



# The Benefits Of Composite Materials In Deepwater Riser Applications

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Hassan Saleh – Senior Engineer

2H Offshore Engineering Ltd

# Composite Benefits and Challenges

- Composite Materials offer a range of benefits which could be utilised in the offshore riser application to improve riser technology:
  - Composites are light – High specific strength
  - Can be formed into complex shapes
  - Very good fatigue resistance claimed
  - High corrosion resistance
  - Low maintenance
  - Comparatively low axial and bending stiffness (i.e. compared to steel)
  - Potential ease of installation (i.e. Reeled pipe)
- Disadvantages:
  - High material cost
  - Limited offshore track record (although widely used in other industries)
  - Limited codes and standards with direct applicability to composite risers
  - Hard to inspect sub-laminar damage

# Composites Offshore – History

- In the past composite materials have been used offshore in a range of applications, mainly in secondary structures; Pipework, Caissons, J-tubes, Riser protection, Walkways and Ladders;
- Improvements in structural integrity led to the 1st composite drilling riser joint which was used on Statoil's Heidrun TLP in 2001;
- More recent use as downlines to support pre-commissioning and acid stimulation operations. A 3" pre-commissioning downline was repeatedly used in a water depth of 2100m+ offshore Brazil, 2014;
- A number of companies are now scaling up efforts to produce composite pipe for offshore use.



# Composites Offshore

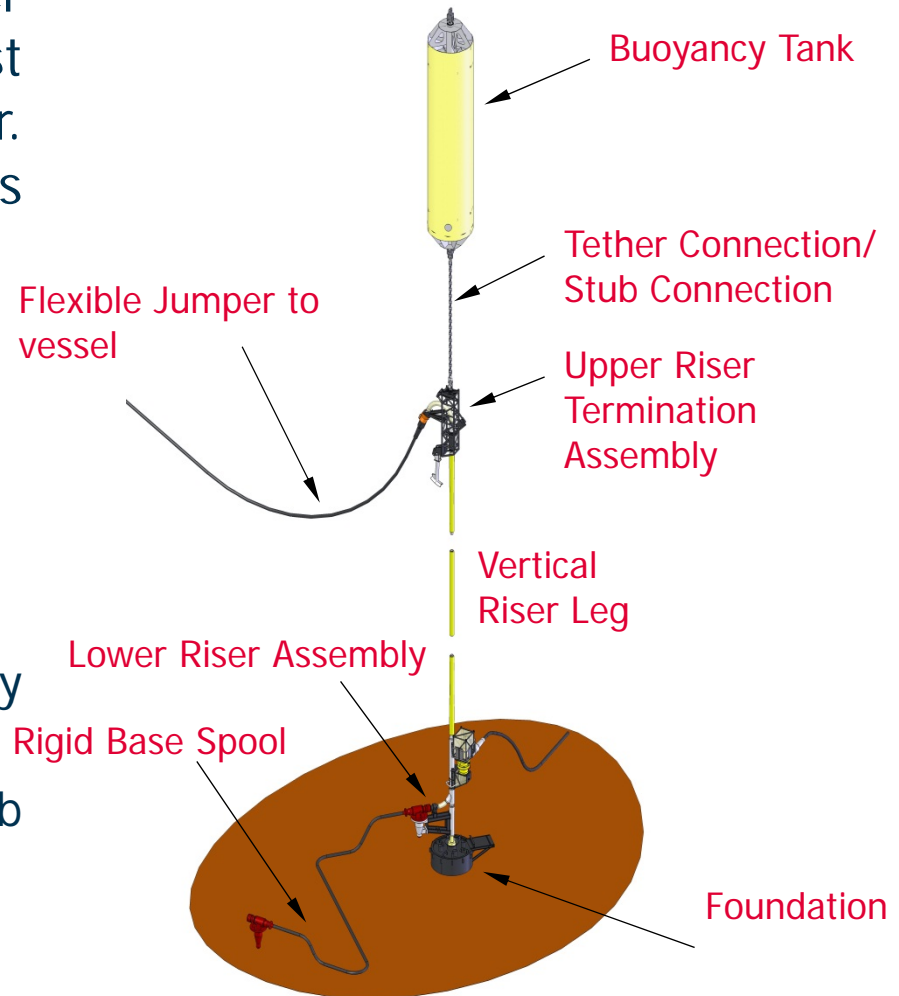
- So how can the enhanced mechanical performance of composites help the riser industry:
  - Reduced hang-off loads;
  - Cheaper installation;
  - Less required maintenance;
  - Low roughness on internal bore;
  - Provide opportunity to extend into more challenging locations.
- Can we reduce cost if we replace steel with composites?
  - In a like for like replacement “ probably no”, but if composites act as an enabling technology for new concepts and operating in challenging locations/environments then potentially yes.
- Study objective
  - To assess the potential benefit, 2H carried out a comparison of a deepwater production riser using both steel and composite pipes;
  - This is a high level study only conducted to gain an appreciation of the potential benefits of composite pipe. It does not present an optimised composite riser design.

# SLHR Configurations – Overview

- A SLHR is a Single Line Hybrid Riser, which employs a vertical steel riser section that is linked to the host vessel via a flexible pipe jumper. Also referred to by other acronyms such as SLOR or FSHR.

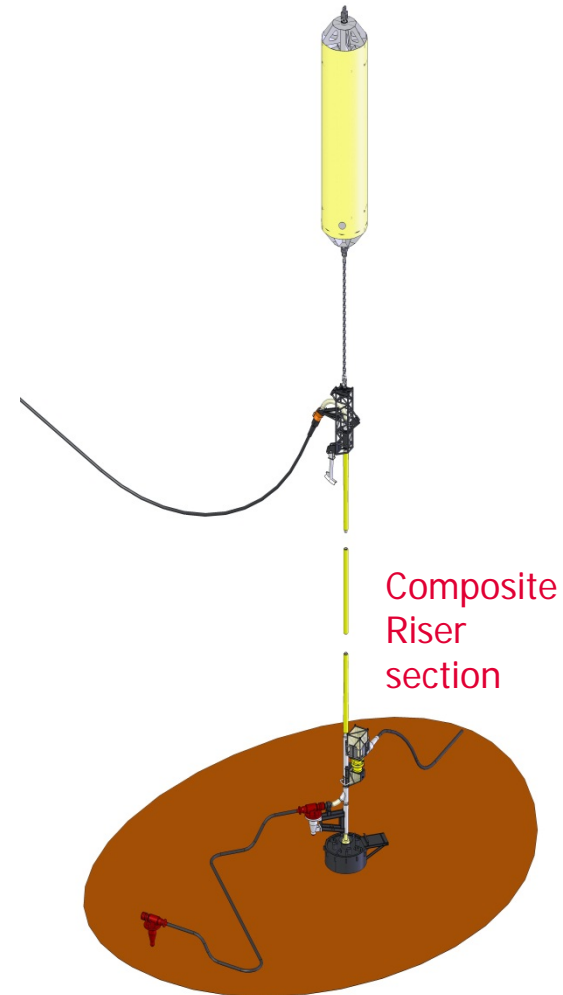
- Main Components:

- Foundation
- Lower Riser Assembly (LRA)
- Standard Riser Joints
- Upper Riser Termination Assembly (URA)
- Buoyancy Can and Tether / Stub Connection
- Flexible Jumper
- Rigid Base Spool



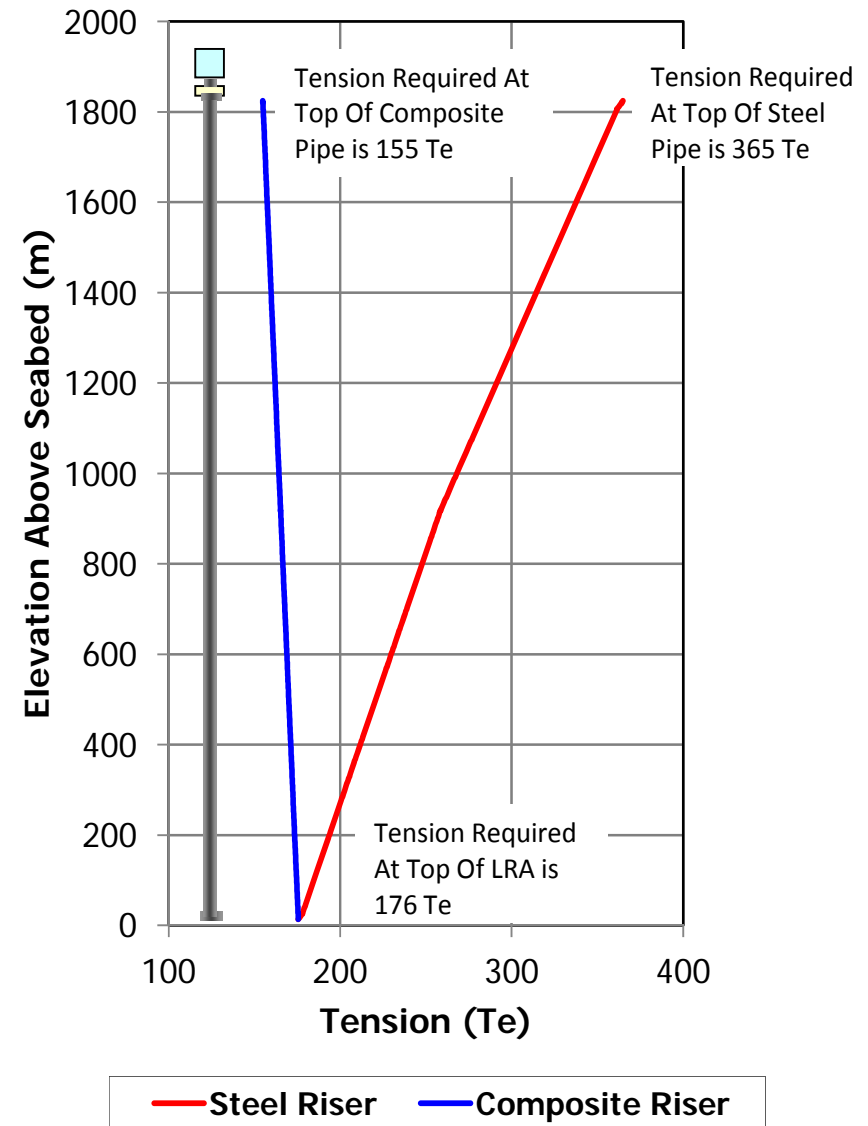
# SLHR Configurations - Analysed

- To compare, 2 risers were analysed, a conventional SLHR with a steel riser leg and another including composite pipe to replace the steel pipe;
- The considered water depth is 2000m. 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;
- The pipe wall thicknesses were selected based on similar static loads
- Global FEA models of the 2 riser systems were created and analysed for this assessment
- So how did it Differ?



# Comparison Of Tension Requirements

- For SLHRs a base overpull is required and is selected to limit riser fatigue and reduce loads on the subsea spool;
- For the steel riser, the required top tension drives the selection of the wall thickness as the high tension causes high stress for the top half of the steel riser;
- The required top tension for the composite riser is less than the base overpull. This is a result of the low riser weight which when combined with some insulation makes the pipe buoyant even when flooded;
- The selection of the wall thickness for the composite riser is not impacted by the tension requirements.



# Buoyancy Tank Comparison

- The volume of the Buoyancy Tank is defined by the required upthrust, which is a function of the total weight of components;
- Supporting the single riser leg weight forms a large proportion of the total required upthrust;
- The weight reduction achieved by utilising a composite riser is shown in the table below:

Parameter	Steel	Composite	% variation
Weight of riser line	105 Te	-110 Te	-205%
Tension At Top	449 Te	235 Te	-48%
Tension At mid Riser	264 Te	166 Te	-37%
Base Tension	150 Te	150 Te	0%



## Composite Riser

- The size of the buoyancy tank can be reduced by up to 40%;
- The cost of the buoyancy tank calculated for the steel riser is approximately £1,000,000 for materials and fabrication. A significant cost saving, potentially approaching 40% is expected when a composite riser is used;
- Handling and installation attract additional savings due to the reduction in required lifting capacity, storage space and pressurisation time.

# The LRA and Base Flexible Joint

- A flexible joint or a rotolatch system is normally required for hybrid risers to accommodate the large bending moment at the base of the riser and thus ensure adequate extreme and fatigue performance
- The potential of removing the flexible joint, taking advantage of the increased compliance of the composite pipe was investigated

Parameter	Steel	Composite	% variation
Flexible Joint Rotation	7.3 Deg	6.7 Deg	-8%
FJ Extension Stress Utilisation	0.42	0.41	-2%
FJ Extension Bending Moment	209 kNm	190 kNm	-9%

Parameter	Steel	Composite No FJ	% variation
Flexible Joint Rotation	7.3 Deg	0 Deg	-100%
FJ Extension Stress Utilisation	0.42	2.15	412%
FJ Extension Bending Moment	209 kNm	1536 kNm	634%

- The loads are too high and hence a lower flexible joint or a rotolatch is still necessary.



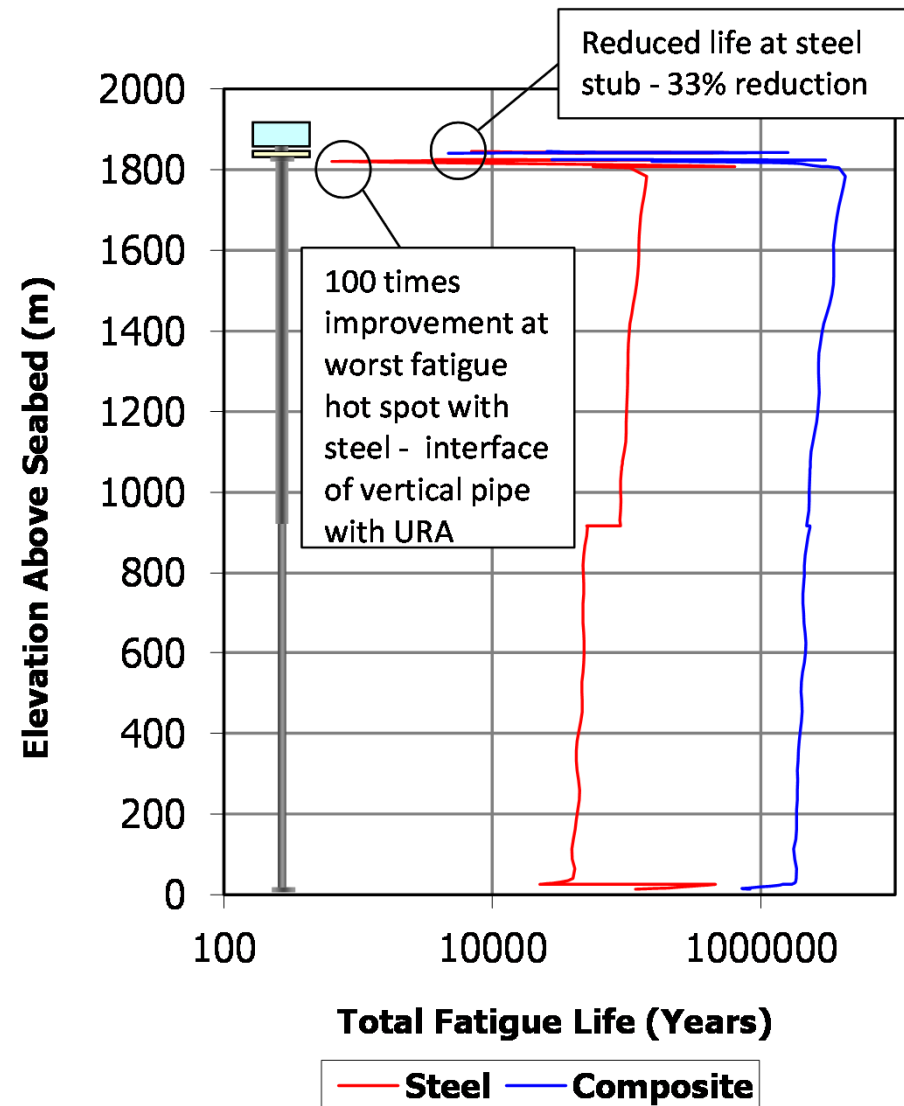
# Riser Performance

- A comparison of the key design aspects of the steel and composite risers is given below:

Parameter	Steel	Composite	Comments
Max Hang-Off Load (Te)	94	93	In an SLHR the flexible jumper to the vessel acts as interface between the vessel and the vertical riser leg thus keeping the two isolated. Therefore negligible change in hang-off loads
Max Hang-Off Bending Moment (kNm)	261	282	
Max Stress Utilisation	0.63	-	While stress is the driving criteria for steel, Strain is the driving criteria for composites
MBR Safety Factor	-	2.76	MBR is larger than minimum acceptable
Max Tension Utilisation	-	0.14	Tension is small in comparison to allowable
Max Buoyancy Tank Displacement (m)	247	211	Smaller drag area causes smaller buoyancy tank displacement
Max Buoyancy Tank Tension (Te)	451	258	43% less tension required
Max Bending Moment At Base of URA (kNm)	116	62	Approximately 50% Lower Bending Moment for Upper and Lower Riser Assemblies
Max Bending Moment At Top of LRA (kNm)	581	270	

# Riser Fatigue Performance Comparison

- The fatigue performance of the riser improved significantly due to the high composite material fatigue performance and the eradication of welds along the structure;
- The reduction of buoyancy has negative impact on the steel stub located below the buoyancy tank, a 33% reduction in fatigue life;
- The fatigue hot spot for the steel riser was found at the weld closest to the URA interface. Replacing the steel pipe with a composite material improves life at this location by a factor  $>100$  times;
- The fatigue hot spot for the composite riser is at the steel stub below buoyancy tank where life is 200% higher than the steel riser minimum fatigue life.



# Cost Summary

- Composite Pipes are very expensive and it is anticipated that the required composite pipe would carry a cost of approximately £10,000,000 compared to approximately £3,000,000 for the equivalent steel pipe;
- Savings are expected from the reduction of the Buoyancy tank size as well as the reduction of the LRA and URA sizes;
- It is anticipated that the biggest saving would be a result of the ease in installation as the reeled pipe and the smaller buoyancy tank would require less offshore installation time and smaller installation vessels;
- It is demonstrated that composites could be considered for this application
  - They are technically feasible and show some improvements
  - There may not be an obvious argument to use composites for reason of cost alone
- Overall, it is deduced that the cost when using a composite pipe, in the existing SLHR arrangement, is comparative to that when steel is used. Though, the mechanical performance is admittedly improved.
  
- So let's consider something more challenging...

# Reaching Further – 4000m Water Depth

- Let's take an example where water depth is increased to 4000m;
- The same comparison is made for the SLHR utilising steel and composite pipes;
- For collapse criteria the internal diameter is limited to 8in;
- Reeled composite pipes can be produced for up to approximately 3km of continuous pipe:
  - Intermediate connections shall be used where smaller pipe wall thickness can be used for shallow water sections (with a smaller collapse criteria).
- If a steel pipe is used, the weight of the steel vertical pipe is expected to be approximately 315Te:
  - Based on static calculations considering a steel pipe with 8in internal diameter and wall thicknesses driven by high tension at the top and the collapse pressure at the base of the riser.
- The size of the buoyancy tank required to support the steel riser is approximately 970 m<sup>3</sup> in this water depth;
- When considering a composite pipe, -9Te total weight is estimated for the vertical riser and thus require no tension to support;
- The size of the buoyancy tank required is approximately 475 m<sup>3</sup> and thus approximately half as large as when steel is used.

# 4000m Water Depth – Riser Performance

- Key results for the composite riser in 4000m water depth

Parameters	Value	Comments
Pipe ID	8in	This is the maximum recommended, and is driven by the collapse criteria
Pipe Max OD	11.9in	The wall thickness can vary, and thus a smaller pipe OD can be used at shallower depths
Tension at Top	257 Te	Similar level to composite in 2000m water depth. Note pipe size is different
MBR Safety Factor	2.84	Acceptable MBR
Max Tension Utilisation	0.17	Very low utilisation
Bending Moment At top Of LRA	237.70	comparative to composite pipe in 2000m
Bending Moment At base Of URA	32.20	comparative to composite pipe in 2000m
Maximum Flexible Joint Rotation	8.1 Degrees	Slight increase in comparison to 2000m

- As the results suggest, while it may be difficult with steel, composite pipe performance is adequate even in a 4000m water depth

# Summary And Conclusions

- Composite systems have been tested and can be utilised in offshore riser applications;
- Now codes and standards which are specifically applicable to risers are being developed
- A hybrid riser system can benefit from changing steel pipe sections to composite pipe sections;
- It is anticipated that the bulk sizes of the buoyancy tank and the riser assembly frames will be reduced as a result of the enhanced weight to strength ratio of the pipe section;
- Installation will require reduced lift capacity and time duration;
- Composites can help the offshore industry reach new depths and operate in harsher environments.
- Composites represent an exciting potential solution to future design challenges for the riser industry, and it will be interesting to see how this area develops
- More radical design solutions should be considered
  
- Thanks to Magma Global and Airborne Oil & Gas for their assistance in providing material data and images for use in this presentation

# Thank you

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