

The Impact of Composites on Future Deepwater Riser Configurations

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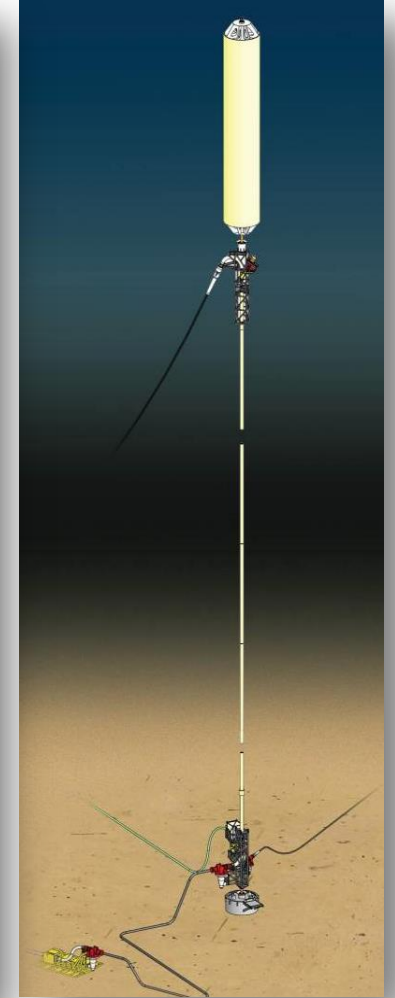
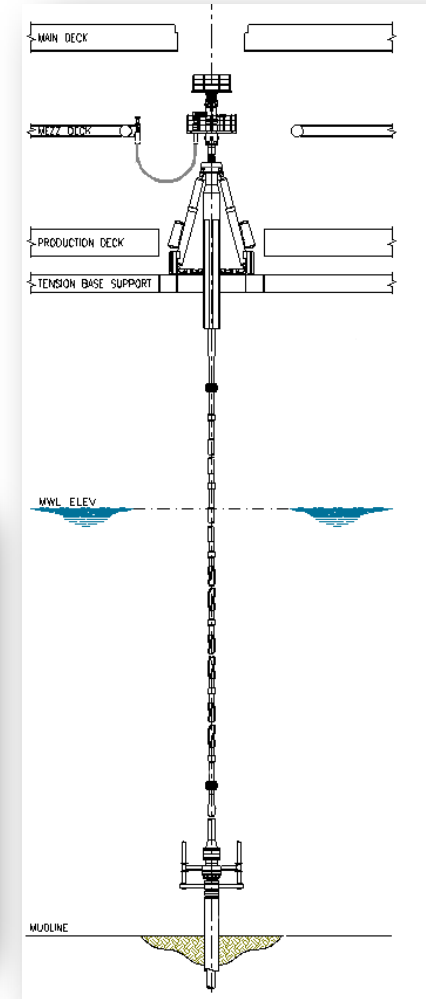
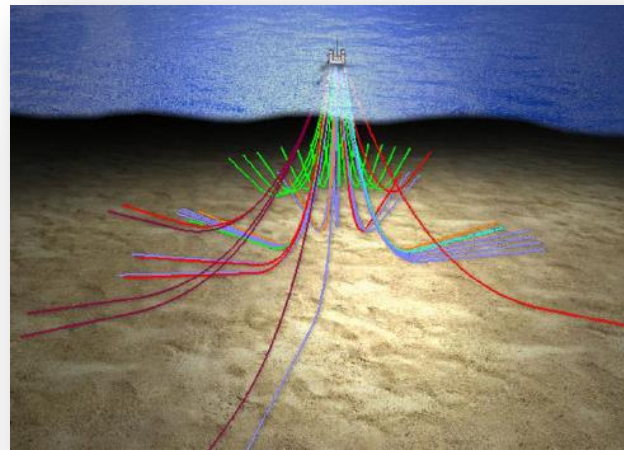
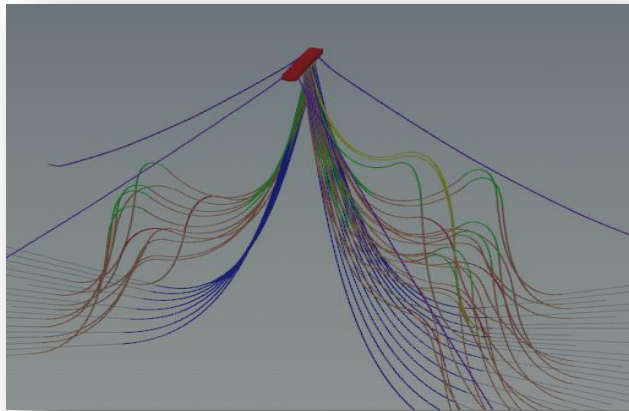
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Deepwater Riser Technology

Today's deepwater risers:

- Top Tension
- Flexible (many configuration options)
- Steel Catenary (including lazy wave)
- Hybrid



Composite Riser Technology Benefits & Challenges

Composites offer opportunities to improve riser technology:

- Composites are light – High specific strength
- Low maintenance claimed – good fatigue and corrosion resistance
- High flowrates claimed
- Potential ease of installation (i.e. Reeled pipe)

However, there are also a number of challenges:

- Composites are light
- High material cost
- Limited qualification and offshore track record
- Limited codes and standards
- Limited number of pipe vendors
- Hard to inspect sub-laminar damage



Composite Riser Technology History

- In the past composite materials have been used offshore in a range of applications, mainly in secondary structures; Pipework, J-tubes, Riser protection, Walkways and Ladders.
- Improvements in structural integrity led to the 1st composite drilling riser joint which was developed for Statoil's Heidrun TLP in 2001.
- A number of vendors are now scaling up efforts to produce composite pipe for offshore use.
- More recent use as downlines to support pre-commissioning and acid stimulation operations. Composite flowlines and jumpers are now beginning to make an appearance.
- Also utilised in the tensile armour of flexible pipe.



Composite Pipe Application on Existing Technology

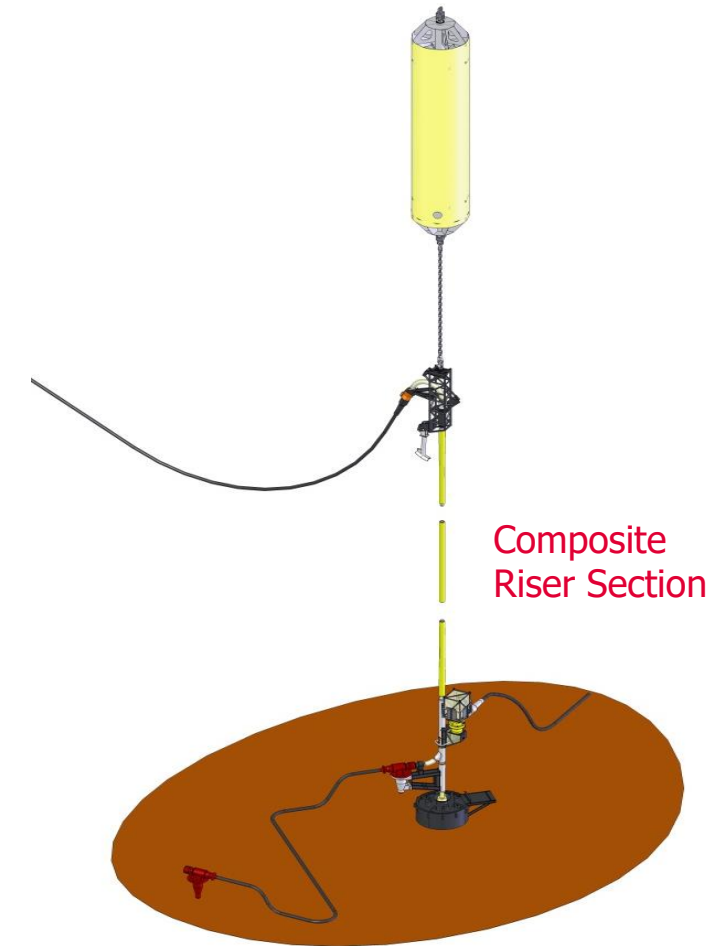
Two Single Lined Hybrid Risers (SLHRs) were compared:

- SLHR with a steel riser leg,
- SLHR with a composite riser leg.

The considered water depth was 2,000 m. This was selected as the SLHR riser concept is already established for this water depth.

The internal diameter for the composite pipe was selected to be of a matching size to the steel pipe.

Found to perform well, reducing buoyancy tank, Upper Riser Assembly (URA) and Lower Riser Assembly (LRA) sizes. However, it was found to only become economic at deeper water depths of 4,000 m.



Objectives

- Assess the global system performance of the application of composite pipe in a production riser scenario.
- Develop a number of simple (although not necessarily conventional) riser arrangements.

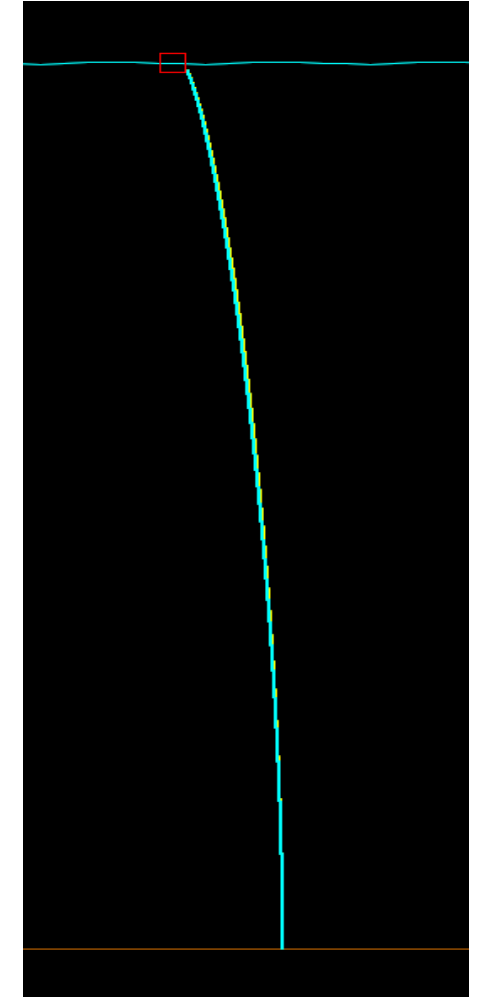
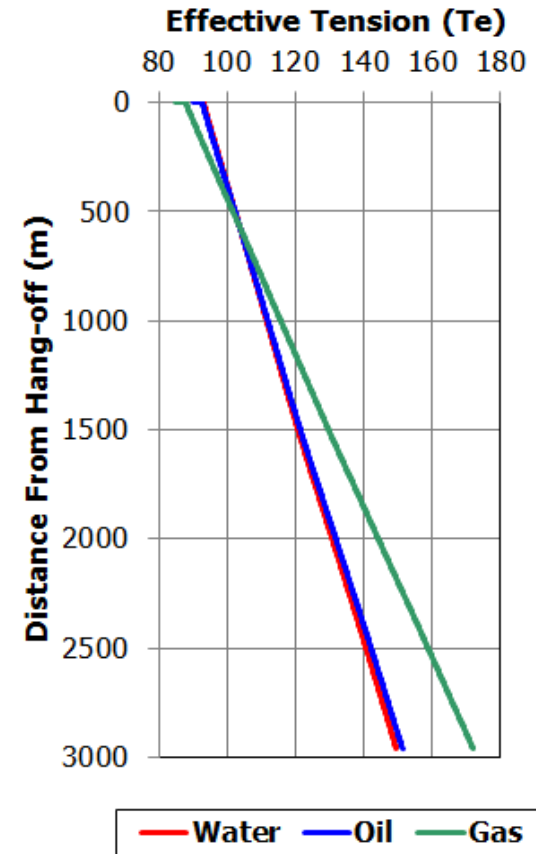
Design Premise:

- 1500 m and 3000 m water depths.
- FPSO & Semi-submersible - offsets up to ± 8 % of water depth.
- West of Africa (WoA) environment up to 100 year event (current and wave).
- 4.5 " insulated production riser.
- Varying internal fluid densities.
- Fully fixed connections at both ends (e.g. SCR hang-off porch).



Configuration A – keep it simple, keep it economic

- Composites strain further than steels – does this positively impact the feasibility of a **simple riser configuration** of a composite top tensioned pipe in a WoA environment?
- Insulation properties are important
- Buoyant tension profile
- Maximum tension at the foundation
- Low vessel loads
- Potential challenges for installation

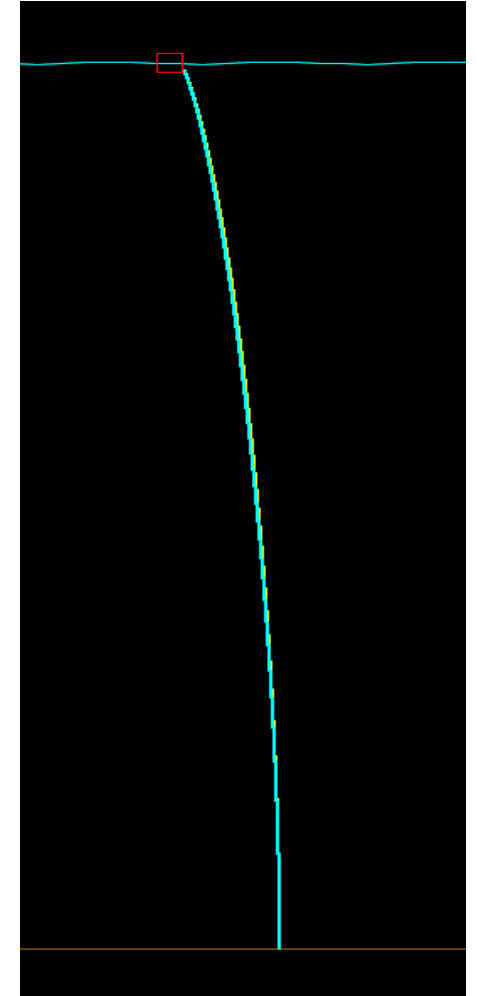


Configuration A – keep it simple, keep it economic

- Operation assessment with a Semi-sub & a turret-moored FPSO

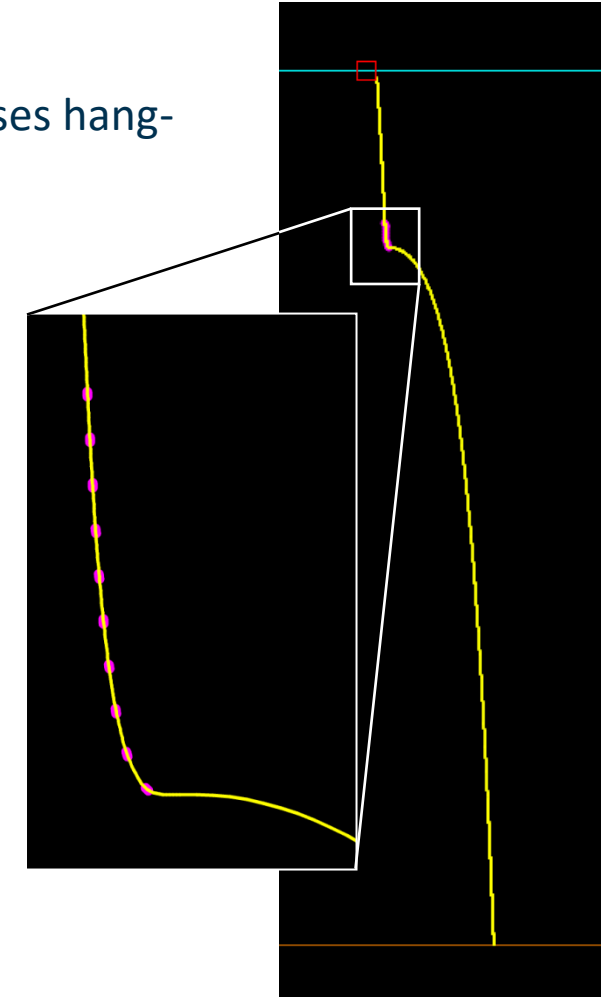
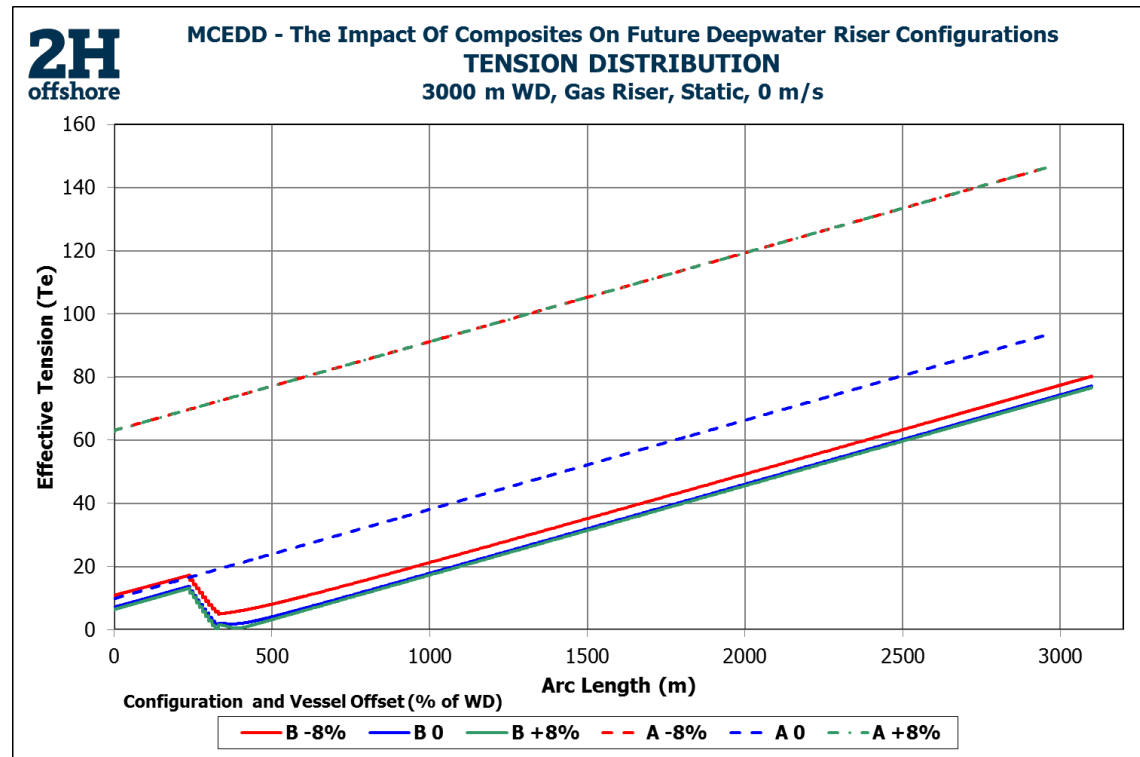
Vessel	Water Depth	Effective Tension (Te)		Vessel Hang-off Load (Te)	Foundation Load (Te)
		Minimum	Maximum		
Semi-sub	1500	16	132	92	132
	3000	6	172	90	172
FPSO	1500	-10	213	163	213
	3000	-7	212	115	212

- Pipe Tension limit = 266 Te
- Acceptable tensions with a Semi-sub
- Challenging tensions with higher dynamic loading from an FPSO
- Meeting allowable bend radius found to be challenging, however this can be addressed with bend stiffeners and bend restrictors.
- Pre-tension used to mitigate low bend radius at vessel



Configuration B - add some flexibility

- Ballast applied to decouple vessel motion.
- Increasing the ballast weight reduces hang-off angles and bending but increases hang-off loads.



Configuration B – add some flexibility

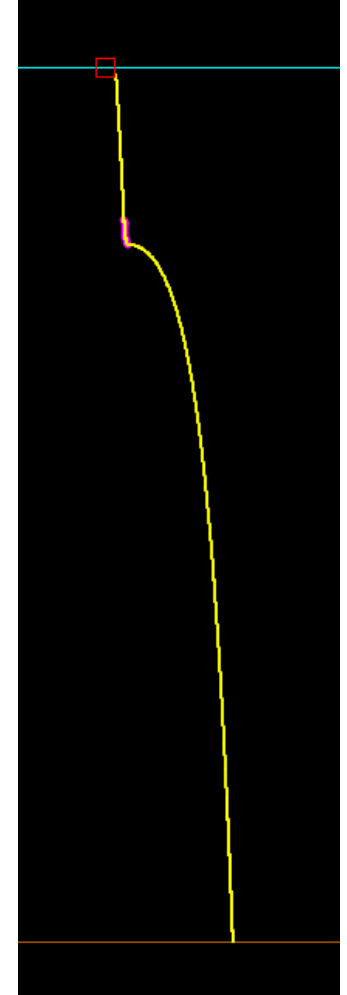
Configuration A:

Vessel	Water Depth	Effective Tension (Te)		Vessel Hang-off Load (Te)	Foundation Load (Te)
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	3000	-7	212	115	212

Configuration B:

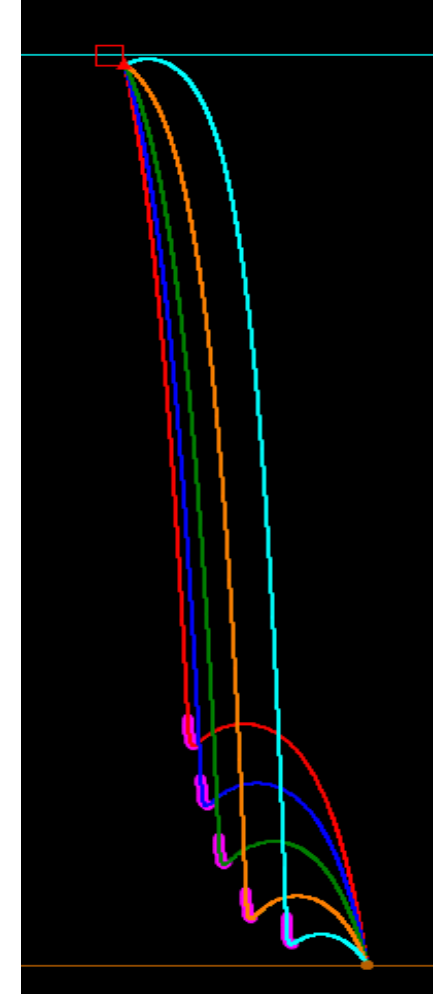
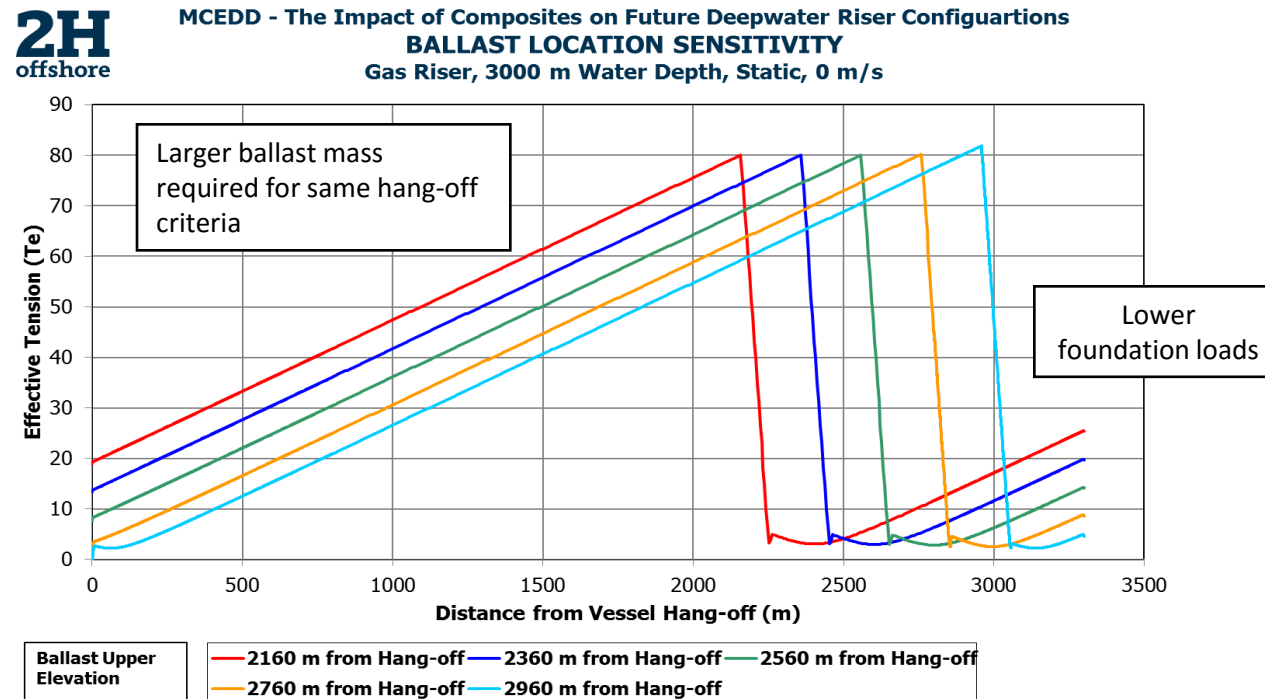
Vessel	Water Depth	Effective Tension (Te)		Vessel Hang-off Load (Te)	Foundation Load (Te)
		min	max		
Semi-sub	1500	-1	65	55	36
	3000	0	81	45	81
FPSO	1500	-14	112	95	86
	3000	-2	97	62	97

- Maximum tensions and hang-off loads reduced.
- Ballast size and depth should be considered carefully.



Configuration C – manage the loads

- The ballast elevation was relocated to the bottom of the riser.



- May be favourable as pipe arch is out of the high current zone.

Configuration C – manage the loads

Potential benefits include, but are not limited to:

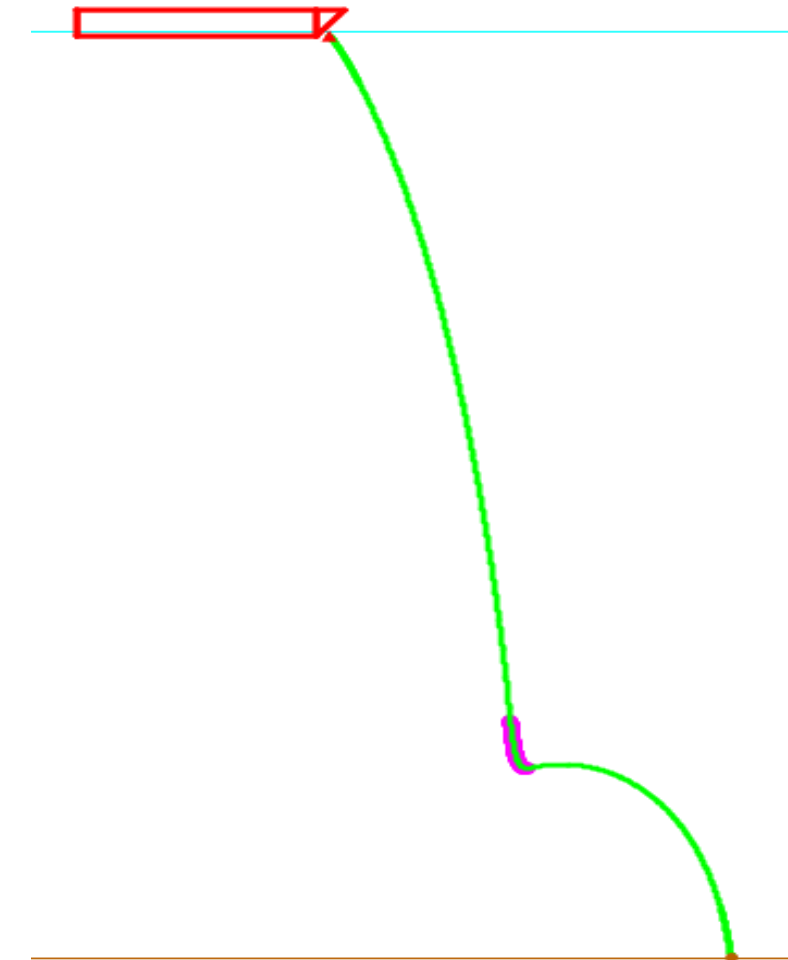
- Low vessel and foundation loads.
- Tension can be managed at key locations.
- Reduced dynamic loading due to riser elbow.
- Vessel offsets are easily accommodated.
- Potentially redeployable over variable water depths during riser life.

Configuration B:

Vessel	Water Depth	Effective Tension (Te)		Vessel Hang-off Load (Te)	Foundation Load (Te)
		min	max		
Semi-sub	1500	-1	65	55	36
	3000	0	81	45	81
FPSO	1500	-14	112	95	86
	3000	-2	97	62	97

Configuration C:

Vessel	Water Depth	Effective Tension (Te)		Vessel Hang-off Load (Te)	Foundation Load (Te)
		min	max		
Semi-sub	1500	0	50	33	34
	3000	-1	101	33	71
FPSO	1500	-28	75	65	30
	3000	-5	147	108	52



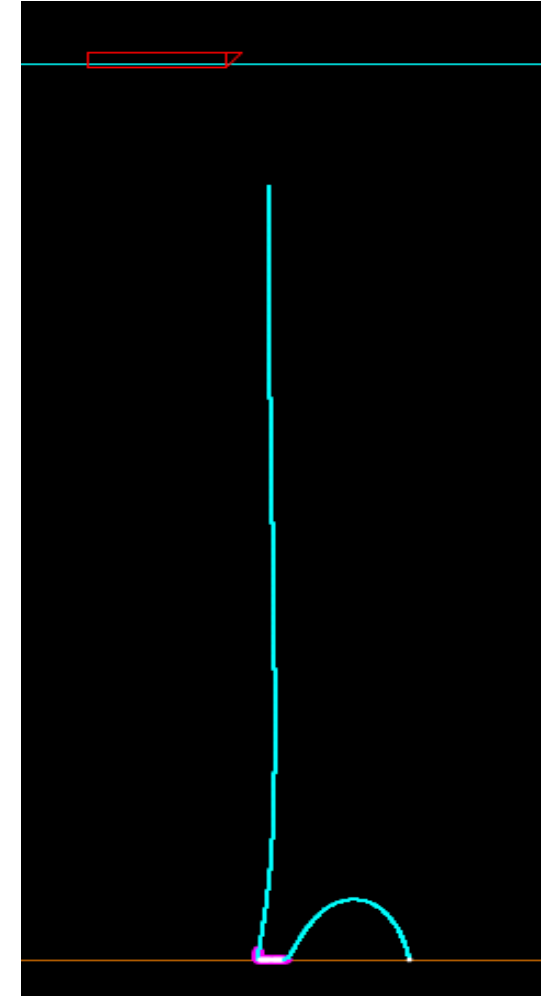
Configuration C – installation

- Vessel head on to the current
- Clump weight required – may be PLET/foundation
- 3 stages of installation considered
- 3,000 m water depth
- 0-1.5 m/s surface currents (up to 1 year WoA)
- 0-3.5 m Hs (up to 100 year WoA), 0 & 90°
- Loads no worse than observed during operations
- Most onerous loading after the ballast has been deployed



Configuration C – wet parking

- Low ballast region may make pre-installation of Configuration C possible.
- Highest tension is above the ballast and is lower than operational loads.
- Ballast touchdown may require management.
- Riser is taken off the critical path.



Summary

- By utilising thermoplastic composite pipe, simpler ultra-deep water riser configurations are possible.
- Ballast is beneficial and allows a composite riser to respond favourably to vessel offsets and dynamic loading.
- Vessel and foundation loads can be managed in ultra-deep water through ballast.
- Through design the maximum tension along the riser may be located away from regions of higher bending.
- Installation of a ballasted composite riser has been shown to be a possibility.
- Composite risers may be taken off the critical path by wet parking.
- Bending and compression at end terminations are still a challenge.

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