Time-domain Nonlinear Coupled Analyses Covering Typical Mooring and Riser Configurations for FPSOs

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DNV GL - Software
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  • Spread mooring (MPM)
  • Turret mooring (SPM)
• Oil offloading Options
  • Tandem offloading
  • Side-by-side offloading
  • Catenary Anchor Leg Mooring (CALM) terminal
• Examples
Analysis for the design of FPSO mooring, riser and offloading system

Mooring alternatives

- Spread mooring (MPM)
  - Mooring and riser
    - SCR
    - Bending stiffener and jumper
  - FPSO coupled with TLP

- Single Point mooring (SPM)
  - Riser alternatives
    - SCR
    - TLR
    - SHLR
  - Accidental analysis
  - Detachable turret
  - SPM with DP

Offloading

- Tandem
  - Side-by-side

- CALM buoy
  - CALM buoy with shuttle tanker
  - CALM buoy with FTB and shuttle tanker
Typical workflow

- Modelling (GenIE)
- FEM models
- Hydrodynamics (HydroD)
- Hydrodynamic coeff.
  - Added Mass and Damping
  - 1st and 2nd wave forces
  - Wave drift damping
  - Etc.
- Time domain coupled analysis (DeepC and Sima)
Mooring Types

Spread Mooring

Turret Mooring
Offloading alternatives

Tandem

Side-by-side
Mooring system

- Water depth 1,400 m
- 14 mooring lines
- Non-collinear environment

### Environment Condition - West Africa - 100 Years Return Period (Ref. DNV-OS-E301, DNV-RP-C205)

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### MPM FPSO Mooring lines

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<th>Length (m)</th>
<th>Nominal D (mm)</th>
<th>Drag Coefficients</th>
<th>Added Mass</th>
<th>Mass in air (kg/m)</th>
<th>Axial Stiffness (N)</th>
<th>Min Breaking Load (N)</th>
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Spread mooring with risers and umbilicals

14 mooring lines, 8 production risers, 4 gas injection riser,
4 water injection risers, 4 umbilicals
Results and post-processing
Results and animation

Bending My

Shear Sz
With TLP

- 2 floaters
  - TLP and FPSO
- Positioning system
  - 14 mooring lines
  - 12 tendons
- Risers and umbilicals
  - 8 production risers for FPSO
  - 11 TTR for TLP
  - 4 gas injection riser and 4 water injection risers
  - 4 umbilicals for FPSO
  - 5 connecting umbilicals
Results

**Surge**

- TLP Surge
- FPSO Surge

**Heave**

- TLP Heave
- FPSO Heave

Frame: 280/400
Time: 344.5 s
Turret mooring and riser analysis

• Mooring analysis

• Riser configurations\(^4\)
  • Steel Lazy Wave Riser (SLWR)
  • Tension Leg Riser (TLR)
  • Single Line Hybrid Riser (SLHR)
SLWR

• Compliant riser system
  • An alternative to SCR
• Lower stress and fatigue damage near the touch down point (TDP)
  • Maximum vertical motion at the riser hang off point is high in 100-year hurricane
• Optimized by
  • Examining riser performance in extreme sea states
  • Minimizing mount of buoyancy
• Parameters of interests
  • Max and min effective tensions
  • Max Von Mises stresses
Results

Preferable to [4]

• Place the “wave” as close as possible to the seabed
• Have enough buoyancy to maintain the “wave” shape up to the extreme far position
Tension Leg Riser (TLR)[5]

In the case study, 6 SCR was used, departing on each side of the buoy.
Decoupling motions of FPSO
Single Line Hybrid Riser (SLHR)\textsuperscript{[5]}

• A hybrid decoupled riser system
  • Decoupled from motions of FPSO

• SLHR composed of
  • Vertical rigid pipe
  • Stress joint and suction pile
  • Gooseneck connecting riser and flexible jumpers
Modelling
Brief comparison
Breaking line transient analysis
Comparison – Intact and damaged, motions
SPM FPSO with rotatable turret model
Detachable turret (e.g. MUNIN FPSO)
Turret motions

-97 m
Side-by-side offloading with SPM FPSO

- Multi-body coupling
- Hydrodynamic coupling
- Fenders
- Connecting lines
- Etc.

Hydrodynamical Couplings
- c_FPSO_Tanker
  - Radiation Data
    - Coupled Frequency Dependent Added Mass
    - Coupled Frequency Dependent Damping
    - Retardation Function
    - Coupled Added Mass Infinite

- Point Fenders
  - PF
  - Roller Fenders
    - RF_1
    - RF_2
    - RF_3
    - RF_4

Fixed Elongation Couplings
- Conn_bf1
- Conn_bf2
- Conn_bf3
- Conn_bf4
- Conn_sfl1
- Conn_sfl2
Hydrodynamic coupling calculation in Wadam
CALM buoy
More complex setting

3 bodies
20 slender structures
Decoupled motion of SPM and FTB
Dynamic loading on the flowlines reduced
Summary

- Sesam from DNV GL covers comprehensive analysis of FPSO mooring and offloading alternatives including
  - Spread mooring and turret mooring
  - Turret mooring with thrusters
  - SCR, FTB, Hybrid, etc.
- Global and local analysis easily simulated
  - Bellmouth and jumper analysis
  - Local turret analysis
- Mooring (riser) disengaged transient analysis provides more confidence
- Detachable turret analysis
References


