TMR 4585 Specialization Course UWT
Introduction to Subsea Pipeline Technology

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Objective

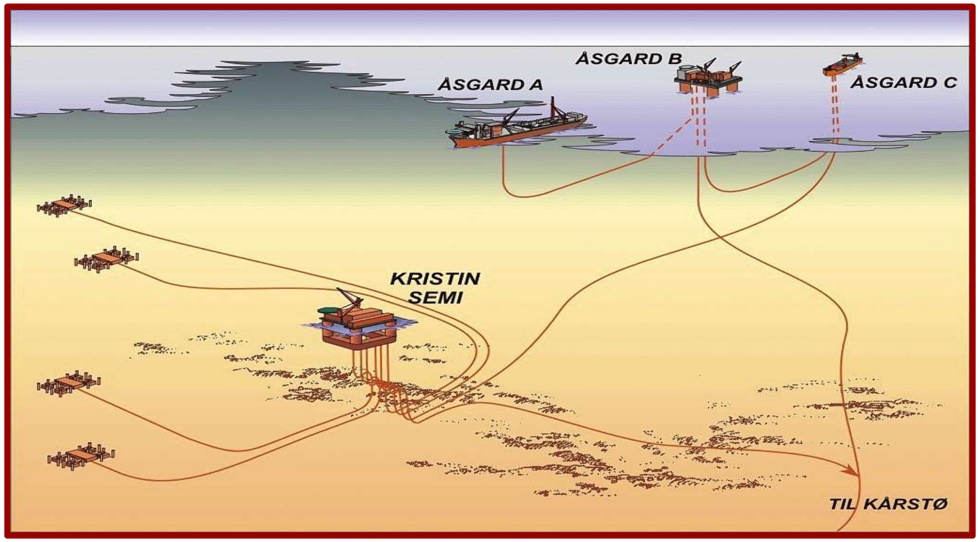
- **The give the student basic knowledge related to pipeline technology such that he is able to:**
  - Perform pipeline design with reference to the DnV standard related to:
    - ✓ Minimum wall thickness
    - ✓ Hydrodynamic stability
    - ✓ Free span length
    - ✓ Installation design
    - ✓ Temperature buckling
  - Understand the basic principles related to:
    - ✓ Flow assurance issues
    - ✓ Material selection
    - ✓ Welding
    - ✓ Stress and fatigue issues related to free spans in irregular seabed areas

Contents

- **Pipeline systems**
- **Relevant failure modes**
- **Load scenarios - pipelines**
- **Challenges for Pipeline systems in Irregular areas**

Pipeline Systems

- **Export (transportation) pipelines**
  - Processed fluid
  - Carbon steel
- **Flowlines to transferr products from wellhead to platform and between platforms**
  - Corrosive environment (CO_2 , H_2S)
    - ✓ Advanced corrosion resistent materials
    - ✓ Corrosion environment control by inhibitors
  - Flow assurance
    - ✓ Watercontent and hydrates
- **Waterinjection lines**
  - To keep pressure in reservoir
  - Advanced materials if unprocessed seawater
- **Chemical injection lines**
  - Corrosion inhibitor
  - Anti-freeze inhibitor
- **Umbilicals**
  - Signal transmission
  - Power supply
- **Bundles**
  - Flowline
  - Injection line
  - Umbilicals



Subsea pipeline system design is a multidisciplinary task

- **Fluid flow technology**
  - Fluid composition
  - Pressure profile
  - Temperature profile
  - Transcients
  - Operation philosophy
- **Material techology**
  - Material selection - corrosive fluid composition (CO_2 , H_2S)
  - Corrosion control by inhibitor systems
  - CP design - Corrosive external environment (seawater)
  - Welding defects - allowable strain at the welds
  - Material behaviour
- **Geotechnics**
  - Pipe-soil interaction
  - Design of rock supports in free spans
- **Coastal engineering**
  - Current models and characteristics
- **Oceanography/Hydrodynamics**
  - Metocean data
  - Loads
- **Structural mechanics**
  - Analyse pipeline installation and operation load scenarios
  - Design against relevant failure modes

Relevant system failure modes

- **Flow failure**
  - Hydrate or vax blocking
- **Corrosion failure**
  - Internal corrosion
  - External corrosion
- **Structural Failure**
  - Excessive yielding
  - Local buckling due to bending and external pressure
  - Buckle propagation
  - Impact loads denting
  - Buckle propagation
  - Ovalization
  - Fracture
  - Fatigue

Example – Hydrate plugging

Hydrates

Example - bending induced local buckling

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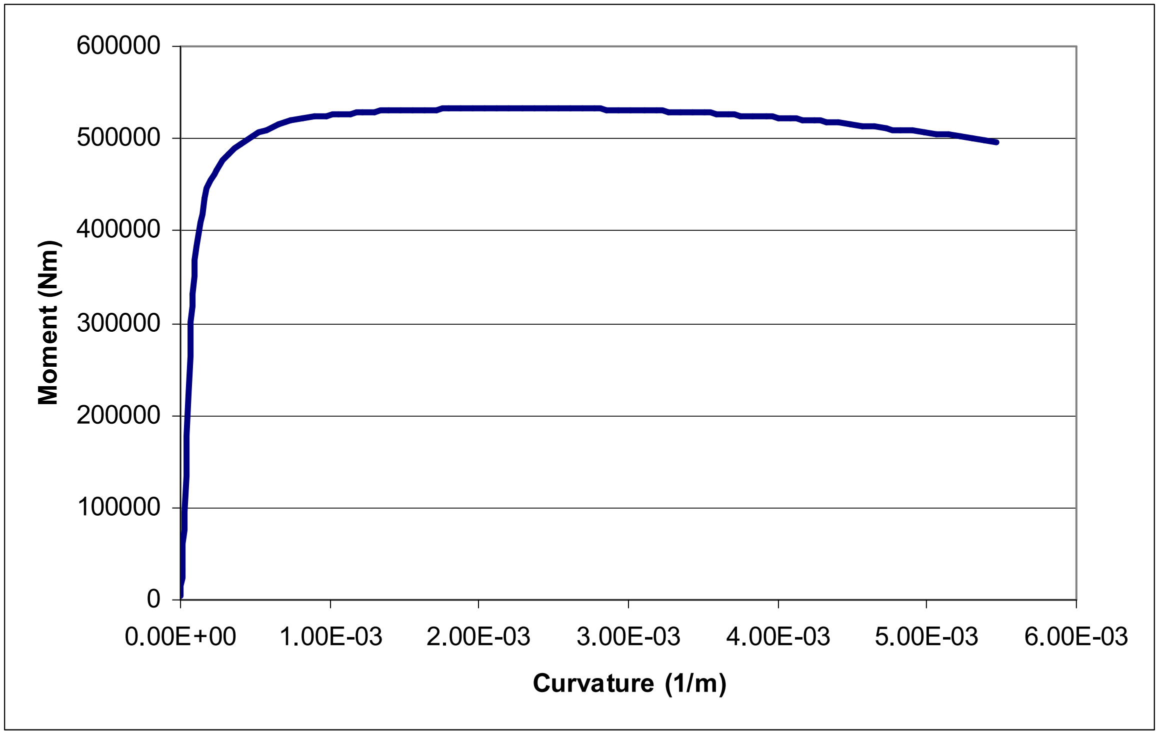
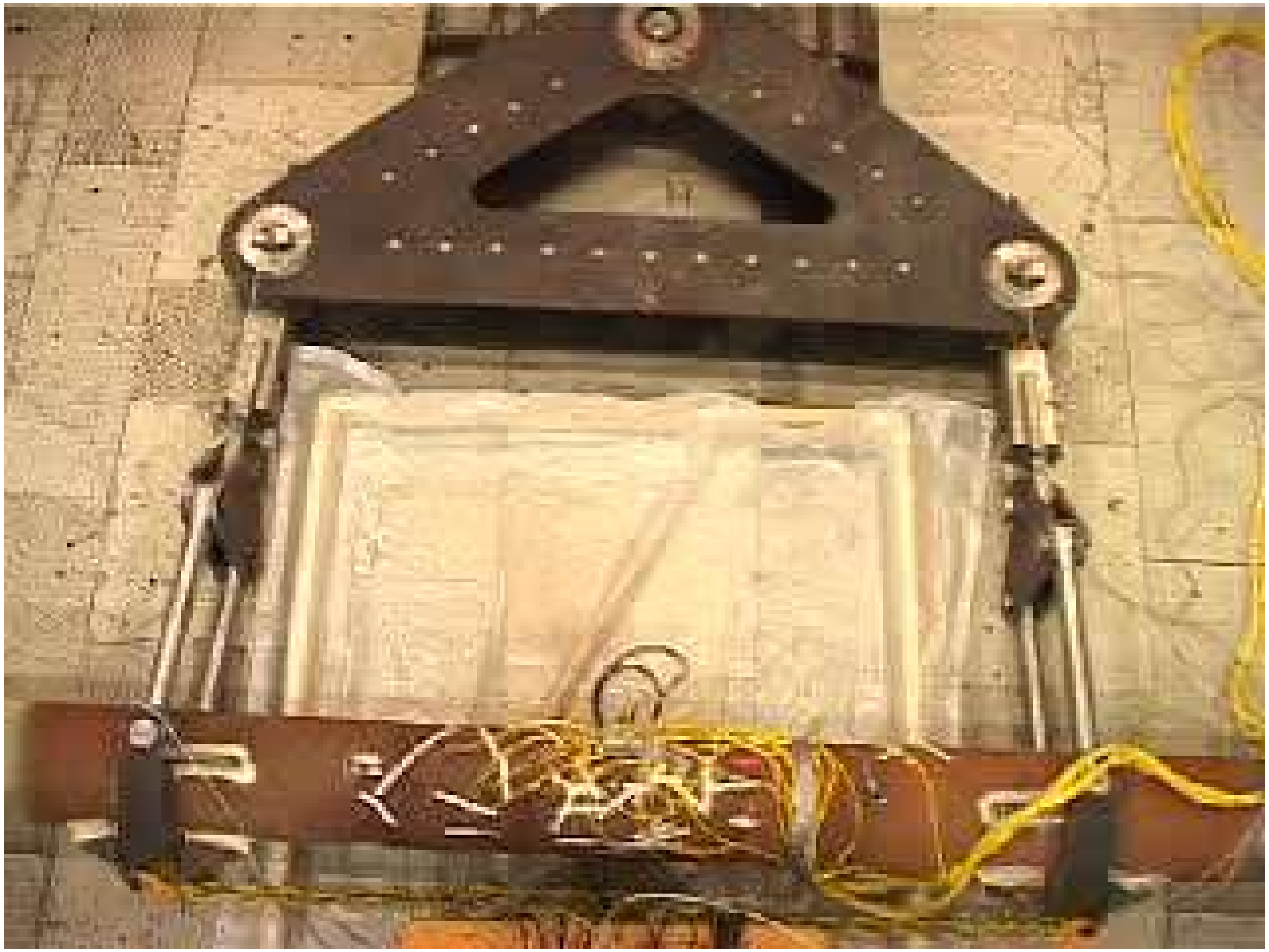
Example - bending induced local buckling



Fracture



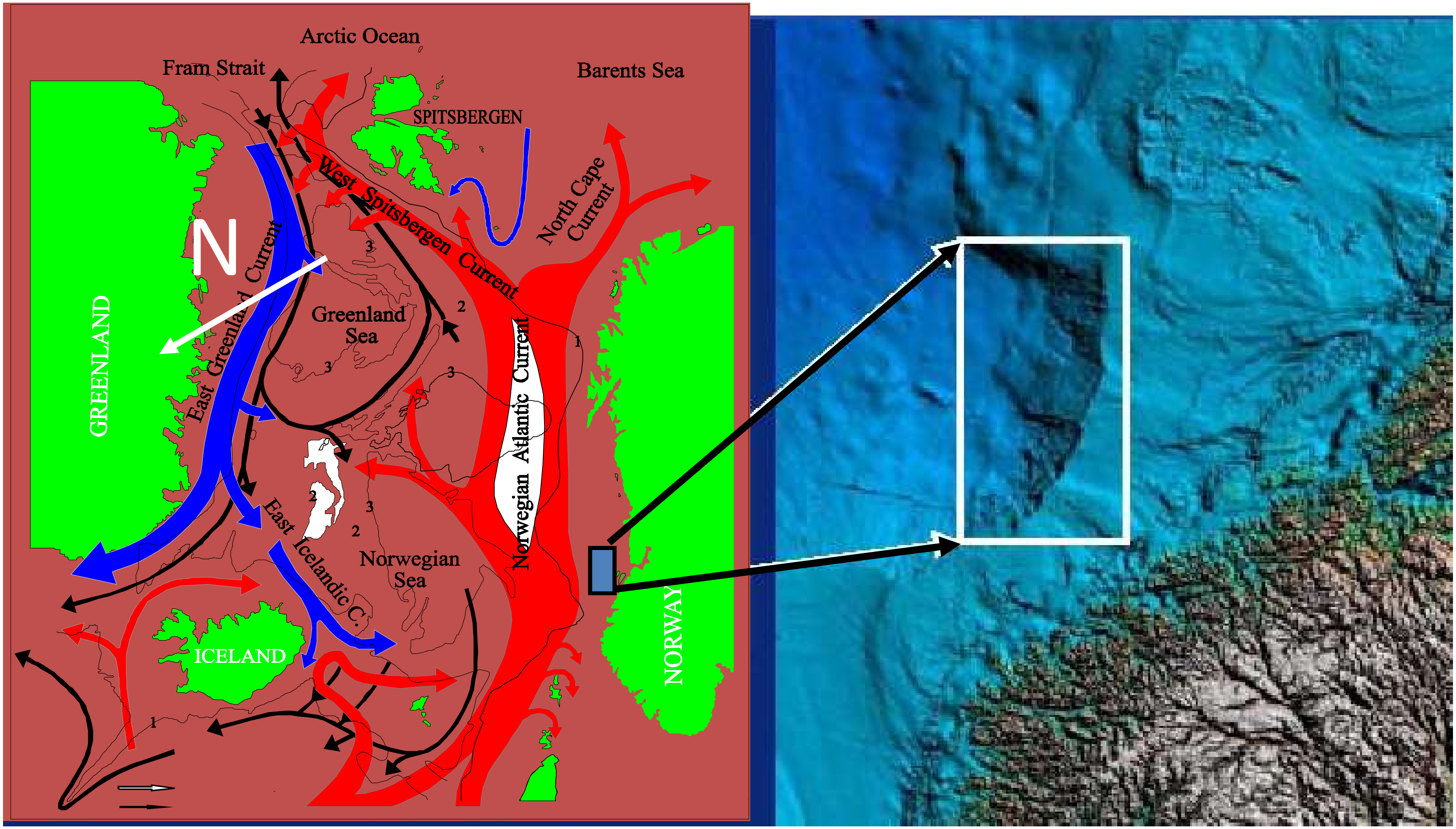
Load scenarios - pipelines

- **Pipeline installation:**
  - Gravity
    - ✓ Excessive yielding
    - ✓ Local buckling including buckle propagation
    - ✓ Fracture
    - ✓ Lateral stability
  - Wave and current induced loads and vessel motion
    - ✓ Fatigue
    - ✓ Lateral stability
      - Interference with other installations
      - Excessive yielding and buckling
    - ✓ Vortex induced vibration and fatigue
  - External pressure
    - ✓ Local buckling and collapse
  - Hydrostatic testing
    - ✓ Bursting

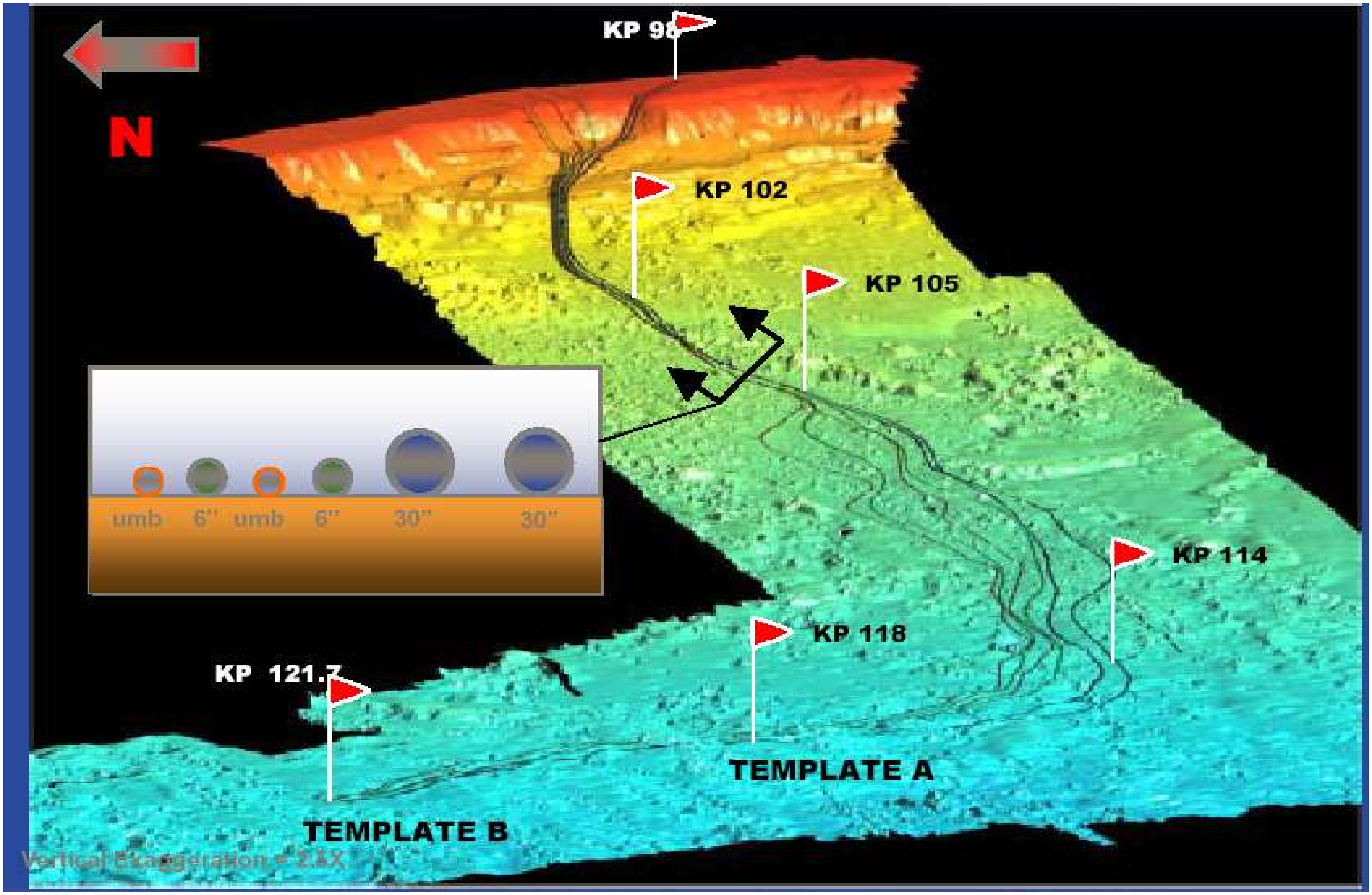
Load scenarios - pipelines

- **Pipeline operation:**
  - ➢ Gravity
    - ✓ Excessive yielding at free-span shoulders
  - ➢ Wave and current loads
    - ✓ Fatigue
    - ✓ Lateral stability
      - – Interference with other installations
      - – Excessive yielding and local buckling
    - ✓ Vortex induced vibration and fatigue
  - ➢ Operation temperature and pressure
    - ✓ Bursting
    - ✓ Global buckling
      - – Excessive yielding and local buckling
      - – Fracture
    - ✓ Low cycle fatigue due to shutdown
  - ➢ Interference with shipping activities
    - ✓ Excessive yielding and local buckling due to trawl pull-over
    - ✓ Fatigue

Case - The Ormen Lange field



Routing challenges



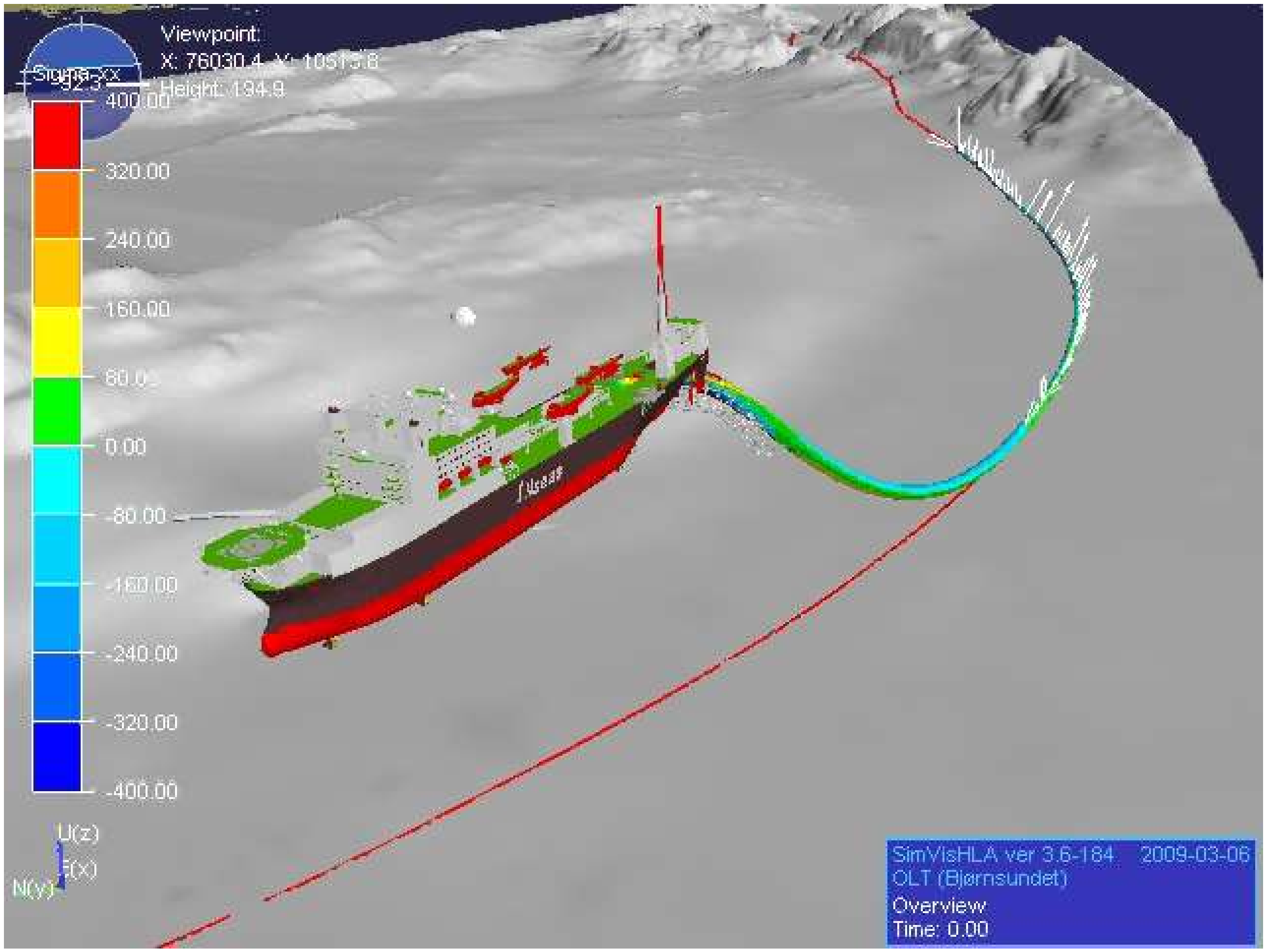
Challenges for Pipeline Systems in Irregular areas

- Curve stability during installation
- Routing, free spans
  - Screening on allowable spans
- VIV induced fatigue in free spans
  - Cross flow and inline responses
- Expansion control
  - Feed-in analysis as basis for rock dumping
- Trawling
  - Impact, hooking, bending moment capacity
- Accidental loads (e.g. anchor dragging)

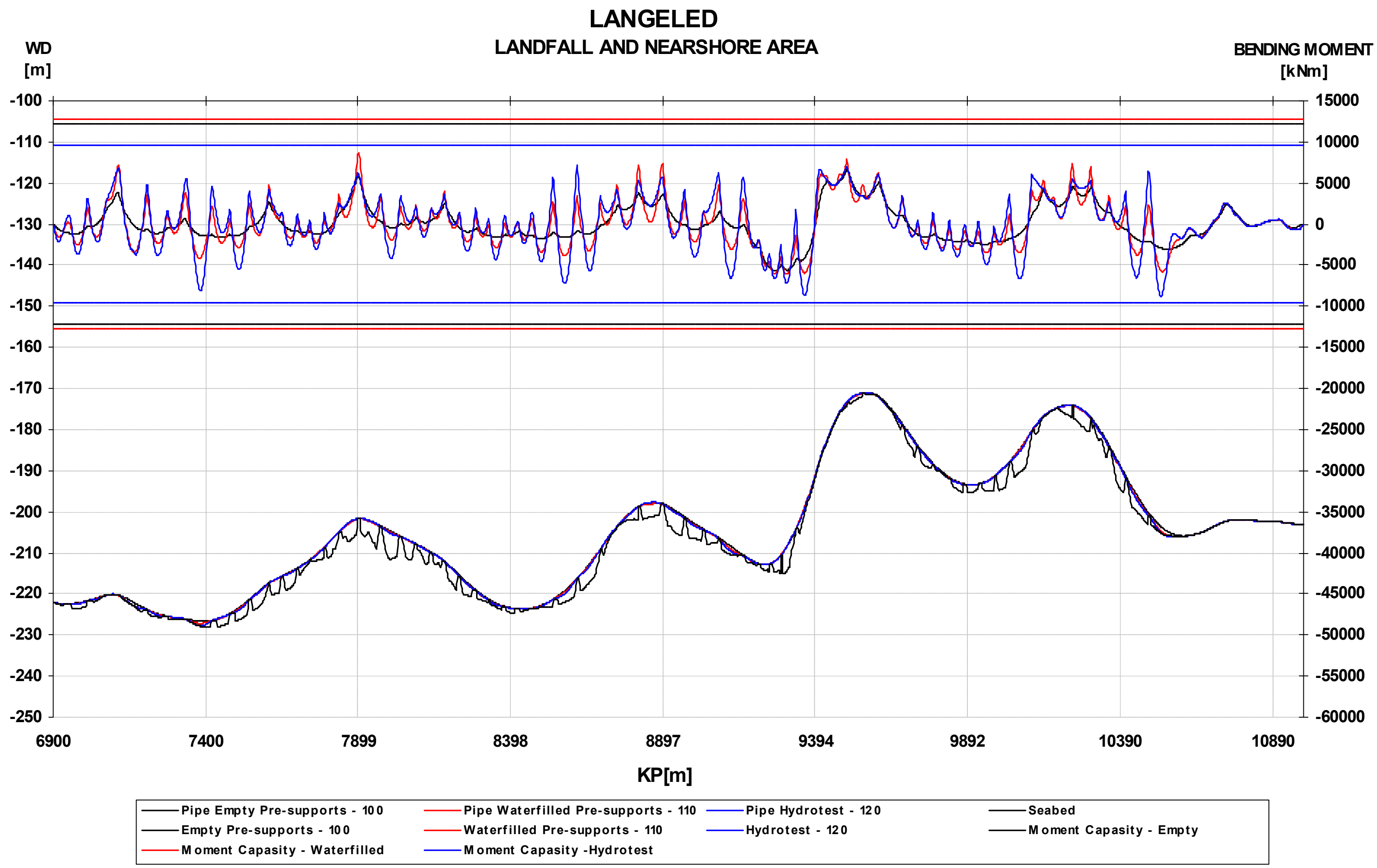
Dedicated finite elements

- Pipe elements
- Roller contact elements to describe vessel/pipe interaction
- Nonlinear springs to handle tensioner systems
- Seabed contact elements to describe the pipe/seabed interaction
- Formulation of finite elements for analysing pipelines requires:
  - ✓ Large displacement kinematics
  - ✓ Elastoplastic material laws
  - ✓ Energy Principle on total and incremental form

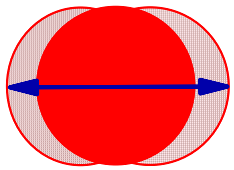
Curve stability during installation



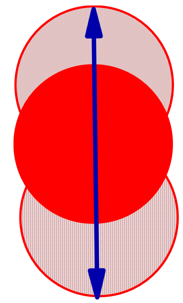
FREE SPAN ANALYSIS RESULTS



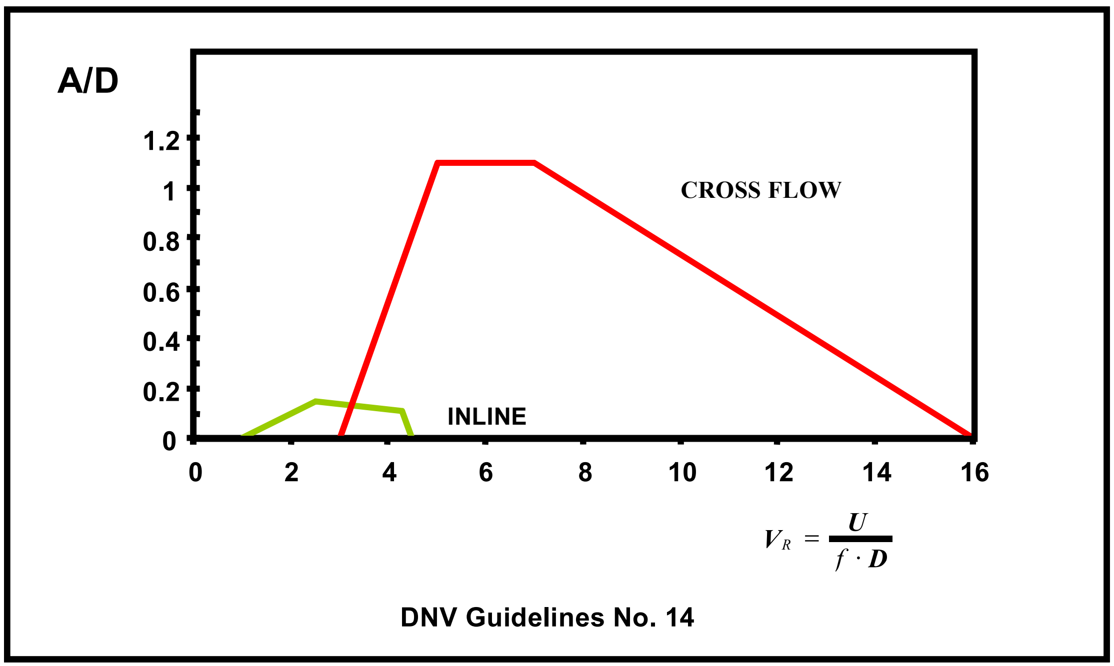
FREE SPAN VIV RESPONSE MODELS



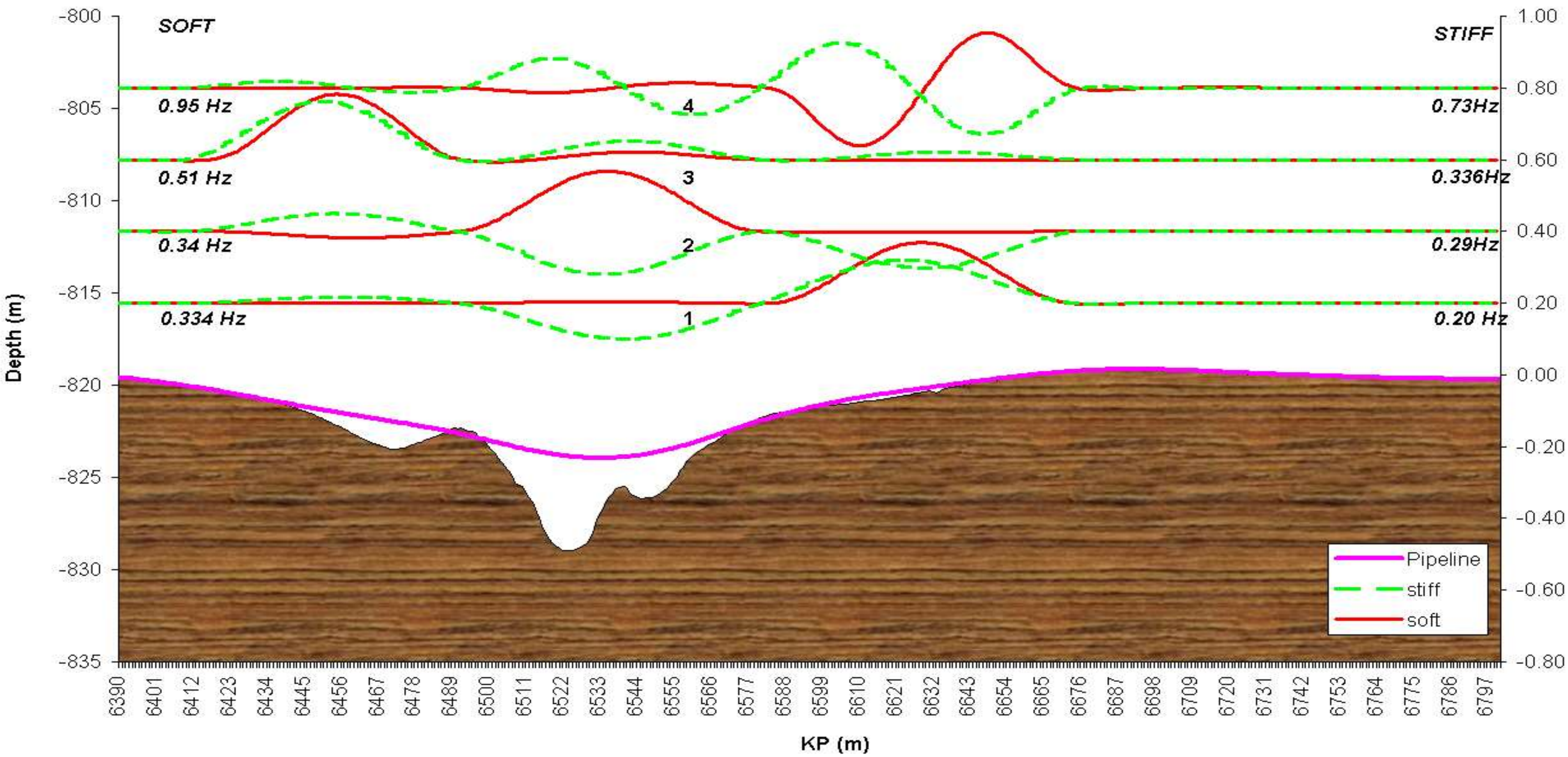
Inline
vibrations



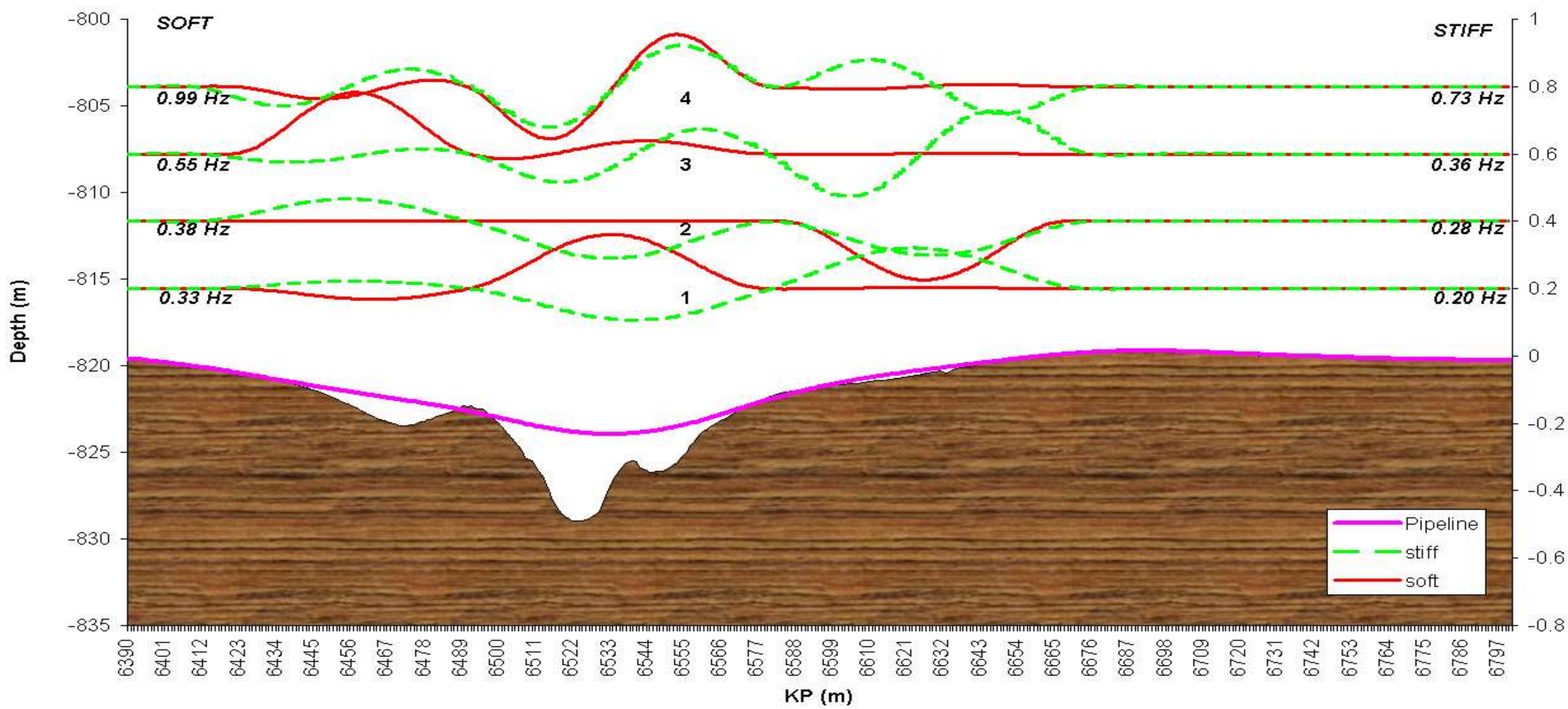
Crossflow
vibrations



Modal analysis – Inline modes

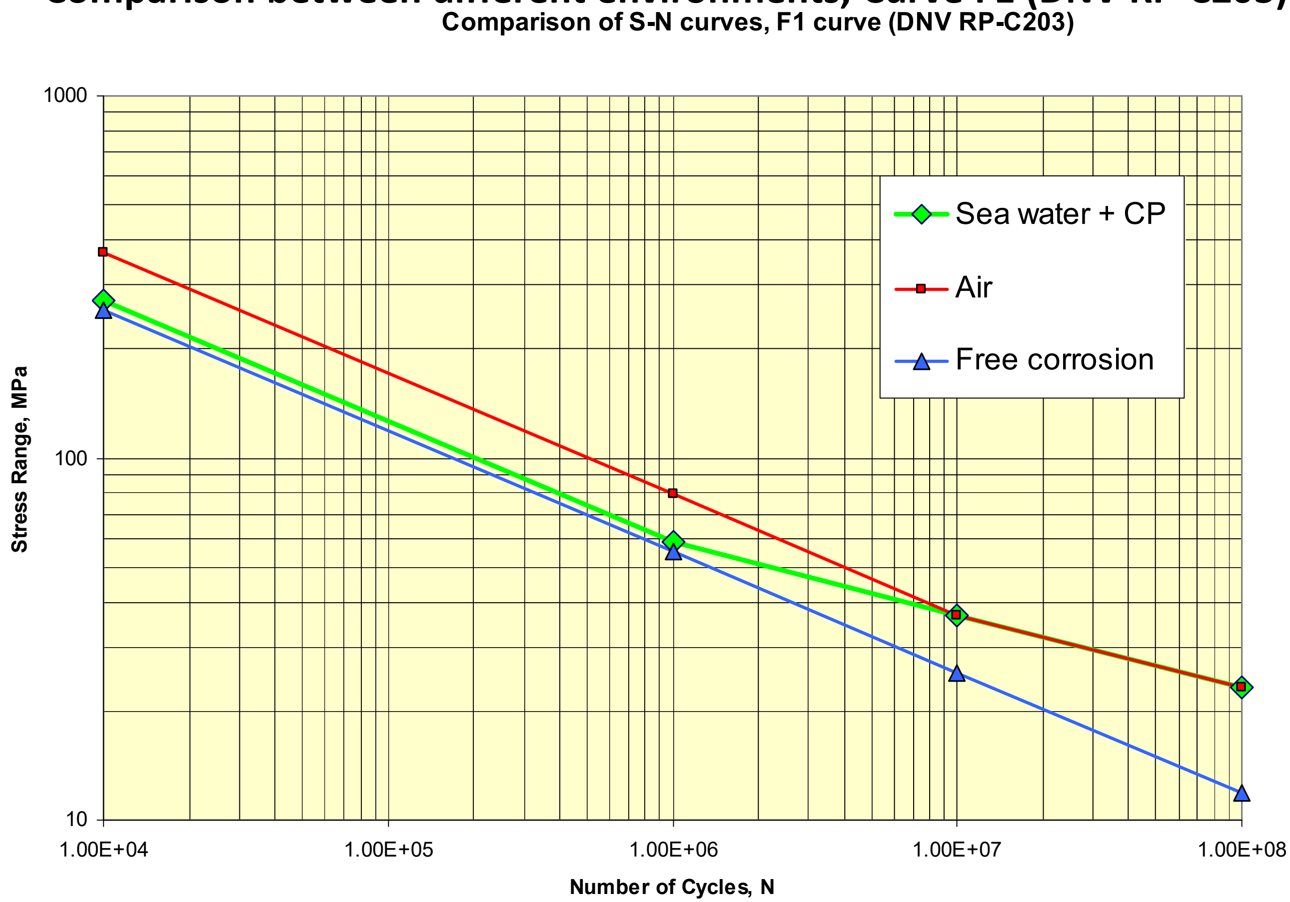


Modal analysis –
Cross flow Modes

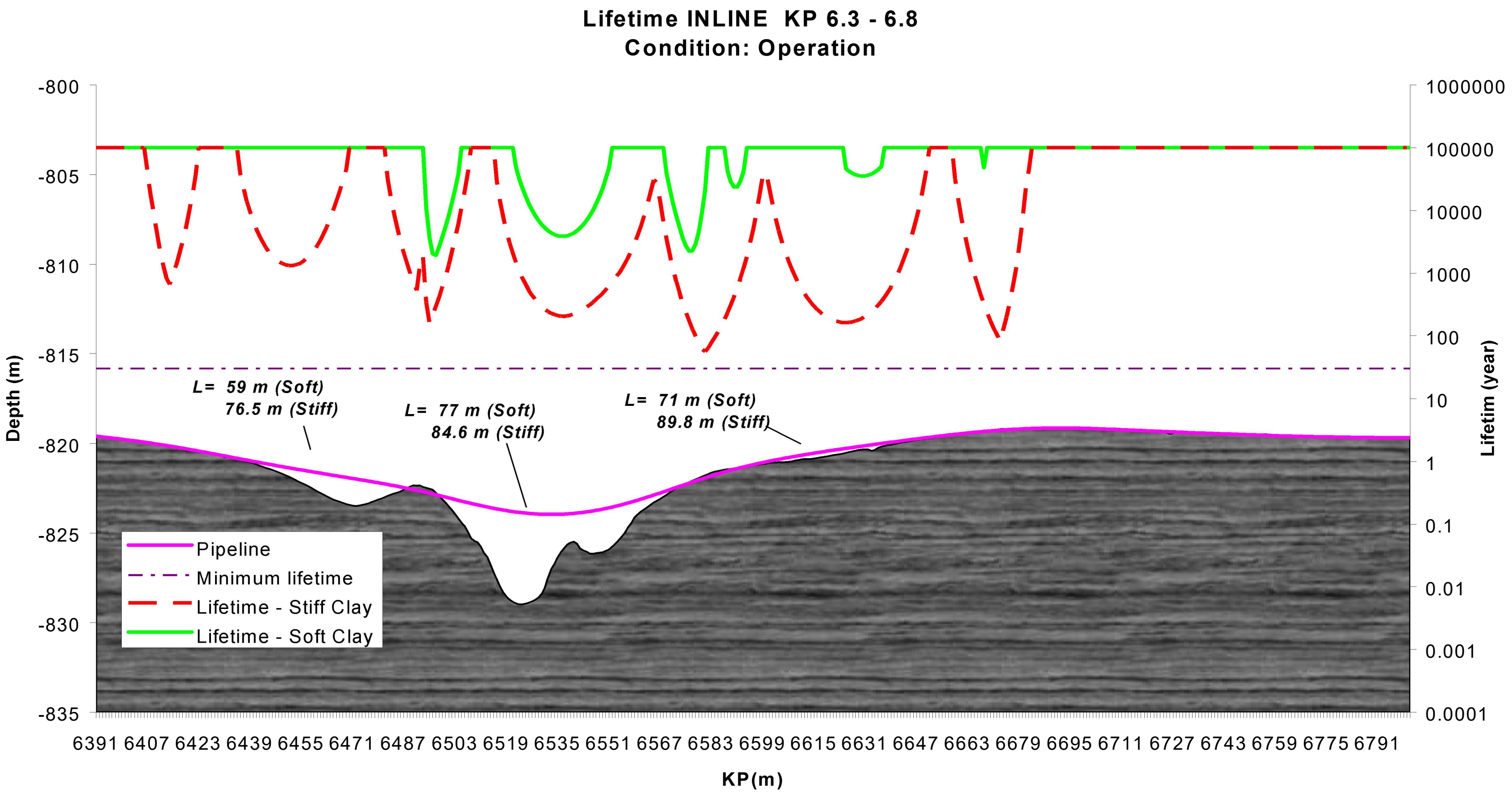


FATIGUE PROPERTIES OF LINEPIPE STEEL

Comparison between different environments, Curve F1 (DNV RP-C203)

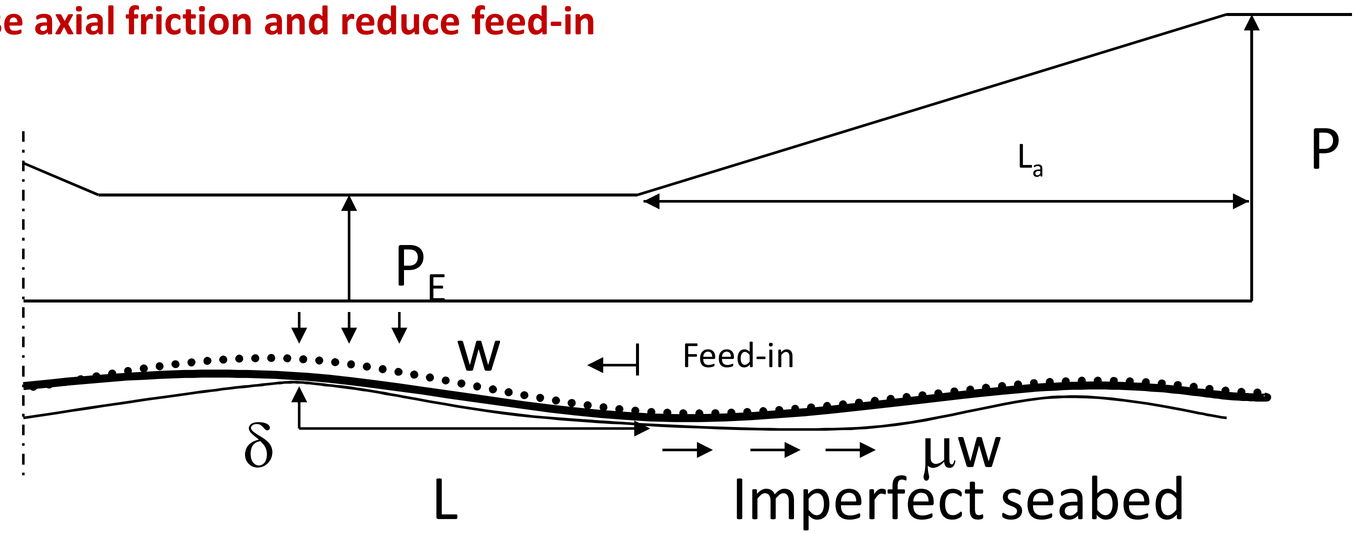


FATIGUE LIFETIME - INLINE



Expansion control

- **Pipelines resting on seabed and exposed to high temperatures and pressures may buckle as a bar (Euler Buckling)**
- **Due to seabed irregularities the buckling may be localized at the point of max imperfections:**
  - The pipe first undergoes uplift at crown of imperfection
  - Having lost contact at the crown of imperfection the pipe will then buckle laterally
- **To avoid excessive strains it may be necessary to perform rock installation to increase axial friction and reduce feed-in**



Expansion control - Analysis

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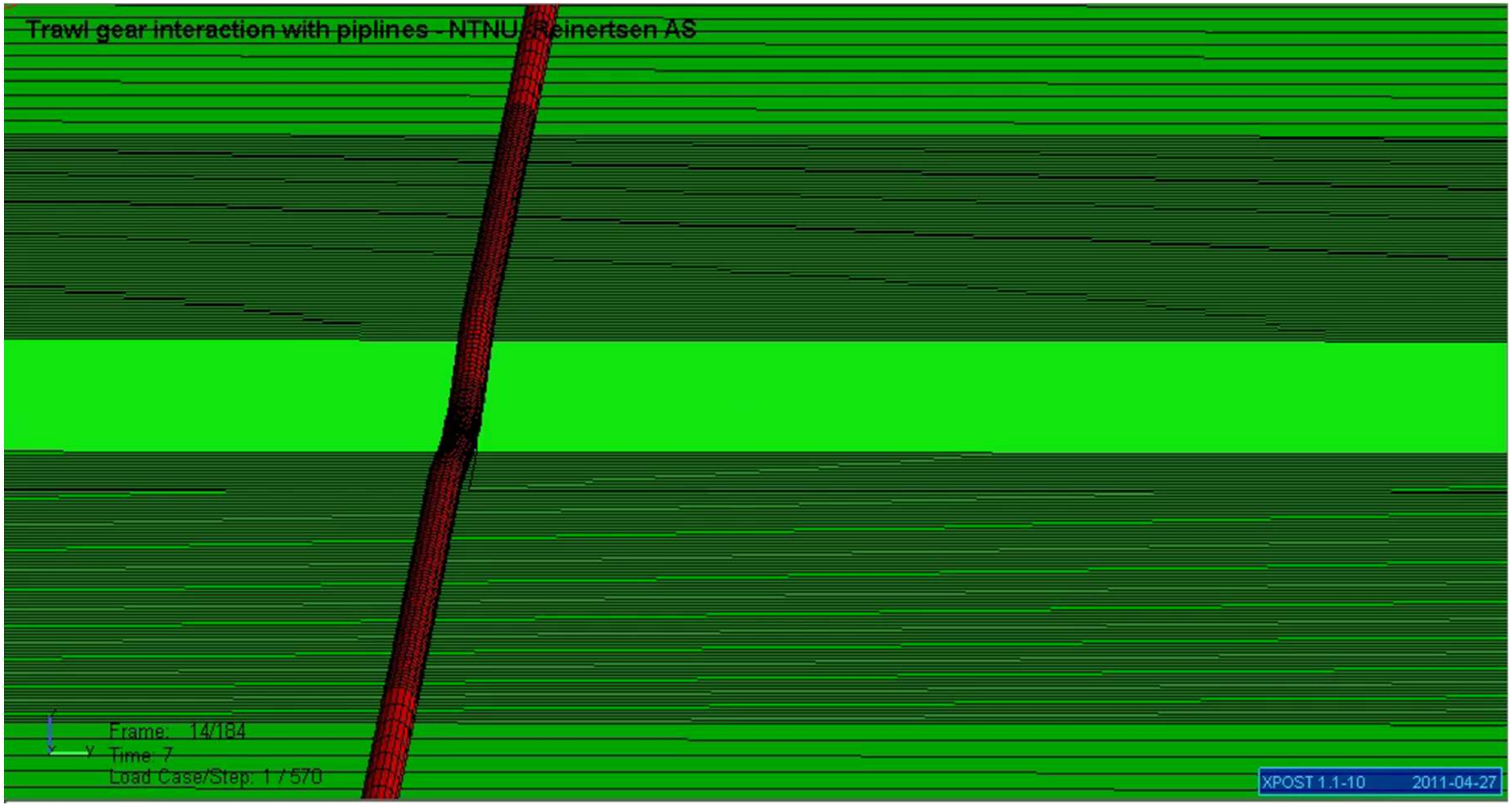
Load and Response from Trawlboard/Pipe interaction



Accidental load analysis – Anchor hitting pipeline in trench

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