Steel Lazy Wave Risers – A Step Change in Riser Technology for the NWS

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A Step Change in Riser Technology for the NWS

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Agenda

- Lazy wave risers – an enabling technology for the North West Shelf (NWS)
- Design drivers
- Configuration development
- Riser strength and fatigue
- Installation feasibility
- Reducing conservatism through measurements (STREAM JIP)
- Summary

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Riser Design in the NWS

The Australian NWS is a challenging design environment:

- Directional swell seastates
- Tropical cyclones
- 10,000 year design criteria
- Calcareous soils
- Lack of existing subsea architecture
- Large diameter gas lines
- Long service lives
- Harsh chemical environment
- Temperature and pressure ranges

Flexible risers are limited by size, fluid pressure and long service requirements
Why SLWRs for NWS

- Steel catenary risers (SCRs) could be a viable solution:
  - Simple concept and long track record
  - SCRs are subject to fatigue issues, especially with FPSOs or semisubs

- Steel lazy wave risers (SLWRs) are a feasible solution:
  - Robust configuration
  - Allows flexibility (vessel type and top loads)
  - Field proven on BC10, Blind Faith, Julia. Liza & Mad Dog2 will have SLWRs
  - Overall cost of hull, mooring and riser can be lowered

Some operators have developed feasible SLWR configurations for NWS 1000m+ fields

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Lazy Wave vs. SCR

Pros:
- Reduces top tension
- Decouples (partially) vessel and TDZ movements
  - Improves strength performance 10-30%
  - Fatigue performance improves 3-10x
- Permits tieback to vessels with poor motion characteristics e.g. semi-sub or FPSO
- More riser configuration and heading arrangements allowed (for lateral and vertical clearance)

Cons:
- Installation (and hardware) costs
- Increased design complexity

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SLWR Suitability for North West Shelf

- Swell seastates, cyclones
  - SLWR reduces TDZ compression and fatigue allowing large diameters, long design lives (40+ years)
  - Allows larger motion vessels (e.g. semisubs, FPSOs)
  - All risers need not be orthogonal to dominant NE swell direction

- Internal fluids
  - SLWR better suited than flexibles for sour service, high pressure and large OD

- Calcareous soil
  - Reduces interaction at TDZ with calcareous soil which has high vertical and horizontal stiffness
  - Hence reduced fatigue loading

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Steel Lazy Wave Risers (SLWRs)

- Tapered stress joint or flex joint
- Buoyancy modules
- SCR pipe with strakes (as required)

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SLWR Design Challenges

- Riser fatigue in the hang-off and TDZ
- Slugging induced fatigue
- VIV of buoyancy modules
- Motion induced vibration (MIV, sometimes called heave induced VIV) is more pronounced than SCRs
- Sagbend may touch seabed during hydrotest
- High flex joint rotations in extreme cyclones
- Installation of empty riser with buoyancy modules
- Stability/fatigue in wet parked condition
- Loss of buoyancy
- High pull in loads

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Preliminary Configuration

- Sufficient length to avoid TDZ overstress
- Minimise height to minimise buoyancy & associated costs
- Avoid seabed contact with heaviest fluid & extreme near offset

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SLWR Configuration Development

- Configuration is highly dependent on:
  - Internal fluids
  - Vessel motions

- Fatigue life improvement
  - Increased buoyancy
  - Increase in overall suspended length
  - Hang-off angle

- Typically, what is good for fatigue is bad for installation

- Configuration development requires iteration

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High Arch Strength Response

- FPSO Feasible
- Better stress response than SCR
- Highest stresses distributed between hang-off, sag and hog bends, and TDZ
- High stress fluctuation at critical locations

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Low Arch Strength Response

- Critical location at start of buoyancy
- High stress driven by:
  - Sag bend heave motion
  - Less damping
- Increased likelihood of local buckling
- Can be optimised by increasing arch height

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Typical Wave Fatigue Response

- Critical locations
  - TDP
  - Hang-off point
- Better fatigue life than SCR
- Relatively low fatigue life occurs at hog and sag bends with high curvature fluctuations
- Fatigue life increased by longer suspended length - by increasing hang-off angle or buoyancy coverage.

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Arch Height Effect on Fatigue

Fatigue Life (years)
- Low Arch = 670
- Mid Arch = 750
- High Arch = 1,500

Sag Bend Height: 2400 ft
Arch Bend Heights:
- Low Arch 2600 ft
- Mid Arch 3100 ft
- High Arch 3600 ft

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Sagbend Effect on Fatigue

Fatigue Life (years)

- Low Sagbend = 2,700
- High Sagbend = 2,100

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Lazy Wave Riser VIV

- SLWRs in the NWS are expected to be fully covered with VIV suppression due to the possibility of strong cyclonic currents.
- Buoyancy section is typically not fitted with suppression. Lock-in of buoyancy module and gaps can occur.
- Lazy wave riser VIV is still an active research topic. Previous studies include – Shell tests at MARINTEK (OTC 23672), CFD studies by Chevron (OMAE 24522).

CFD based flow visualization
(Constandinides and Zhang, OMAE-24522)

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Lazy Wave Riser VIV

- Buoyancy modules and bare pipe modes compete
- Preference is to have buoyancy modules vibrate (low modes)
- Buoyancy module L:D ratio and module to gap length ratio critical in determining VIV response
- Bounding approach suggested while using empirical programs such as SHEAR7

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SLWR Motion Induced Vibrations

- MIV of SLWRs can contribute significantly to fatigue, particularly in cyclonic seastates
- MIV is not yet well characterised
- Deepstar® SLWR test campaign (OMAE 54970) demonstrated MIV in the out of plane direction at up to 4 times applied frequency
- MIV can be modeled using a global model and VIV software and updated hydrodynamic coefficients based on tests/field data

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SLWR MIV Modeling

Extract riser velocities at discrete timesteps

Relative “current” profiles for VIV assessment

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Optimisation for Clearance

Configuration envelope due to fluid variation

Configuration envelope optimised to allow crossing without interference:

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SLWR Installation

- Major challenge - high strain during installation of buoyancy modules
- Installation aids include clump weights, retrofit buoyancy modules
- Installation and wet-parked conditions should be assessed for strength and fatigue

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**SCR/SLWR Monitoring Programs**

- While laboratory tests are a good indicator of riser behavior, they are not a substitute for real field behavior.
- A number of catenary risers have been monitored in the past 2 decades.
- The ongoing STREAM (STeel Riser Enhanced Analytics using Measurements) JIP is focused on leveraging field measurements to improve typical design standards.

**STREAM JIP Datasets**

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<th>TLP SCR</th>
<th>TLP SCR</th>
<th>Mini-TLP SCR</th>
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<td></td>
<td></td>
<td>30% faired</td>
</tr>
</tbody>
</table>

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Learnings from Monitoring (STREAM JIP)

- Measurements indicate wave response damps down the riser to a greater extent than predicted by current industry standard modelling methods.
- Fatigue near TDP is over-predicted by factor of ~3.
- Inline and higher harmonic VIV are infrequently observed but can cause significant fatigue.
- Motion induced vibrations occur during storm seastates.

3 more datasets to be assessed – including 1 SLWR with semi.
Conclusions

- Steel lazy wave risers are suitable for the NWS
- Field proven extension to SCRs
- Enables larger diameters and pressures than flexibles
- Better fatigue and strength response
- Calibration of analysis parameters by monitoring is reducing conservatism

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