Application of Steel Lazy Wave Riser Solution in Deepwater and Comparison to Other Riser Types

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Abstract

In the current low oil price market, innovative low cost solutions are necessary for development of new fields and life extension of existing fields. For deep water applications, Steel Catenary Risers (SCRs) and Steel Lazy Wave Risers (SLWRs) provide low cost alternatives to flexible risers and offer flexibility during design and life extension for Floating Production Systems (FPS) in deepwater.

The majority of deepwater fields in offshore West Africa and the North Sea have traditionally been developed using flexible risers. SLWRs, a variation of the steel catenary riser (SCR) with added buoyancy near the touchdown point at the seabed, have recently been deployed in the GoM and Brazil for deepwater applications. Due to simplicity of design, good track record and qualified suppliers, fabrication and installation methods for SCRs, SLWRs have become a logical extension of the SCR. Buoyancy installed on the SLWR helps reduce top tension and decouple vessel motions from the riser touchdown zone, which ensures that the required strength and fatigue performance can be achieved.

SLWR and SCR configurations are developed for mild environment, deepwater applications representative of offshore West Africa and in severe environment moderate water depths, representative of the North Sea. Riser configurations, hang-off loads, strength and fatigue responses are compared for the configurations. The advantages and disadvantages of SCR and SLWRs are discussed and compared to other riser types. Costs for flexibles, SCR’s and SLWR’s are also compared.

Introduction

More than 90% of deepwater fields in the North Sea and 50% of the fields in West Africa have been developed using flexible risers. In relatively shallow water depths, low pressures and temperatures, good strength and fatigue performance make flexible risers very attractive. However, for deepwater application, flexible risers are limited by qualified size, cost and reliability.
SCRs and SLWRs have gained track record for deepwater application with a wide range of FPS’s. SCRs have been used in up to 1200m water depth in West Africa and 2500m water depth in the Gulf of Mexico. SLWRs, a variation of the SCR configuration, are getting an increasingly strong track record with applications in deepwater Gulf of Mexico and offshore Brazil where they have been used in up to 2000m water depth. SLWRs are a variation of the SCR with added buoyancy close the riser touchdown region. SLWRs help decouple vessel motions in the touch down region from those induced by waves and vessel motions at the surface, resulting in better strength and fatigue performance compared to an SCR and they offer a potential low cost alternative to flexible risers.

For a deepwater application, typical of offshore West Africa, SLWR/SCR configurations are compared for 8” and 10” riser in 2500m water depth. Hang-off loads, strength and fatigue responses are compared for the SCR and SLWR configurations. For moderate water depths typical of North Sea environments, SLWR configurations for a range of pipe sizes are compared in ~800m water depth. Strength and fatigue responses for a typical 24” riser in harsh North Sea environments are discussed. The design considerations, advantages and disadvantages of SLWR and SCRs are also evaluated and costs for SCRs and SLWRs are compared to those for flexible risers.

**SCR/SLWR Deepwater Application**

SCR and SLWR configurations are developed for 8” OD and 10” OD risers in 2,500m water depth. The configurations and hang-off loads for the two riser types are compared in Table 1. Extreme stresses along the length of the SCR and SLWR are compared in Figure 1. The total lengths of the risers for the SLWR configurations are 20-25% more than for the SCR’s. The longer riser along with the buoyancy for SLWRs means more material and installation costs compared to SCRs. The hang-off tension for the SLWRs are 20% lower for the nominal offset and 50% lower for extreme offsets compared to the SCR which is beneficial in terms of turret loading and cost.

The SLWR has lower stresses compared to the SCR, particularly at the hang-off and the TDP. In severe environments, if the SCR motions at the hang-off and TDP get too high, SLWRs should be considered. The stress distribution in the SLWR can be varied by changing amount and distribution of buoyancy.

<table>
<thead>
<tr>
<th>Riser</th>
<th>Distance to TDP (m)</th>
<th>Riser Length (m)</th>
<th>Buoyancy Section Length (m)</th>
<th>Distributed Buoyancy Upthrust (te)</th>
<th>Nominal Hang-Off Load (te)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8” SCR</td>
<td>1,500</td>
<td>3,100</td>
<td>350</td>
<td>N/A</td>
<td>205</td>
</tr>
<tr>
<td>8” SLWR</td>
<td>1,810</td>
<td>3,700 (1)</td>
<td>350</td>
<td>80</td>
<td>160</td>
</tr>
<tr>
<td>10” SCR</td>
<td>1,480</td>
<td>3,100</td>
<td>470</td>
<td>N/A</td>
<td>460</td>
</tr>
<tr>
<td>10” SLWR</td>
<td>1,770</td>
<td>3,900 (2)</td>
<td>470</td>
<td>165</td>
<td>355</td>
</tr>
</tbody>
</table>

*Table 1 – SCR/SLWR Configuration – 2,500m Water Depth*
The first order fatigue response of a 10” SCR and SLWR are compared in Figure 1 – Maximum von Mises Stress Along SCR/SLWR. The critical location for fatigue response is at the riser hang-off and near the touchdown point on the seabed for both riser types. The SLWR has better fatigue response compared to the SCR at both these regions. The fatigue response at the hang-off can be improved, as required, by using a tapered extension to the FlexJoint, using a thicker wall pipe at the hang-off region or specifying higher quality welds in the fatigue critical region. Further optimisation of the riser configuration by varying the hang-off angle and buoyancy distribution can also help improve fatigue response.
SCRs and SLWRs can be configured for use with a wide range of environments and vessels. In deeper water and harsh environments, deep-draft production systems are preferred due to their improved heave response. In West Africa and Brazil they have been used with FPSOs and in Gulf of Mexico they have been used with Spars, TLPs and Semi-submersibles. For both an SCR and SLWR, VIV suppression strakes are typically required to mitigate against VIV fatigue.

SCRs are typically recommended for systems where the environments are less harsh, vessel motions are lower and where top tension is not a concern. SLWRs are generally preferred over SCRs for deeper water depth when riser hang-off tensions need to be controlled and in severe environments for improved strength and fatigue response.

When compared to flexible risers, some of the benefits of SCRs and SLWRs are lower cost, application in deeper water depth, high pressure and high temperatures application and feasibility of larger riser diameters.

**Application of SLWR in the North Sea**

Moderate water depths between 400m to 1300m, low pressures and temperatures and harsh environments are characteristic of the North Sea oil and gas developments. Potential SLWR configurations for pipe sizes ranging from 6” to 30” OD, in 800m water depth are shown in Figure 3. The horizontal length between the hang-off and the touchdown increases with pipe size as more buoyancy is needed to accommodate bending in the critical sag bend and hog bend sections. The sag and hog bend sections are also higher in the water column as the pipe size increases. The buoyancy upthrust and distribution length selected are based on being able to accommodate vessel motions and offsets ranges in storm conditions and internal fluid variability.

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To examine the potential limits for SLWR risers in the North Sea a 24” SLWR configuration in 850m water depth in a North Sea environment is developed typical of what may be used for a gas export riser. In order to accommodate the range of vessel offsets, the selected riser configuration has a large hang-off angle of 18 degrees, 620m of distributed buoyancy giving an upthrust of 420Te and a large horizontal distance between hang-off and touchdown point of approximately two times the water depth. The strength response of the 24” riser is shown in Figure 4. The riser configuration is optimised such that, the maximum stress peaks in the SLWR are similar in the sag, buoyancy and touchdown sections of the riser. The dynamic effect due to the vessel motions coming from wave loading increases maximum stresses by 20% while stresses at the riser touchdown remain almost unchanged.

The fatigue response along the length of the riser for the 24” SLWR is shown in Figure 5. The critical locations for fatigue are at the riser touch down point and the top of the riser, below the hang-off point.
which are in line with the fatigue response for the 8” and 10” risers discussed above. In order to get the design fatigue response, high quality welds can be specified at the fatigue critical regions. Other alternatives discussed above to improve fatigue response should be considered.

Figure 5 – 24” SLWR First Order Fatigue Response

**Cost Assessment**

Fabrication and installation activities are major factors in the costs for SCR and SLWRs and account for around 50% of total riser delivery costs with material and engineering costs making up the remaining 50%. Hence, installation method plays a key role in the costing. Reel-lay, J-lay and S-lay are available options for installation. Riser less than 16” OD can generally be reel laid and is typically the cheapest option for installation. Reel-lay operations however require access to a spoolbase which can be a challenge in some regions such as West Africa. For larger sizes, if feasible, J-lay is the preferred option, as it is the cheaper than S-lay.

Installation of strakes and buoyancy modules add to installation costs as they have the potential to become a bottle neck during installation. Hence their design and coverage should be optimised to reduce installation time and cost. This is less of a concern for S-lay as these activities can be conducted in parallel with welding. Since welding accounts for most of the installation time and costs, specification of high quality welds also increase installation costs as they increase the risk of weld cut-outs. Hence high quality welds should be minimised or avoided offshore.

For flexible risers, about 65% of total delivery costs come from material costs which is significantly higher than it is for SCRs and SLWRs. In current market conditions, installation costs are generally lower, which when combined with an optimised design can help bring down overall costs. Overall, when comparing costs for similar size risers, SCR and SLWR risers are 20-30% cheaper than flexible risers. The larger available diameters for SLWRs also provide even further potential savings compared to multiple smaller flexible risers offering benefits for applications such as gas export. Hybrid risers are roughly twice the cost of SCR/SLWR and are not considered to be feasible in the current low price oil market.

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Conclusions

The majority of fields in the North Sea and offshore West Africa in moderate to deep water have been developed using flexible risers. Low pressures and temperatures combined with good strength and fatigue performance make flexible risers a very attractive solution. However, for deepwater applications, flexible risers are limited by qualified size, cost and reliability. SCRs and SLWRs offer a potential low cost alternative to flexible risers and have track record for deepwater high pressure and temperature applications.

The suspended lengths for the SLWRs are more than those for the SCR’s leading to more material and installation costs compared to SCRs. The hang-off tensions for the SLWRs are lower than for SCRs, which is beneficial in terms of turret loading and cost. SLWRs generally have better strength response compared to SCRs, particularly at the hang-off and the TDP, which combined with lower top tension, makes them particularly suitable for production systems with high vessel motions and harsh environments in deep water.

In typical North Sea conditions, it is demonstrated that large diameter SLWRs are feasible in terms of strength and fatigue response. Some technology challenges exist in terms of fatigue response and hydrotest, which can be overcome through use of qualified solutions.

Fabrication and installation costs account for about half of the SCR/SLWR delivery costs. Hence, design and coverage of strakes and buoyancy modules should be optimised to reduce installation time and cost. Overall, SLWRs are expected to be cheaper than equivalent flexible risers and hybrid risers. A further significant cost benefit over flexible and hybrid risers comes from being able to use large diameter SLWRs instead of multiple smaller risers leading to even more significant cost savings.

References


Definitions

API American Petroleum Institute
CoG Centre of Gravity
DNV Det Norske Veritas
FOF First Order Fatigue
FPSO Floating Production Storage and Offloading Vessel
Hmax Theoretical Maximum Wave Height
Hs Significant Wave Height
MSL Mean Sea Level
SCF Stress Concentration Factor
SCR Steel Catenary Riser
<table>
<thead>
<tr>
<th>SLWR</th>
<th>Steel Lazy Wave Riser(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDP</td>
<td>Touch Down Point</td>
</tr>
<tr>
<td>TDZ</td>
<td>Touch Down Zone</td>
</tr>
<tr>
<td>Tp</td>
<td>Spectral Peak Period</td>
</tr>
<tr>
<td>VIV</td>
<td>Vortex Induced Vibration</td>
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