Installation of deepwater risers

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SYNOPSIS

A number of different installation methods and vessels may be used to install the various deepwater riser systems available. The choice of installation method has a significant impact on both the detailed design of the riser system and the installation cost. This paper presents a summary of the current installation methods offered by contractors for each deepwater riser system. Based on a number of detailed deepwater riser design and system engineering projects, this paper will examine the alternative approach of using readily available low cost vessels which will allow more efficient riser system design and reduced installation costs. Limitations to the application of the new approach in terms of current contract strategy will be identified and solutions suggested. This paper seeks to show that considering alternative, novel installation methods of the riser system from day one means improvements in riser system design and reductions in installation costs may be achieved.

INTRODUCTION

Operator's developing offshore oil and gas reserves are constantly facing the challenge to reduce costs of all components and activities associated with the selected development scheme. As developments move into deep and ultra-deep water (>3000m) total development costs increase, as does the pressure to reduce them. The riser system cost is particularly sensitive to any increase in water depth, as is the installation cost of the riser system. The majority of current deepwater riser systems are based on a welded construction. High specification vessels are required to install deepwater riser systems, these vessels incur high day rates and mobilisation costs. This paper will review the current installation methods available for deepwater riser systems.

An alternative to welded construction is the use of threaded and coupled (T&C) connections, T&C connections are a reliable, low cost method of joining pipe and have been used extensively in applications such as down hole casing, tubing strings and have recently been used successfully on Spar and TLP riser systems in deepwater.

This paper addresses the application of T&C connections to alternative deepwater riser types. Deepwater riser types based on T&C connections may be installed using drilling vessels, rather than conventional pipelay installation vessels. This construction method and installation approach have a number of benefits when compared to current installation methods.

Author's Biography

Matthew Burgess is a graduate in Mechanical Engineering from The University of Manchester. Matthew joined 2H Offshore Engineering Limited, an independent engineering consultancy that specialises in riser system design, in 2003. Since this time Matthew has been closely involved with the design and development of production and export risers for deep water developments, focusing in particular on freestanding risers.

OVERVIEW OF DEEPWATER RISER TYPE INSTALLATION METHODS

Flexible Catenary Risers

Flexible pipe is built up of a number of independent spiral laid steel and thermo-plastic layers, and has been used for many years for both riser and flowline applications worldwide. The beneficial feature of flexible pipe is its ability to accommodate high curvature, allowing ease of installation and accommodation of dynamic motions. Flexible risers are used in a simple or wave catenary arrangement, as shown in Figure 1.

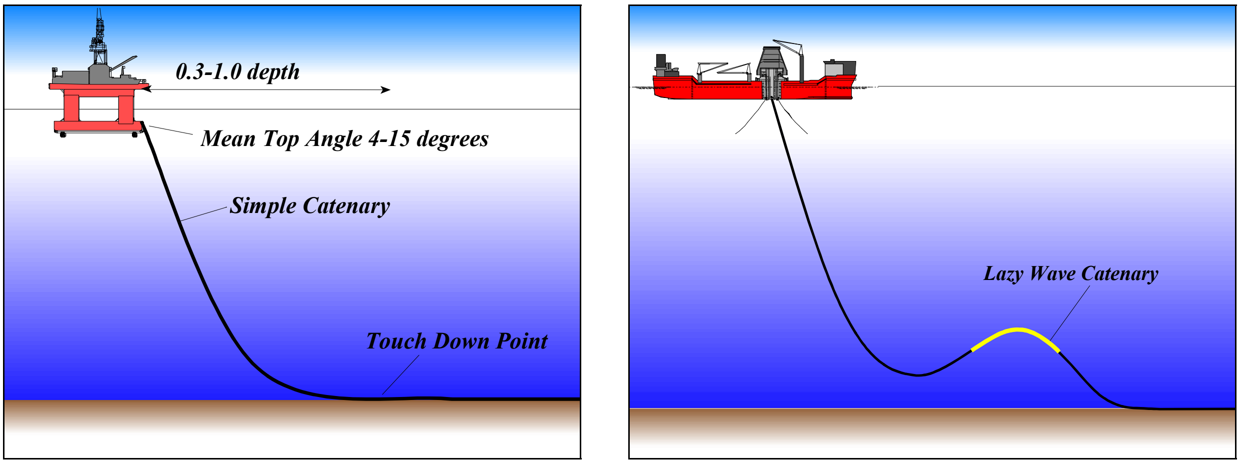

Figure 1 Simple and Wave Catenary Arrangements

From an installation perspective, use of flexible risers in deepwater is often limited by the collapse resistance of the riser as they may be installed empty to keep the riser weight within the pipe lay vessel's tensioning capacity. As the external hydrostatic pressure increases with water depth, the maximum riser diameter is thus limited by the practicality of strengthening the flexible pipe structure to resist the external pressure.

Flexible risers and flowlines are normally designed, procured and installed from a single vendor. There are only a small number of companies worldwide which manufacture flexible pipes for riser systems.

The flexibility of these pipes allows them to be spooled continuously on a reel, or in a carousel, for efficient and quick transportation and installation. Installation speeds can average 500 metres per hour, but care must be taken as high curvatures and bending moments can be experienced at the TDP, which can result in pipe failure. Flexible risers can be installed from a large number of reel lay vessels, however for larger pipe diameters and deeper water the number of capable vessels is reduced. Special reels may have to be built in the case of large diameter flexible risers.

The installation weather window is mainly determined by the vessel response to environmental loading. In mild environments such as Indonesia, riser installation can be conducted almost year round and so installation schedules are generally quite flexible. For harsh environments suitable weather windows are very small and risers are often pre-installed in summer months. The risers are wet stored and simply lifted from the seabed and connected to the host vessel when it is brought on station.

Steel Catenary Risers

Steel catenary risers (SCRs) have emerged as a major alternative to flexible risers in recent years for mild to moderate deepwater environments, such as Gulf of Mexico, West Africa, Brazil and Indonesia. The main advantage of the SCR is that steel pipe costs significantly less than flexible pipe, and is "flexible" in a long length.

The SCR consists primarily of a steel pipe string free hanging from the vessel to form a simple catenery. SCRs are typically used with tension leg platforms or spars where heave motions are small, or with semi-submersibles or FPSOs where the environment is mild.

A SCR is made up of a series of welded pipe joints. The fatigue performance of the welds is highly dependant on several inter related factors including pipe and weld material properties, joint dimensional tolerances, welding processes, welding procedure and inspection criteria. Good quality offshore welds are required in order to achieve sufficient fatigue lives for SCRs. As such, high specification vessels are required to perform these critical offshore welds, even if these vessels command high day rates and mobilisation costs. The installation window is determined by the vessel response whilst the riser joints are fixed during welding.

Unlike flexible risers, SCRs do not lend themselves to being wet stored before arrival of the host vessel, so they are generally installed in one campaign to avoid additional vessel mobilisation costs. Several installation methods are possible including:

J-Lay – The majority of SCRs installed to date use the J-lay technique. Riser stalks of up to 6 joints (hex-joint) are prefabricated onshore, reducing the number of welds that need to be made during offshore installation. J-lay collars used to support the pipe during installation are welded around the pipe and can act as buckle arrestors. The number of vessels capable of deeper water J-lay installation decreases with water depth due to tensioning capacity. The current maximum tension limit is around 1000Te for high-end installation vessels, with several more vessels with capacities of over 500Te.

S-Lay – Installation of a riser by the S-lay method is similar to the J-lay method except the pipes are handled in the horizontal attitude allowing multiple joints to be welded simultaneously. However the technique is generally not suited to deepwater due to the very high back tensions required to prevent over stressing of the sag bend and overbend. This high back tension also makes dynamically positioning the installation vessel difficult. Consequently increased water depths reduce the number of capable installation vessels.

Free Standing Hybrid Risers

Although a relatively new technology, the free standing hybrid riser (FSHR) design has been proven or is planned on a number of projects including Kizomba A & B and Petrobras P52. The FSHR employs a vertical steel riser section that is linked to the host vessel via a flexible pipe jumper. The key advantage of this hybrid arrangement is that the vertical riser response is largely decoupled from the vessel motions and hence becomes less susceptible to fatigue damage.

An example FSHR arrangement is shown in Figure 2. The vertical riser section is tensioned by steel buoyancy cans positioned at a distance below the water surface to minimize wave and current loading. It is offset from the host vessel such that a suitable length of flexible pipe jumper joining the top of the steel riser to the vessel can be fitted to accommodate the vessel motions. The FSHR can be used with any floating vessels and is suitable for deepwater and ultra-deepwater applications in all environments.

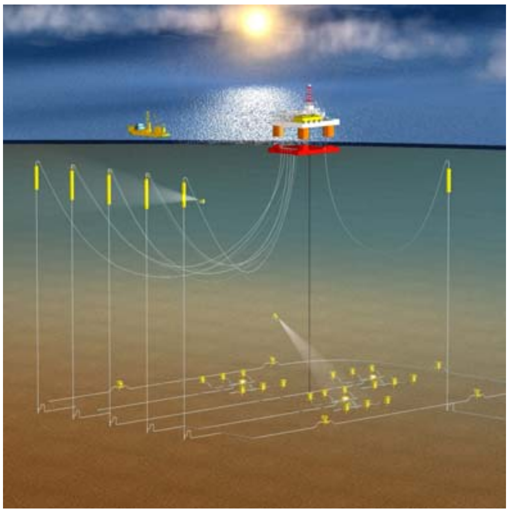

Figure 2 Global Arrangement of Free Standing Hybrid Risers

The FSHR pipes can be either welded or mechanically connected, allowing installation from a range of vessels including drilling and pipeline construction vessels. The riser is purposefully designed using proven components and installation procedures.

The welded FSHR may be procured using established contractual frameworks. Large diameter steel pipe is readily sourced from steel mills. Upsetting and machining of the pipe, if required, can also be carried out by a range of suppliers.

Installation of a welded FSHR must be performed using a J-Lay derrick barge. As previously discussed, high vessel day rates and mobilisation costs are applicable to this type of vessel. The installation window is determined by the vessel response whilst the riser joints are fixed during welding. However, the FSHR can be pre-installed and left free standing before the host vessel arrives. Some FSHR designs allow one end of the flexible jumper to be pre-installed with the free standing riser and left free hanging such that the lower end can be picked up for connection to the vessel later; other FSHR designs present an upward facing connection hub at the top of the free standing riser to ease the installation of the whole jumper later. These features have the benefit of simplifying project schedule by eliminating complex logistics with installation vessels, and reduces riser hook up time

Bundled Hybrid Risers

Bundled risers consist of a number of small diameter steel pipe strings and umbilicals that are grouped together, usually around a structural core pipe. The bundled riser strings are kept free standing by a buoyancy can near the surface, where the vertical riser pipes are linked to the vessel by multiple flexible pipe jumpers. The free standing idea is essentially similar to the FSHR arrangement, and the riser strings can be configured in a number of ways, with the pipe strings and umbilicals inside and/or around the periphery of the structural core pipe, or the pipes shrouded in syntactic foam buoyancy. Figure 3 shows a typical bundled hybrid riser cross-section.

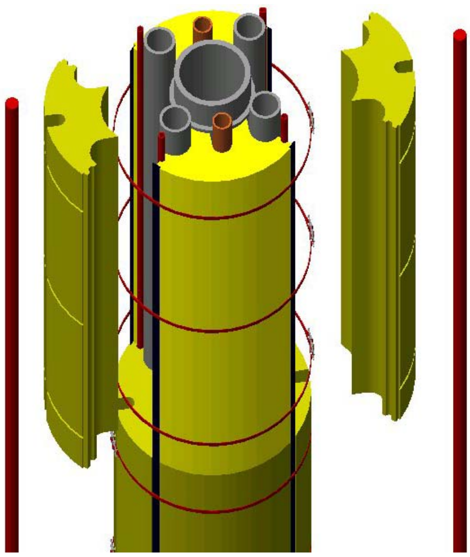

Figure 3 Bundled Hybrid Riser Cross Section

Due to the complexity of assembling and testing bundled hybrid risers, onshore fabrication facilities must be used. This may be considered a positive fabrication method when contracts specify that a large percentage of local content is required for the project. After assembly, the riser is towed out before being upended and installed. For deepwater applications the bundled hybrid riser will typically need to be fabricated in several sections, which are then floated and either assembled at the dockside prior to tow-out or assembled in the field after tow-out.

Suitable fabrication facilities for assembly and tow-out of bundled hybrid risers can be found in the Gulf of Mexico and West Africa. Tow-out is less desirable in more active wave areas due to the increased damage obtained, and hence the proximity of the construction site to the field is important.

Several tow methods are possible, shown in Figure 4.

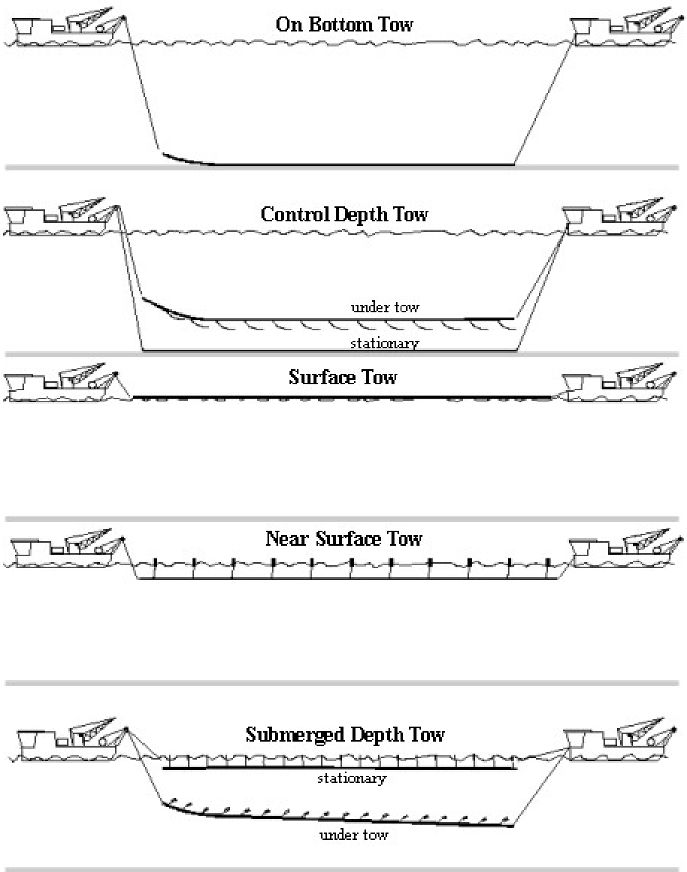

Figure 4 Tow Out Methods

The tow method is selected to minimise damage to the riser, cost and vessel requirements. Considerations include:

- Surface Effects – Unless the conditions are mild, wave induced cyclic stresses and fatigue can pose a significant design issue. The bundle may require tow-out outside of the wave zone.
- Depth – The allowable collapse pressure of the riser must not be exceeded.
- Seabed – The risk of interaction with the seabed and seabed objects must be avoided.
- Minimise tow force – Power requirements must be within tow vessels capability.

Overall, the assembly and installation of a bundled hybrid riser is time consuming and can be risky.

Top Tensioned Risers

Top tensioned risers (TTRs) are commonly used with tension leg platforms and spars. The TTR is a riser which runs directly from the subsea wells to the vessel deck where the surface trees are located. Tension is applied to the riser by either buoyancy cans or deck mounted hydro-pneumatic tensioners.

For spars, the installation of buoyancy cans is a complex, costly and time-consuming process. Long, multi-chamber buoyancy cans are typically used so that fewer connections need to be made during installation. However, due to their length, installation usually takes place before the topsides and derrick. The resulting approach will depend on many factors including the schedule for offshore commissioning, the extent of pre-drilling and the preferred handling equipment and derrick design.

Risers tensioned using hydro-pneumatic tensioners on spars or TLPs are less complex, and take less time to install in comparison to using buoyancy cans.

The conventional construction method for riser joints is based on 'weld-on' threaded connectors on the end of each riser joint. However, recent TTRs have been based on riser joints made up using integrally machined threaded and coupled connections. Threaded and coupled connections are made up using similar running procedures to weld-on threaded connectors. However, as the riser joints are not welded, higher strength material grades may be utilised.

Extensive experience is available in the design and procurement of TTRs. Materials are readily sourced, with large diameter steel pipe, pipe upsetting and machining capabilities available from many different suppliers.

Installation windows are driven by the need to avoid clashing of risers and therefore TTRs are typically installed under mild conditions.

ALTERNATIVE INSTALLATION APPROACH

Flexible catenary risers and bundled hybrid risers are proprietary riser systems often chosen due to contractual or functional requirements. Each has specific installation methods; as such the alternative installation approach described in this paper is not applicable to these riser types.

It can be seen that a large proportion of current deepwater risers are currently based on a welded pipe construction. One of the main reasons welded construction remains the 'default' method of construction is that historically, shallow water flowlines (less than 100m) were installed using low strength, readily weldable steel using the S-lay technique. This is a cost effective method for shallow water, which established a high level of confidence and track record in offshore welded connections.

However, this practice continued as the industry moved into deeper water, with installation contractors developing more sophisticated welding techniques and building higher specification vessels to meet the demands of deep water. This has provided the Operator with little choice on installation method. However this approach in deepwater may result in a high cost and often a complex riser solution.

It is inherent that riser steel weight will increase proportionally with water depth, which has a significant effect on the costs of the riser pipe and the buoyancy can or tensioning system. Similarly, payload limitations on the production facility will become an issue along with the tension limit of the installation vessel.

Threaded and Coupled Connections

An alternative construction method to welded risers utilises premium mechanical connections in the form of non-welded threaded and coupled (T&C) connections, as have been used on recent TTRs. A typical connection and make-up are presented in Figure 5.

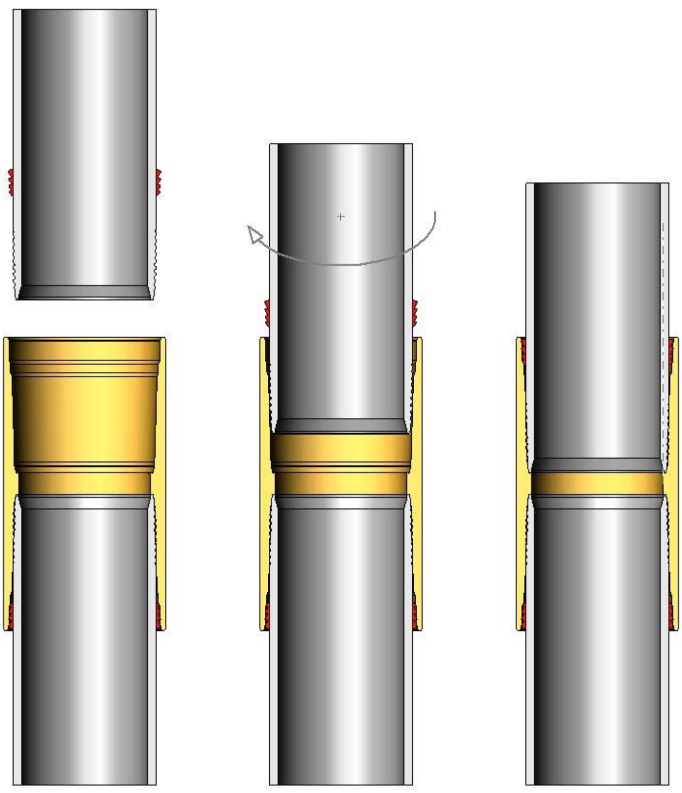

Figure 5 Integral Threaded and Coupled Connection

T&C connections are a cost effective method of joining pipes together. There are a large number of threaded connector designs available on the market. The use of threaded couplings for riser and flowline solutions can provide significant benefits:

- Faster make-up speed compared to welding - threaded connections (9 5/8-inch diameter) can be made up in 2-5 minutes compared to 30-50 minutes for a typical offshore welding and inspection procedure for a fatigue sensitive application. Non-welded construction allows the use of high strength steel (P110), this reduces riser weight, reducing the buoyancy requirements or payload on the vessel.
- Improved fatigue performance – Qualification testing of threaded couplings shows that the fatigue performance is comparable to or even better than what can be achieved with a good quality single sided weld.
- Cost – the cost of pipe machined threaded and coupled connections is greater than that of plain ended pipe. However it is noted that the steel cost is a small proportion of the total system cost, cost savings are achieved through alternative installation as discussed below.

Installation Based on T&C Connections

One of the key benefits of using T&C connections is the ability to improve the installation procedure, particularly for FSHRs and SCRs. To date, the use of T&C connections have been for applications which involve installation from a drilling derrick which is specifically designed to efficiently handle and install threaded pipe joints such as down hole casing. Along with their extensive use down hole, recent successful applications of T&C connections for TTRs qualify them to be considered a suitable solution for deepwater risers.

Although mobile offshore drilling units (MODUs) are not generally used for installation of flowlines, SCRs or FSHRs, the facilities available on these vessels are well suited for J-lay mode. The available handling equipment such as spiders and torque tongs are tailored for the use of threaded connections. The derrick capacity is variable, but is usually greater than the majority of J-lay installation barges. The MODU is often already mobilised in the field to drill development wells, and probably on a long-term charter, which can facilitate flexible scheduling. Typically MODU costs are less than that of a J-lay barge. In addition, the motion characteristics of a MODU are more superior to those of a pipelay barge. The peak roll and heave response periods of MODUs are further from the wave periods that occur in installation conditions, leading to less installation downtime. Furthermore, lay barges tend to be more sensitive to vessel heading and must be orientated during installation towards the waves. This can lead to difficulties during lay operations.

As with AUT inspection of welded joints, threaded and coupled connections require integrity confirmation upon completion of the make up. Poor make up of T&C connections is eliminated by the introduction of computer controlled torque tongs with feed back logic control. This has allowed the precise control of threaded connection make up, producing torque turn charts, allowing the Operator to efficiently confirm whether a good connection has been made.

Threaded connections can be made up in 2-5 minutes and it conservatively estimated that completion of each 80ft double joint can be done in a total of 15 minutes. This includes the joint make up, integrity confirmation, installation of field joint half shells and application of a heat shrink sleeve. Unlike welded construction, the lay rate of threaded pipe is not sensitive to variations in pipe diameter or wall thickness.

Threaded FSHR Installation

The FSHR lends itself to installation using a drilling derrick, with the riser joints being passed vertically into the derrick prior to being connected at the drill floor. The handling and connection of the buoyancy can to the riser may be the most challenging aspect of the installation; this can be achieved by keel hauling the buoyancy can underneath the MODU, hanging it from the drilling riser tensioner chains and running the riser string through the buoyancy can, as shown in Figure 6.

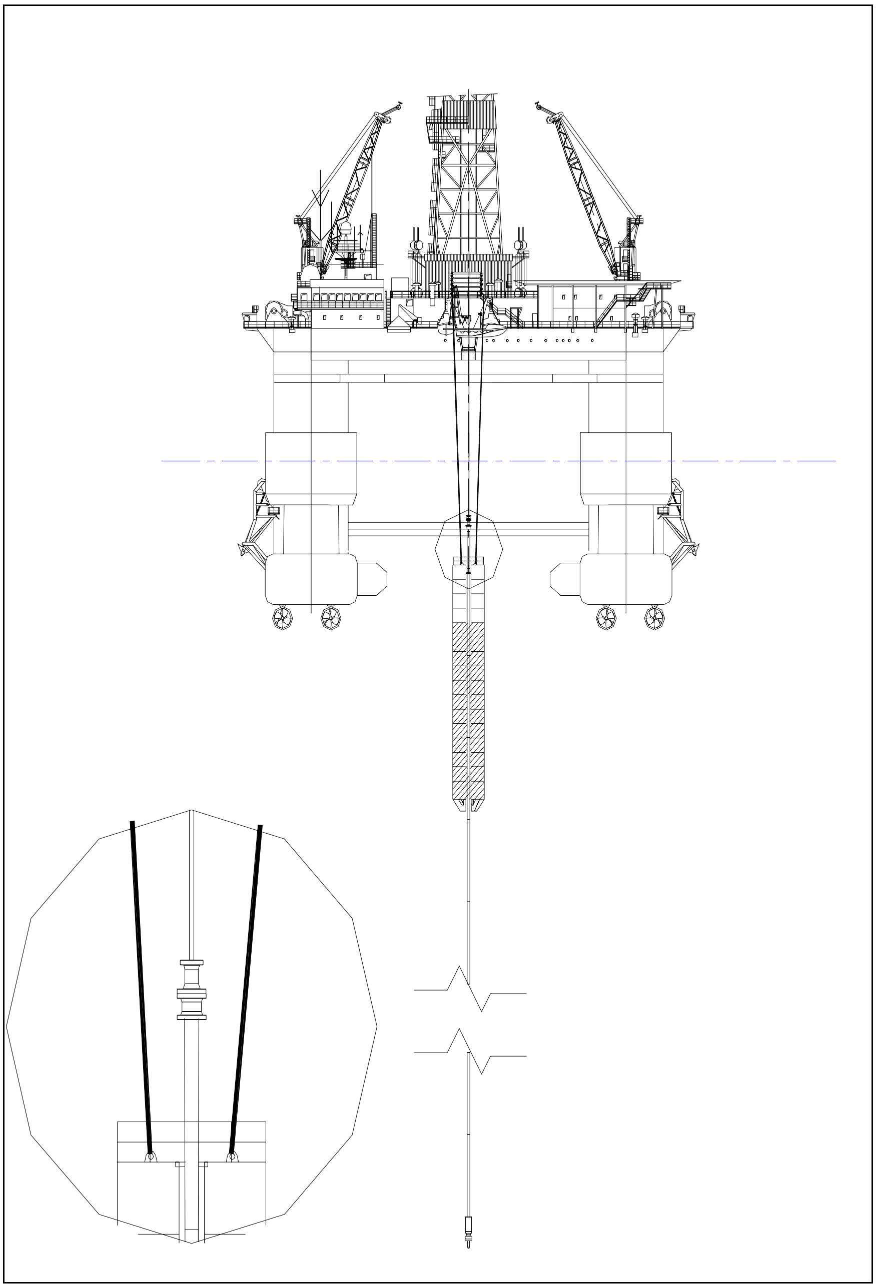

Figure 6 Riser Joints Run from Drill Floor through Buoyancy Can

After all riser joints are made up and run through the buoyancy can, the riser string is landed on the top of the buoyancy can, where a fixed connection between the riser and the buoyancy can is made. The buoyancy can is then released from the drilling riser tensioner chains, and the entire riser system is lowered using the riser running string. The bottom of the riser is landed and locked to the foundation pile using an ROV. The buoyancy can is de-watered and the riser allowed to free-stand. The flexible jumper is then installed independently (and at a later date if the host vessel has not arrived) by a flexible pipe lay vessel in a standard installation procedure.

Threaded SCR Installation

The drilling derrick is specifically designed for pipe make up in the vertical orientation whilst SCR's require a small top angle to ensure stability of the catenary. However, for threaded connections, make up angles of more than a few degrees are not acceptable and make stabbing and supporting of the riser impractical. In order to provide the catenary with the necessary stability during installation from a MODU, it is possible for the riser to be held vertically at the drill floor and deflected off the vertical immediately below, providing clearance with the moonpool and pontoons is maintained. This approach requires a vertical stinger to be fitted below the drill floor to control catenary curvature. The stinger is designed to be fitted into place for SCR installation mode, and removed upon completion, ready for the rig to return to its normal drilling duties.

Contract Approach

The main challenge in implementing a T&C riser system is the absence of a clear contracting approach. The riser package is currently awarded to a contractor within the subsea umbilical, riser and flowline (SURF) package. Typically, only 15%-20% of the total SURF package cost is due to the riser package, as such SURF packages are awarded to large pipeline installation contractors who have confidence and pre-investment in welded technology. This contract strategy currently suits Operators, who prefer to work within single lump sum contractual frameworks and have resisted contract strategies that divest responsibility and risk away from the contractors.

In order for T&C connections and the resulting installation approach to be applied, the risers should be included as an optional element in the SURF package, and offered as a stand-alone package to be bid by specialist riser installation contractors or drilling contractors, thus widening the competition. Both T&C connections and welded riser development options should be considered as viable solutions from initial scheme development to FEED. Dialogue with drilling contractors throughout the FEED development will ensure that the full benefits of the T&C connection approach may be achieved during installation.

This approach implemented from day one of a project will allow Operators to benefit from the improved installation approach which T&C connections offer for deepwater risers.

CONCLUSIONS

The majority of current deepwater riser systems are based on a welded approach, which is an extrapolation of shallow water technology. High cost, high specification vessels are required to install these riser systems. As the industry moves into deeper water this approach may not be the best solution. Threaded and coupled connections offer a low cost and effective method of joining pipe in deepwater and are a field proven solution, having been used for deepwater TTP applications. T&C connections installed by MODU offer the following benefits:

1. Lower day rates and no mobilisation costs
2. Faster lay rates
3. Improved vessel motion response
4. Higher tension capacity
5. Improved availability

The benefits listed above show that the use of T&C connections for deepwater riser systems should be evaluated from the initial stages of a development. However it is appreciated that the current contracting strategies for riser design and installation are not suitable for the implementation of T&C connections because of the way risers are included within the flowline package and the significant investment installation contractors have in welding technologies. Whilst it is believed that the implementation of T&C connections for deepwater risers will have a significant benefit on the installation of these risers, it can only occur if contract methods are modified and the process is Operator led.

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