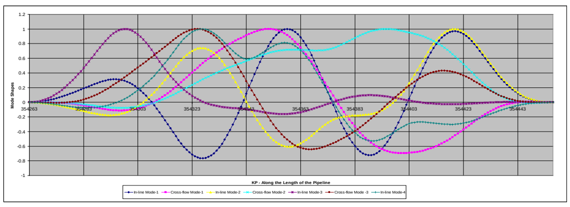


Response Model for VIV Amplitude (XF)

This approach utilizes the conservative approximations in calculation of free span fundamental natural frequency, unit diameter stress amplitude and etc.

Finite Element Assessment

"Screening" and "Approximated Fatigue Damage Assessment" levels cannot be utilized for situations where effective axial force is more than half the Euler buckling force of the pipeline because the frequency calculation approximation of the code loses its accuracy. Also it cannot be used when there is interacting spans or in case of several vibration modes may be excited simultaneously in the same direction (in-line or cross-flow).



Pipeline Multi-Span Multi-Mode VIV

For such cases and also if allowable free span length need to be pushed to the maximum possible limits, a "Detailed Finite Element Assessment" need to be performed.

Free Span Assessment of Pipelines & Risers

Finite Element Analysis extraction of natural frequencies of pipeline can take into account:

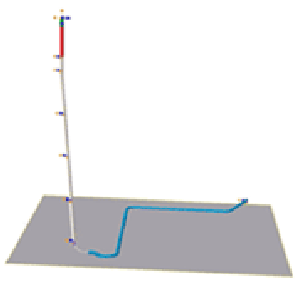
- boundary conditions
- interacting spans
- multi-mode in single span
- soil properties
- effective axial force
- span feed-in
- seabed features on pipeline route

Z-Subsea utilises advance modelling for situations where spanning requires FE analysis. The FE assessment is performed considering:

- In-place model of pipeline and spans based on seabed features along the route
- Single pipe, pipe-in-pipe, or piggybacked pipelines can be modelled
- Pressure and temperature profiles
- Extraction of In-line as well as Cross-flow mode shapes and frequencies
- The nonlinear effects of pipeline deformation, pressure, and temperature on natural frequencies

Advanced in-house calculation sheets are utilised to calculate the fatigue life of the spans.

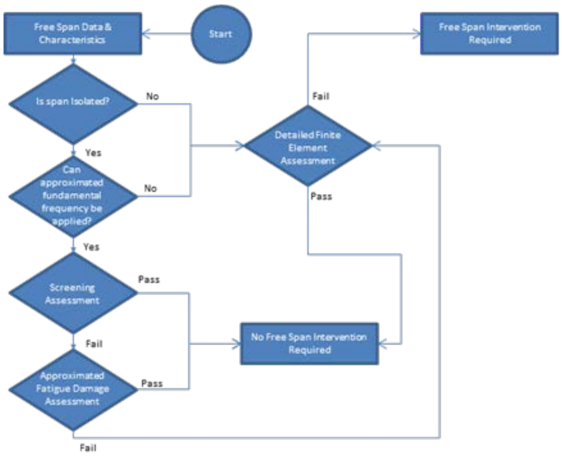
It is noted that these approaches can be also used for span calculations of platform rigid risers with spans between the riser guides with some considerations.



Jacket Rigid Riser Free Span VIV Assessment

Z-Subsea approach for free span assessment is shown in the following flow chart taking into account:

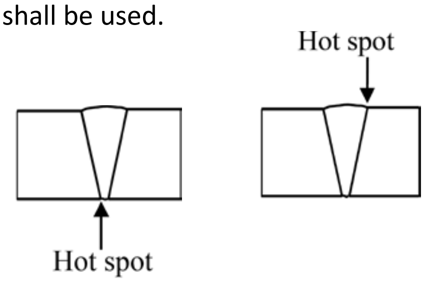
- Maximum allowable span length to avoid VIV if possible
- Assessing VIV fatigue damage of pipeline/riser welds if VIV occurs
- Local buckling or stress check at critical points
- Intervention methods if the above criteria fail



Z-Subsea Free-Span Assessment Methodology

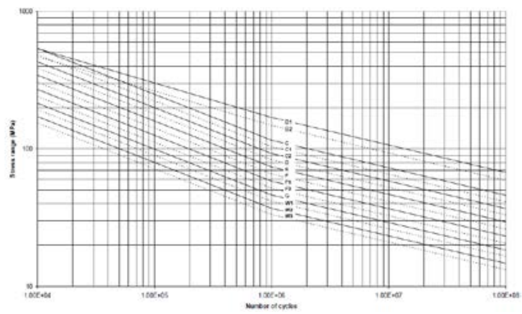
S-N Curves

To calculate the fatigue damage of pipeline spans it is conservatively assumed to have welds in most critical locations. Depending on crack initiation location (root or toe), appropriate S-N curve shall be used.



Weld Hot Spot Location For Fatigue Check

The application of S-N curve also depends on the type of the pipeline internal (sour service, clad, etc.) and external (cathodic protection, corrosion coating, etc.) condition for each of which there is appropriate S-N curve.



Typical S-N Curve

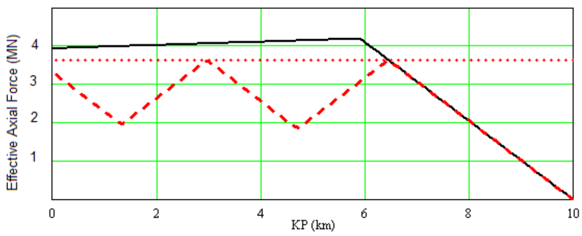
Global Buckling Analysis and Design of HPHT Pipelines

FE Modeling of Subsea Pipelines Global Buckling

Another aspect of advanced analysis and design capability at Z-Subsea is Lateral and Upheaval Buckling of subsea pipelines.

For HPHT systems in deep waters, lateral buckling is a major design concern. The traditional approaches such as trenching/ backfilling cannot be utilized to prevent pipeline global buckle and therefore controlled lateral buckle is necessary to release the axial force while preventing excessive bending in the pipeline.

For initial assessment of lateral buckle formation, calculations sheets are used. This will provide an estimate to effective axial force and distance between buckles based on pipeline properties, pressure & temperature profiles and soil properties.

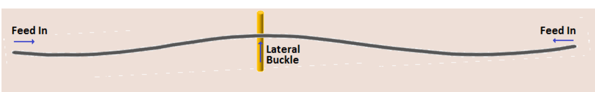


Pipeline Lateral Buckle Assessment

Nonlinear Finite Element models are developed to assess and design pipelines for engineered lateral buckles more efficiently. As there are inherent uncertainties in design parameters, traditional deterministic approaches cannot be utilized to ensure a certain reliability level in the design.

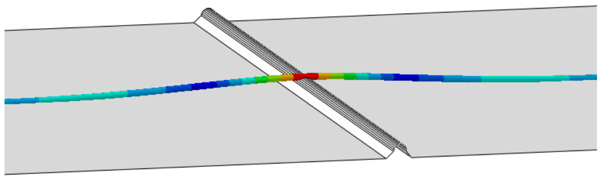
The main design parameters for such FE-based analyses are:

- Pipeline cross sectional dimensions.
- Pipeline configuration and seabed features
- Pipe-soil monotonic and cyclic interaction
- Cyclic start-up/shut-down
- Pressure/temperature transient profiles
- Material and geometric nonlinearities
- Pipeline sleepers or buoyancy modules



Plan View of Subsea Pipeline FE Lateral Buckling Analysis

The sensitivity of target design or failure (local buckling, stress/strain level, low cycle fatigue, etc.) with respect to the above parameters will be established through running numbers of FE sensitivity cases.



FE Lateral Buckling Parametric Model of Pipeline on Sleeper

The results of these parametric analyses will be used for Structural Reliability Analysis (**SRA**) and Monte Carlo simulation to ensure acceptability of design and reliability of initiation of engineered lateral buckles at deliberate locations and with certain intervals to fulfill a specific limit of reliability in line with pipeline safety class.

In this type of analysis, one of the main targets is to reduce number of required FE analyses used for the SRA without losing the accuracy on calculation of reliability.

Z-subsea ensures the best lateral buckling initiation strategy i.e. snake-lay, sleepers, dual sleepers or buoyancy modules based on specific field features and architecture are selected.

Engineered Lateral Buckle in a Subsea Pipeline

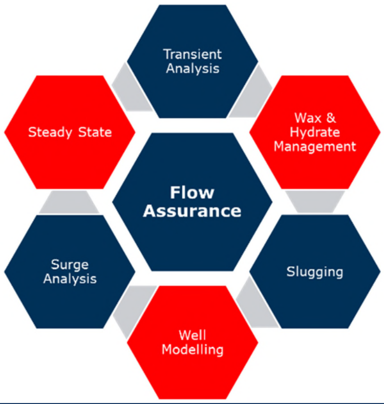
For Upheaval Buckling (UHB) and Out-Of-Straightness (OOS) design, similar design variables are looked into and used in the FEA and structural reliability analysis. The backfill interaction behavior with buried pipe will then become an important parameter for FEA and reliability analysis.

The target of UHB design will be optimizing the required backfill and rockdump, while maintaining the required safety factor against upheaval buckle and having acceptable level of stress/strain and fatigue life.

Flow Assurance

Z-Subsea has capability to perform flow assurance and process design of subsea and onshore pipelines. We have extensive experience in flow assurance of multiphase production fluid starting from the reservoir, through the production tubing, Xmas Tree, Choke and subsea pipeline up to the subsea or onshore processing facilities. We also speciaslie in single phase oil, Liquefied Petroleum Gas (LPG) and natural gas flow assurance. We have long experience in hydraulics of special petroleum products like Aviation Turbine Fuel, which needs special treatment.

Our areas of expertise is shown below.



Z Subsea's Flow Assurance Expertise

Multiphase Flow Assurance

Production Fluid comes out of reservoir as a mixture of oil, gas, water and sludge. Pipeline transportation of the fluid poses flow assurance challenges. Based on the composition of the fluid, its reservoir pressure and temperature, ambient temperature of the environment in which the pipeline is laid, several challenges may arise. We engineer the system to make sure that uninterrupted production takes place and at desired arrival condition.

As part of multiphase flow assurance, steady state and transient analysis is performed.

Steday state Analysis

Steady state analysis is the first step towards understanding the overall behaviour of the transportation of the fluid, independent of time, after the flow has stabilized. As part of steady state analysis, pressure and temperature profile along the pipeline length is calculated. Flow rate turndown analysis is also performed.

Velocity of fluid is maintained below the erosional velocity calculated as per API RP 14E.

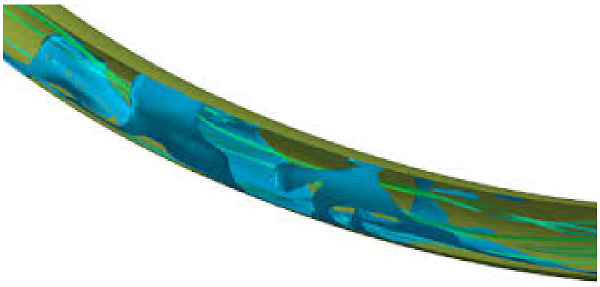
Transient Simulation

Transient simulation is time dependent. This analysis is performed to study the behavior of various flow assurance parameters during the transition between the start-up of the flow and steady state.

As part of the transient simulation, following analyses are performed:

- Start-up
- Shutdown
- Ramp-up and Ramp-down
- Joule-Thomson cooling
- Surge Analysis

Slugging Assessment



Slugging occurs in multiphase flow condition as a result of difference in velocity of liquid and gas phases (hydrodynamic slugging) and as a result of terrain condition (terrain slugging). While the liquid phase flows in the lower section of the pipe, the gas phase being lighter flows on the upper section of the pipe. As a result of skin friction between the two layers, liquid moves and gets accumulated at the lower section of the pipeline, for example at the bottom of the riser and lower sections of spool pieces. Intermittently, a large liquid volume arrives at the separator, which may result in severe vibration of the riser or spools. To accommodate the large liquid volume at the separator, slug catcher is required to be designed.

Z-Subsea perform the slugging simulation and calculate the slug density and slug volume, which is used to calculate the force on the riser or sections of the spool. Volume of the slug catcher is also calculated.

Flow Assurance and Process Design

Z-Subsea can also perform slug tracking in which a visual representation of course of movement of slug is simulated.

Software used

Software used for slugging is Pipesim, OLGA Core and Slugtracking Module of OLGA.

Pigging

In pigging simulation, pigging velocity and slug volume calculated because of pigging is calculated. Pigging simulation is performed by OLGA or Pipesim.

Hydrate Management

Hydrates are crystalline structures of water and natural gas, which form at high pressure and low temperature.

If the temperature of the fluid in the pipeline goes below the hydrate formation temperature, hydrate plug could form in the pipeline leading to blockage and consequently production loss. We adopt two-pronged approach of hydrate management as below:

- Hydrate formation avoidance
- Hydrate Inhibition

Hydrate Formation avoidance

In this approach, we make sure that that the fluid temperature is maintained above the hydrate formation temperature along the pipeline. We perform flow assurance modelling and recommend appropriate level of insulation, flow rate etc. to make sure that the temperature of the fluid is maintained above the hydrate formation temperature.

Softwares used

Z-Subsea use industry standard softwares like OLGA-Hydrate, Pipesim in association with Multiflash Hydrate or DELFI to perform this simulation.

Hydrate Inhibition

In case hydrate formation can not be avoided, we adopt an alternative approach by which hydrates molecules formed are not allowed to grow. This is achieved by hydrate inhibition: There are three techniques of hydrates inhibition as given below.

- Environmental inhibitors
- Thermodynamic inhibitors
- Kinetic inhibitors

In environmental inhibition, the production fluid is dried before it cools down by alcohol or silica gel or by adsorption of hygroscopic salt. Water is also removed by heating the production fluid and condensation subsequently.

Thermodynamic inhibition is achieved by

- Reducing the pressure of the gas
- Injecting salt solutions
- Injecting glycols/alcohols

Z-Subsea perform calculation of dosage rate of glycols/alcohols/salts.

Typically, glycol used is Mono Ethylene Glycol (MEG), and typical alcohol used is Methanol.

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Kinetic Inhibition

In Kinetic hydrate inhibition, LDHI (Low Dosage Hydrate Inhibitors are used to stop agglomeration of hydrates. LDHI are typically polymers and copolymers. In this technique, rate of hydrate formation is reduced such that hydrate is not formed by the time the fluid reaches the destination. This method is not effective in case the fluid remains in the pipeline under stagnant condition during prolonged shutdown or line packing condition. We perform calculation of dosage rate of kinetic inhibitors.

Wax Management

We perform wax formation study to calculate potential for wax formation and deposition in the pipeline. As an outcome of this study, recommendations are made on insulation requirement for the pipeline such that fluid's temperature does not go below Wax Appearance Temperature (WAT) along the pipeline. If this can not be achieved by insulation of the pipeline, several other techniques could be recommended such as

- Dilution of the fluid in case of onshore pipeline
- Use of wax inhibitors (like Pour Point Depressants)
- Use of electrical heating systems

We also perform calculation of thickness of wax deposited on the inner wall of the pipeline.

Softwares Used

OLGA Wax
Pipesim
Multiflash Wax

Softwares

There are many commercially available softwares popularly used in the oil and gas industry as given below.

Software	Capability
Pipesim	Steday state, single phase and multi-phase flow assurance
Olga	Steday State and transient, single phase and multiphase flow assurance
Pipeline Studio (TLNET/ TGNET)	Single Phase steady state and transient Oil and Gas pipeline flow assurance
Maximus	Life Cycle Management Software
Flowmaster	Flow Assurance Software
DELFI	DELFI is a web-based environment, which includes Pipesim and OLGA and all its associated packages. This feature has been recently launched by Schlumberger in which the access to unlimited use of Pipesim and its associated suit of software is provided to the user based on a committed monthly or yearly subscription. Use of OLGA and its associated packages is provided on an hourly simulation based payment. The advent of DELFI has made more cost effective access to the Pipesim and OLGA packages, which was otherwise prohibitively expensive. We at Z Subsea make are keen to help our clients perform flow assurance studies with industry recognized softwares at reasonable.

For further info about Z-Subsea Flow Assurance and Process capabilities contact us on enquiries@z-subsea.com.

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Z-Subsea Ltd. and its personnel selected Subsea Design and Advanced Analysis Track Record

Item	Project Title	Client name	Project Phase	Country
1	Tee and Wye piece design to ASME VIII Div. 2, in challenging Ultra Deep Water, 2300m water depth	Peritus	Detail Design	Brazil
2	Dynamic Nonlinear FEM of semi-sub impact to jacket	FailLead Maritime	Design Verification	UK
3	Verifcation and Development of Free-Span and VIV analysis tool	Neptune Marine Services	Tool Verification	Australia
4	Jordbaer field development	BG Norge	FEED	Norway
5	Flyndre Cawdor field development	Talisman and Maersk	FEED	UK
6	Devenick field development	BP	FEED	UK
7	Rev / Varg South gas condensate field	Talisman Energy Norge AS	FEED/Detail Design	Norway
8	Shah Deniz Stage 2 Risers and J-Tubes	BP	FEED/Detail Design	UK/Azerbaijan
9	West Delta Deep Marine (WDDM) Phase IX Development	BG	Pre-FEED	Egypt
10	Jasmine and Jade development HPHT pipe-in-pipe riser and spools and bulkheads design	Conocophillips	FEED/Detail Design	UK
11	Ptarmigan Field Development	Oilexco	FEED	UK

Item	Project Title	Client name	Project Phase	Country
12	Skarv field development	BP	Detail Design	Norway
13	Al-Rayyan Pipeline and PLEM	Occidental Petroleum of Qatar Limited;	Detail Design	Qatar
14	Lyell pipeline, tie-in spool and flanges design	CNR International	Detail Design	UK
15	Galley redevelopment	Talisman Energy	Design Verification	UK
16	Halfdan Notheast Phase 3 filed development	Maersk Oil and Gas AS	Design Verification	Denmark
17	Turkey-Greece natural gas pipeline system (Offshore Section)	Petroleum Pipeline Corporation of Turkey	Design Verification	Turkey
18	Dumbarton field development	Maersk Oil North Sea UK Limited	Design Verification	UK
19	Chestnut field development	Venture Production Company	Design Verification	UK
20	Field lay out Study at Scott PD platform	Endeavour Energy, Nexen and Premier Oil partnership	Study	UK
21	Field layout of West Delta Deep Marine (WDDM) Phase IX Development	BG	Study	Egypt

Item	Project Title	Client name	Project Phase	Country
22	Laggan tie-in spool and flange design	Total UK	Detail Design	UK
23	Dunbar and Alwyn Pipe-in-Pipe Tie-in spools Design verification	Total UK	Design Verification	UK
24	Design verification of topside modification of Bukha-A Platform including piping, process and material disciplines	DNV Middle East/Oman Oil Company Exploration & Production LLC (OOCEP)	Design Verification	Oman
25	Design verification of subsea pipeline of Musandam Gas Plant Project	DNV Middle East/Oman Oil Company Exploration & Production LLC (OOCEP)	Design Verification	Oman
26	Preparation of design Performance Standards for onshore pipeline, structures and facilities	Petroleum Development Oman (PDO)	Verification	Oman

QMS International plc

ISO 9001 REGISTERED

This document certifies that the quality management systems of

Z-SUBSEA LTD

The Chandlery Business Centre, 50 Westminster Bridge Road, London SE1 7QY

have been assessed and approved by QMS International plc to the following quality management systems, standards and guidelines:-

ISO 9001 : 2008

The approved quality management systems apply to the following:-

THE PROVISION OF SUBSEA DESIGN, INTEGRITY MANAGEMENT, ADVANCED SIMULATION AND ENGINEERING TRAINING COURSES.

Original Approval: 09 September 2014

Current Certificate: 09 September 2014

Certificate Expiry: 08 September 2024

Certificate Number: GB 22513

IAC ACCREDITATION

On behalf of QMS International plc

This Certificate remains valid while the holder maintains their quality management systems in accordance with the standards and guidelines above, which will be audited by QMS International plc

This Certificate is the property of QMS International plc and must be returned in the event of cancellation.

QMS International plc

ISO 14001 REGISTERED

This document certifies that the environmental management systems of

Z-SUBSEA LTD

The Chandlery Business Centre, 50 Westminster Bridge Road, London SE1 7QY

have been assessed and approved by QMS International plc to the following environmental management systems, standards and guidelines:-

ISO 14001 : 2004

The approved environmental management systems apply to the following:-

THE PROVISION OF SUBSEA DESIGN, INTEGRITY MANAGEMENT, ADVANCED SIMULATION AND ENGINEERING TRAINING COURSES.

Original Approval: 09 September 2014

Current Certificate: 09 September 2014

Certificate Expiry: 08 September 2024

Certificate Number: GB 22514

IAC ACCREDITATION

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