CHALLENGES BY DISCIPLINE ...

- MECHANICAL DESIGN
- SEABED MECHANICS
- MATERIALS & WELDING
- FLOW ASSURANCE
- DESIGN FOR INSTALLATION
- PIPELINE INTEGRITY MANAGEMENT
- DESIGN FOR OPERATION
- OCEAN ENGINEERING

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MECHANICAL DESIGN – MEETING DEFINED SAFETY TARGETS

Design guidelines such as ISO and DNV OS-F101 adopt a LRFD (Load Resistant Factor Design) approach relating failure modes and consequences to “Safety Class” categorization.

- A set of limit state design formats, including partial safety factors for both load and resistance, are defined.
- The partial safety factors to meet a predefined safety target have been calibrated using structural reliability methods.

Reliability methods applied directly to specific structure, avoiding the use of pre-established partial safety factors, are allowed and sometimes recommended.

Table 2-5 Nominal failure probabilities vs. safety classes

<table>
<thead>
<tr>
<th>Limit States</th>
<th>Probability Bases</th>
<th>Safety Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>SLS</td>
<td>Annual per Pipeline(^1)</td>
<td>10(^{-2})</td>
</tr>
<tr>
<td>ULS (^2)</td>
<td>Annual per Pipeline(^1)</td>
<td>10(^{-3})</td>
</tr>
<tr>
<td>FLS</td>
<td>Annual per Pipeline(^3)</td>
<td>10(^{-3})</td>
</tr>
<tr>
<td>ALS</td>
<td>Annual per Pipeline</td>
<td>10(^{-4}).10(^{-5})</td>
</tr>
<tr>
<td>-</td>
<td>Pressure containment</td>
<td>10(^{-4}).10(^{-5})</td>
</tr>
</tbody>
</table>

SLS serviceability limit state; ULS ultimate limit state; FLS fatigue limit state; ALS accidental limit state

DNV OS-101 2013
Load and Resistance Factors Targeting given Safety Level

The limit state format is a functional relationship including any parameter influencing the relevant failure mode.

\[ L_d(\gamma_C, \gamma_F, \gamma_C, 8_S) \leq R_d(\gamma_{SC}, \gamma_m) \]

where:
- \( L_d \): design load effect function
- \( R_d \): design resistance function
- \( \gamma_C \): condition load factor
- \( \gamma_E \): environmental load factor
- \( \gamma_F \): functional load factor
- \( \gamma_S \): system safety factor
- \( \eta \): resistance usage factor
ULTIMATE LIMIT STATES (ULS):
- Bursting / Pressure Containment
- Collapse
- Propagating Buckling
- Local Buckling due to Combined Loading (DCC and LCC)
- Fracture/Plastic Collapse/ Ductile Tearing of Defective Girth Welds
- Ratcheting (accumulation of plastic deformation in case of excessive bending at the S-lay Stinger)

SERVICEABILITY LIMIT STATES (SLS):
- Ovalization Limit due to Bending

FATIGUE LIMIT STATES (FLS)

ACCIDENTAL LIMIT STATES (ALS)
Minimum wall thickness for **pressure containment/bursting** according to DNV OS F101 design criteria

The criterion shall be fulfilled in both Operating and System Pressure Test conditions at the applicable water depths.

\[
p_{li} - p_e \leq \frac{p_b(t_1)}{\gamma_{SC} \cdot \gamma_m}
\]

- \(p_{li}\): Pressure Containment Resistance
- \(p_e\): Local External Pressure
- \(\gamma_{SC}\): Safety Class Resistance Factor as per Tab. 5-5 of DNV RP F101
- \(\gamma_m\): Material Resistance Factor as per Tab. 5-4 of DNV RP F101

\[
p_b(x) = \min(p_{b,1}(x); p_{b,2}(x))
\]

\[
p_{b,1}(x) = 2 x f_y \frac{D - x}{2} \frac{x}{3}
\]

\[
p_{b,2}(x) = \frac{2 x f_y u}{D - 0.115} \frac{x}{3}
\]

\[
x = t_1
\]

Operational: \(t_1 = t_{nom} - t_{fab} - t_{corr}\)

Pressure Test: \(t_1 = t_{nom} - t_{fab}\)

\[
p_{li} = p_d \cdot \gamma_{inc} + p_{cont} \cdot g \cdot h
\]

According to DNV OS F101 Sect. 3 B305, the incidental over design pressure ratio, \(\gamma_{inc}\), can be set to 1.05, which is the minimum allowed ratio, provided that the requirements to the Pressure Safety System are satisfied. This implies that the Pressure Safety System shall guarantee the maximum incidental pressure does not exceed the design pressure by more than 5%.
MECHANICAL DESIGN - LRFD DNV OS-101 (COLLAPSE LS)

\[ p_e - p_{\text{min}} \leq \frac{p_c(t_1)}{\gamma_m \cdot \gamma_{sc}} \]

- \( p_e \): External Pressure
- \( p_{\text{min}} \): Minimum Internal Pressure (zero for installation except in case of flooded pipe)
- \( p_c \): Characteristic Resistance to External Pressure (collapse)
- \( \gamma_{sc} \): Safety Class Resistance Factor as per DNV OS-F101 Tab. 5-5
- \( \gamma_m \): Material Resistance Factor as per DNV OS-F101 Tab. 5-4

\[ p_e = \frac{2E \left( \frac{t}{D} \right)^3}{1 - \nu^2} \]

\[ p_{\text{el}} = 2 \cdot \text{SMYS} \cdot \alpha_U \cdot \frac{t_{\text{fab}}}{D_o} \]

\[ f_o = \frac{D_{\text{max}} - D_{\text{min}}}{D} \]

Elastic Collapse Pressure
Plastic Collapse Pressure
Ovality

Note:
- \( D \): Nominal Outside Diam.
- \( D_{\text{max}} \): Maximum In/Outside Diam.
- \( D_{\text{min}} \): Minimum In/Outside Diam.
- \( \alpha_U \): Material Strength Factor
- \( t_1 = t_{\text{nom}} - t_{\text{fab}} \) (Install & Hydrotest)
- \( t_1 = t_{\text{nom}} - t_{\text{fab}} - t_{\text{corr}} \) (Operating)
- \( t_{\text{nom}} \): Nominal Steel Wall Thickness
- \( t_{\text{fab}} \): Fabrication Thick. Tolerance
- \( t_{\text{corr}} \): Corrosion Allowance
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MECHANICAL DESIGN - LRFD DNV OS-101 (LOCAL BUCKLING LS LCC)

\[
\left\{ \gamma_m \cdot \gamma_{SC} \left( \frac{|M_{Sd}|}{\alpha_c \cdot M_p(t_2)} \right) + \left( \gamma_m \cdot \gamma_{SC} \cdot S_{Sd} \right)^2 \right\} + \left( \gamma_m \cdot \gamma_{SC} \cdot \frac{p_c - P_{min}}{p_c(t_2)} \right)^2 \leq 1
\]

\[
P_e \quad \text{External Pressure}
\]

\[
P_{\text{min}} \quad \text{Minimum Internal Pressure (zero for installation except in case of flooded pipe)}
\]

\[
P_c \quad \text{Characteristic Resistance to External Pressure (collapse)}
\]

\[
\alpha_c \quad \text{Flow Stress Parameter}
\]

\[
M_{Sd} \quad \text{Design Moment}
\]

\[
S_{Sd} \quad \text{Design Effective Axial Force}
\]

\[
\gamma_{SC} \quad \text{Safety Class Resistance Factor as per DNV OS-F101 Tab. 5-5}
\]

\[
\gamma_m \quad \text{Material Resistance Factor as per DNV OS-F101 Tab. 5-4}
\]

**Plastic Axial Capacity**

\[
S_p = f_y \cdot \pi \cdot (D_0 - t_2) \cdot t_2
\]

**Plastic Bending Capacity**

\[
M_p = f_y \cdot (D_0 - t_2)^2 \cdot t_2
\]

\[
\left( \frac{p_c}{p_{el}} - 1 \right) \left( \frac{p_c}{p_p} - 1 \right) = f_o \frac{p_c}{p_{el}} \frac{D_0}{t_2}
\]

\[
\alpha_c = (1 - \beta) + \beta \cdot \frac{f_o}{f_y}
\]

\[
\beta = \begin{cases} 
0.5 \quad \text{for} \quad \frac{D_0}{t_2} < 15 \\
\left( \frac{60 - D_0/t_2}{90} \right) \quad \text{for} \quad 15 \leq \frac{D_0}{t_2} < 60 \\
0 \quad \text{for} \quad \frac{D_0}{t_2} \geq 60
\end{cases}
\]

**Collapse Pressure**

- \( f_o = f(D_{\max}, D_{\min}, D_0) \)
- \( p_{el} = f(E, D_0, t) \)
- \( p_p = f(\text{SMYS}, \alpha_U, \alpha_{fab}, D_0, t) \)

**Note:**
- \( D_0 \): Nominal Outside Diam.
- \( \alpha_U \): Material Strength Factor
- \( t_2 = t_{\text{nom}} \) (Install & Hydrotest)
- \( t_2 = t_{\text{nom}} - t_{\text{corr}} \) (Operating)
- \( t_{\text{nom}} \): Nominal Steel Wall Thickness
- \( t_{\text{corr}} \): Corrosion Allowance

<table>
<thead>
<tr>
<th>Safety class</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure containment</td>
<td>1.046</td>
<td>1.138</td>
<td>1.306</td>
</tr>
<tr>
<td>Other</td>
<td>1.04</td>
<td>1.14</td>
<td>1.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Limit state category</th>
<th>SLS/ULS/ALS</th>
<th>FLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma_m )</td>
<td>1.15</td>
<td>1.00</td>
</tr>
</tbody>
</table>
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### MECHANICAL DESIGN - LRFD DNV OS-101 (LOCAL BUCKLING LS DCC)

\[
\left( \frac{\gamma_e \cdot \varepsilon_{sd}}{\varepsilon_C(t_2,0)} \right)^{0.8} + \frac{\gamma_m \cdot \gamma_{sc} \cdot (p_e - p_{min})}{p_C(t_2)} \leq 1
\]

- \( P_e \) External Pressure
- \( P_{min} \) Minimum Internal Pressure (zero for installation except in case of flooded pipe)
- \( \varepsilon_c \) Characteristic Bending Strain Resistance
- \( \varepsilon_{sd} \) Design Compressive Strain
- \( P_c \) Characteristic Resistance to External Pressure (collapse)

\( \gamma_{sc} \) Safety Class Resistance Factor as per DNV OS-F101 Tab. 5-5

\( \gamma_m \) Material Resistance Factor as per DNV OS-F101 Tab. 5-4

\( \gamma_e \) Resistance Strain Factor as per DNV OS-F101 Tab. 5-8

\[
\alpha_h = \left\{ \begin{array}{ll}
1.0 & \text{if } \frac{D_0}{t_2} \leq 20 \\
1.0 - \left( \frac{D_0}{t_2} - 20 \right) \times \frac{100}{20} & \text{if } 20 < \frac{D_0}{t_2} \leq 60 \\
\text{not defined} & \text{if } \frac{D_0}{t_2} > 60
\end{array} \right.
\]

\( \sigma_{gw} = 0.78 \cdot \frac{t_2}{D_0} \cdot 0.01 \)

\( \sigma_{gw} = \frac{3}{2} \alpha_h \)

\( \sigma_{gw} = \max \left( \frac{\text{SMYS}}{\text{SMTS}} \right) \)

Collapse Pressure
- \( f_0 = f(D_{max}, D_{min}, D_0) \)
- \( p_{el} = f(E, D_0, t) \)
- \( p_p = f(\text{SMYS}, \alpha_U, \alpha_{fab}, D_0, t) \)

Girth Weld Factor

\( \varepsilon_c = \frac{t_2}{D_0} \cdot 0.01 \)

\( \alpha_h = \left\{ \begin{array}{ll}
1.0 & \text{if } \frac{D_0}{t_2} \leq 20 \\
1.0 - \left( \frac{D_0}{t_2} - 20 \right) \times \frac{100}{20} & \text{if } 20 < \frac{D_0}{t_2} \leq 60 \\
\text{not defined} & \text{if } \frac{D_0}{t_2} > 60
\end{array} \right.
\)
CHALLENGES BY DISCIPLINE ...
DESIGN FOR INSTALLATION – RELEVANT LIMIT STATES

The relevant failure modes and limit states for offshore pipeline installation are the following:

- **Collapse** due to external pressure.
- **Buckle propagation** due to the external pressure in case of buckle initiation.
- **Local buckling** due to external pressure and bending at the sagbend and due to tensioner and bending on the stinger in case of S-Lay installation or in flute of the J-Lay tower.
- **Concrete crushing** at the stinger in case of S-lay technology.
- **Plastic collapse & fracture** of defective girth welds.
- **Fatigue damage** of the girth welds due to severe loads and long time interval from ramp exit to touch down point.
**S-laying:** consists of assembling the pipe joints on the horizontal ramp of the lay vessel.
- Even for large diameter pipes, 2-4 (6) km/day
- High curvature applied on the overbend
- High tensioner forces required to hold the pipe in suitably “S” shaped lay span

**J-laying:** the pipe departs from the lay vessel at a near vertical angle, hanging like a cable and gently curving towards the horizontal as it approaches the seabed.
- Low tension forces required to hold the pipe in suitably “J” shaped lay span
- Slow lay rate, 2-3 (5) km/day
- Low curvatures of the lay span

**Rationale for safe installation of subsea and sealines:**
- pipeline
- lay operation mode
- lay equipment
- vessel strength/stability capacity
- calculation
Laying Criteria aiming to define allowable moments and strains is the following:

- **At the Overbend region (mainly S-Lay):**
  - Strain (DNV OS – F101) Simplified Criteria
  - Strain (DNV Design Guideline) Design Criteria
  - Allowable Bending Moment (JIP Design Guideline) Design Criteria

- **At the Stinger Tip (mainly S-Lay):**
  - Allowable Bending Moment (DNV OS – F101) Design Criteria
  - No contact to the Stinger Tip (Recommended Practice)

- **At the Sagbend region (both S & J-Lay):**
  - Bending Moment (DNV OS – F101) Design Criteria
  - Bending Strain (JIP Design Guideline) Design Criteria
  - Bending Strain of 0.15% (API Recommended Practice) Design Criteria

1. The red one are generally used.
2. Load Controlled Condition (LCC) i.e. Bending moment criterion is generally used in Shallow Waters.
3. Displacement Controlled Condition (DCC) i.e. Bending strain criterion is generally used in Deep Waters.
- The required residual lay tension is low due to the very large $\alpha_{\text{exit}}$ (~90 deg).
- Rollers reactions are due to pipe lay pull (not to pipe weight).
- Tensioner tension is a function of pipe column weight.
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**DESIGN FOR INSTALLATION - S-LAY LOAD CONDITIONS**

Mean sea level

From:
- Average Stinger Radius $\leftrightarrow$ Exit Angle
- Allowable Strain at Stinger $\leftrightarrow$ Wall Thickness

To:
- Top Tension $\leftrightarrow$ Tension Capacity
- Bottom Tension $\leftrightarrow$ Propeller Capacity

Main Relationship:
- $ST_T \sim BT + SW \times WD - BK^2/2$

Where:
- $ST_T$ is the stinger Tip Tension
- $BT$ is the bottom tension
- $SW$ is the submerged weight per unit length
- $WD$ is the water depth
- $B$ is the bending stiffness
- $K$ is the pipe curvature at the point where $ST_T$ is applied

**Touch down point**

Bottom Tension

TDP

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DESIGN FOR INSTALLATION - S-LAY LOCAL LOAD CONDITIONS

\[ M = f(\text{R}_{\text{stinger}}) \]

\[ F = f(N, \text{R}_{\text{stinger}}) \]

\[ N = \frac{1}{2} EJ \cdot k^2 + \text{RLT} + \text{WD} \cdot S_{\text{Weight}} \]
The amplification of the **pipe local curvature** increases considering a concentrated contact (1 roller vs. 4 rollers) and reducing the stinger curvature radius.
DESIGN FOR INSTALLATION – MINIMUM PIPE WALL THICKNESS

Generally:
- For pipeline exposed to frequent point load events (occurrence >= 10^-4 per year per km)
  - 16"<OD<20": 14 mm wall thickness
  - 20"<OD<36": 16 mm wall thickness
  - OD>36": 18 mm wall thickness
- For pipeline not exposed to frequent point load event
  - 10<OD<16": 10 mm wall thickness
  - 16<OD<20": 12 mm wall thickness

\[ F_{\text{elastic}} = 3.9 \cdot \sigma_y \cdot t^2 \]
**DESIGN FOR INSTALLATION - ANALYSIS**

- **Inputs**
  - Ramp Management vs. Water Depth
  - Metocean condition along the route

- **Tasks**
  - Stinger Setting vs. KP
  - Limit Sea State Conditions vs. Pipe Dynamics
  - Station Keeping
  - Lay Vessel Operability

- **Activities**
  - Normal Laying
    - Initiation / Lay-Down
    - Abandonment & Recovery
    - Stinger Movimentation
    - Accidental Flooding
    - Vessel Loss of Position
  - Dynamic Analyses
    - Fatigue Analyses
  - Fully integrated DP and Pipelay Analyses
  - Metocean forecasting
    - Operation Wave Nowcasting

- **Tools/Analysis**
  - Offpipe (static)
  - Abaqus (static)
  - Pipelay (static)
  - Offpipe (dynamic reg. & irreg. wave)
  - Pipelay (dynamic reg. & irreg. wave)
  - FIPLA
  - In-house software

---

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DESIGN FOR INSTALLATION – ANALYSIS OUTCOME

Analysis results (Overbend region & Stinger Tip)

SEMAC1 - Wheatstone Project - OD = 44.0 in - WT\textsubscript{steel} = 24.6 mm - WT\textsubscript{conc} = 110 mm

Pipe Configuration

- Tenstop = 329 Tons
- clr = 15.25 cm
- \(\alpha\)\textsubscript{out} = 28.50 deg
- WD = -124 m
- Sag\textsubscript{max} = 0.1238 %
- Tensbottom = 245 Tons

Strain

- R10 = 0.2525 %

Moment

- \(S_{tip} = -2920\ kNm\)
- \(R10 = -6616\ kNm\)

Reactions

- R7 = 428 kN (44 Tons)

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DESIGN FOR INSTALLATION – LARGE CAPACITY EQUIPMENT

A&R/SUBSEA DEPLOYMENT SYSTEM WITH HIGHER CAPACITY

- Fabrication: feasibility up to dia 180mm, MBL 2500mT, length 3800 m
- Testing: availability of test facilities up to 2500 t
- Alternative solutions (use of multiple steel wires system) move problems from the fabrication/testing of the steel wire to the inspection/discard criteria

DESIGN CRITERIA

- Applicable standards for offshore A&R/Subsea deployment winches/steel wire
- Safety factor definition criteria in Normal/Emergency Operation
- Wire Rope Fatigue Life design Criteria
- Test Requirements: break testing and test facilities available

MAINTENANCE/INSPECTION CRITERIA

- Maintenance of subsea ropes: lubrications (type of lubricants, application methods, regulations)
- Monitoring/inspection during operation: method and criteria (visual inspection, NDE, cut back and test, cycles data logging and fatigue monitoring)
- Discard criteria: definition, methodology and regulation
Accidental Flooding Scenarios failure modes:

- Excessive Bending Moment/Strain combined with Point Load Force at stinger tip (mainly Deep Water scenarios);
- Excessive Bending Moment/Strain at TDP region (mainly Shallow Water scenarios);
- Defective through thickness girth weld
- Leaking valve on special items

Accidental Flooding Scenarios shall take into account:

- Distinguish Deep vs. shallow water scenarios;
- Distinguish Trunkline vs. flowline (different pipe flooding time and evolution);
- Contingency measures, if any, and lay vessel structural integrity more than pipe integrity;
- Accidental flooding is generally driven by the lay equipment and vessel integrity;
- Vessel equipment includes a smart wet buckle detection system.
• **Principles / Application**
  Use a market available pipeline isolation tool for reducing flooding risk when laying in deepwater.

• **Objectives**
  Drastically reduce the need for a compression station at land, which is needed for pipeline recovery operations in case of pipeline rupture during laying.
  Compression station cost reduction.
  Reduce time to recover a pipeline damage situation, because only the last part of the pipeline need to be deflooded.

Parameters on a large and complex project:
- 55000 hp => 1000 hp
- 100 M€ => 10 M€
- 3600 psi => 36 psi
- RTO 72 h => 72 s

RTO = Ready To Operate
Remote Buckle Detection

- **Principles / Application**
  Injecting a signal (radio, pressure wave) into a waveguide (pipeline) face-end, each geometrical anomaly reflect part of the signal depending on its characteristics.

- **Objectives**
  A system which can provide a certified Buckle Measure up to the end of the stinger and capable to detect obstructions up to about 4 Km.

Reduce risk in case of mechanical BD failure and retrieval. Reduce time for corrective actions.

---

**TECHNOLOGY COMPARISON**

<table>
<thead>
<tr>
<th>Pros</th>
<th>Pressure Wave (AC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>Good Range</td>
</tr>
<tr>
<td>Hi-Repeatability</td>
<td>Hi-Repeatability</td>
</tr>
<tr>
<td>On board noise proof</td>
<td>Simple technology</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Accuracy</td>
</tr>
<tr>
<td>Range</td>
<td>On board noise influence</td>
</tr>
<tr>
<td>Complex technology</td>
<td></td>
</tr>
</tbody>
</table>
Tensile stress-strain test

Obtained curves from simulation

Comparison: Test vs numerical

Compressive stress-strain test

WHERE (across thickness) and WHEN (plate, pipe, before or after coating) to characterise the compression capacity of the line pipe steel \( a_{fab} \)

Line Pipe Manufacturing Issues (JC vs. UO)

Bauschinger effects included in design criteria equation by \( a_{fab} \) (see DNV OS-F101)
Ovality and Collapse Resistance vs. Expansion/Compression Strain

X65 OD=24" t=31.8mm - NUMERICAL ANALYSES (ABAQUS)

UOE / UO / UOC COLD FORMING
PRESSURE vs. OVALITY

External Pressure [Pa]

Ovality [%]

UOE (E=0.4%)
UOE (E=1.3%)
UOC (C=0.5%)
UOC (C=1.0%)
Combined External Pressure and Bending (Baushinger Effect)

X65 OD=24” t=31.8mm - NUMERICAL ANALYSES (ABAQUS)
Combined External Pressure and Bending

X65 OD=24" t=31.8mm - NUMERICAL ANALYSES (ABAQUS)

BENDING MOMENT (Nm)

MINIMUM COMPRESSION LONGITUDINAL STRAIN (%)
CHALLENGES BY DISCIPLINE …
The relevant failure modes and limit states for offshore pipeline in operation are the following:

- **Pressure Containment Capacity** due to internal overpressure during operation and in field pressure tests;
- **Shear Running Fracture** due to internal pressure;
- **Collapse** due to external pressure in case of pipeline depressurization;
- **Buckle Propagation** due to the external pressure in case of buckle initiation and pipeline depressurization;
- **Local Buckling** due to internal and/or external pressure and bending due to bottom roughness or lateral buckling in case of pipeline depressurization and high pressure and temperature conditions.
- **Stress-Strain Capacity** of defective girth welds during operation (it is normal practice to say that an export pipeline has to withstand applied tensile stress - strain up to yielding - 0.5%.
- **Fatigue** damage of the girth welds due to environmental loads in operation (at free spans) and pressure and temperature fluctuations (oligocyclic).
PIPELINE CAPACITY UNDER COMBINED LOADS

Pipeline strength and deformation capacity aims to quantify the maximum loads and the associated deformation the pipeline can taken when subject to:

- Differential Pressure (Internal and/or External)
- Steel Axial Force
- Bending Moment
ABAQUS FE Models have been developed to evaluate the strength and deformation capacity of pipes subjected to combined loads (int/ext pressure, axial force and bending).
PIPELINE CAPACITY UNDER COMBINED LOADS

LOCAL BUCKLING UNDER INTERNAL/EXTERNAL PRESSURE, AXIAL LOAD AND BENDING

PIPELINE BENDING ON S-LAY STINGER

BUCKLE ARRESTOR DESIGN

SPECIAL COMPONENTS FEM ANALYSIS

POST-PROCESSING

CORRODED PIPES

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The need of safely withstanding bending load effects (axial load effects are minor) both during installation and in operation (including hoop load effects).

The strength capacity of girth welds threatened by weld defects must be suitably analysed to establish:

- For given load condition, allowable defect size
- For given defect acceptance, allowable stresses and strains

PROJECT REQUIREMENTS

DEFECTS ACCEPTANCE CRITERIA

Who ECAs???

STRAIN (4.0%) CAPACITY NEEDED FOR SPECIFIC/LOAD SCENARIOS

PROJECT SPECIFICATIONS (CTOD-R CURVE)

Company Responsibility

Contractor to meet

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The relevant load condition for offshore pipeline in operation are the following:

- Operational conditions i.e. design pressure and min and max design temperature;
- External pressure during shut – down;
- Sea bottom roughness giving rise to the formation of free span;
- Environmental loads (surface waves and marine currents) in the shallow water section;
- High pressure and high temperature conditions giving rise to the development of lateral buckling;
- Geohazards particularly plastic flows and turbidity currents.
Sea bed preparation works (berms) by gravel dumping

Seabed morphology indicates the optimum route alignment

Steep deep depression

Fatigue Damage

Cross-Flow Modal Analysis

Cross Flow Vibration Mode - F = 0.370

Bottom Roughness Analysis

Fatigue Usage Factor (-)

Cross Flow Total Damage

Amplitude (-)

Design for Operation – Bottom Roughness
DESIGN FOR OPERATION – HIGH TEMPERATURE HIGH PRESSURE

In-Service Buckling due to HP/HT Conditions

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All the relevant pipe parameters are plotted as a function of the KP.
Detailed ABAQUS FEM analyses to:
- Investigate the puncture resistance of the pipe shell due to the impact
- Quantify the pipe shell behavior due to the interaction with a dragged anchor during hooking
- Quantify the global-local behavior of the pipe beam hooked by large dragged anchors
CHALLENGES BY DISCIPLINE ...

- Mechanical Design
- Seabed Mechanics
- Ocean Engineering
- Materials & Welding
- Flow Assurance
- Pipeline Integrity Management
- Design for Installation
- Design for Operation
MATERIAL - ALTERNATIVE PIPE CONCEPTS

SOLID CORROSION RESISTANT ALLOY PIPE
• DUPLEX OR SUPERDUPLEX

CS OUTER PIPE & CRA INNER PIPE
• MECHANICAL BOND OR LINED PIPE
• METALLURGICAL BOND OR CLADDED PIPE

Weld Overlay
Seal Weld
MATERIAL - PERFORMANCES OF NEW CONCEPTS

• DUPLEX OR SUPERDUPLEX EXPENSIVE NOT SUITABLE FOR EXTENSIVE APPLICATION AND SENSITIVE TO THERMAL DE-RATING

• CLADDED PIPE AND LINED PIPE ARE LESS EXPENSIVE BUT...

• SOME TECHNOLOGICAL GAPS TO BE ADDRESSED BY SUPPLIERS, CONTRACTORS AND OPERATORS JOINT EFFORTS

• APPLICATION FOR HT/HP PIP SYSTEM IN A SNAKED LAY CONFIGURATION PERFORMED BUT EXTREME COMPLEX AND AT THE TECHNOLOGY LIMIT
MATERIAL – TRADITIONAL, NEW PIPE CONCEPT FOR REEL LAY

- Reel-lay is the process where rigid pipes are:
  1. Prefabricated as long strings and stacked in dedicated onshore bases;
  2. Spooled onto a storage reel on-board the reel-lay vessel, yielding the steel;
  3. Transported onto the offshore field;
  4. Unwounded, straightened and laid by a dedicated system on-board the vessel.

- New Competitors (Heerema, EMAS) are entering in the market with an alternative process different from the conventional one by:
  2. Spooling the pipe onto a storage reel placed on-board a dedicated barge/supply vessel;
  3. Transporting it onto the offshore field and lifting it by the reel-lay vessel crane.
MATERIAL – REEL LAY TECHNOLOGY

- Conventional reeling applications (**since '70 up to 2k**):
  - More than **6000 km** of **steel pipelines** laid especially in GoM and North Sea
  - Mainly **flowlines (up to 16")** in water depths that were increasing through the years
  - In the **'90** also more complex products (e.g. PiP, SCR, **thick insulation**, ...) were laid in deep water (**up to 1000 m**) by reeling
  - The best in class vessel of those years, the "**Apache**", is still operative (re-hulled in 2010) and owned by Technip

- Late reeling applications (**2000-2010**):
  - More than **14000 km** of pipelines laid worldwide
  - Contractors invested both in new vessels and in onshore spoolbases to warrant presence in "golden triangle"
  - Complex field development projects in deep water (**up to 3000 m**) increases their market share
  - To face new demanding market needs Technip delivered the best in class multi-lay vessel Deep Blue (**lay tension 550 tons**)
THANKS