Reviews and Some Recent Advances on Installation of Deepwater Risers

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Abstract – This paper reviews key installation methods for installation of deepwater risers, the related installation analysis methods and presents the majority of current deepwater riser systems. Additionally, it describes several hot achievements recently in installation project of deepwater risers, such as “SCRs for Prince Project”, “Reeled PIP SCR for CSO Deep Blue”, “Freestanding Risers in the Gulf of Mexico” and so on.

Key words: *flexible risers; SCR; freestanding risers; deepwater installation*

Introduction

With the needs of energy increasing rapidly these years, the deepwater oil/gas exploration and exploitation is becoming a trend undoubtedly. As one part of deepwater technologies, the knowledge and experience of risers installation have developed, and the petroleum industry presently has expertise on offshore installations in harsh environment and deep water, which is based on disciplines like hydrodynamics, structural mechanics, oceanography, automatic, control, material science, etc. However, as new oilfields are explored and developed, new challenges arise and new knowledge and research are needed. New contributions are searched for within each discipline. It is believed that by integrating the different disciplines, further progress can be made.

For the installation of the pipes (risers and flowlines) it is necessary to use special purpose ships. The most common installation technique consisted of fabricating the line pipe on board, welding and inspecting the pipe, then installing the line at the pre-established spot. The fabrication goes on during installation and usually the S-lay or J-lay methods are employed. In an attempt to reduce installation costs, especially in deep water, the alternative is to fabricate the complete line pipe onshore, storage it on large diameter reels at installation ships and then transport and launch the line at the offshore site.

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. Additionally, it describes several hot achievements recently in installation project of deepwater risers, such as "SCRs for Prince Project", "Reeled PIP SCR for CSO Deep Blue", "Freestanding Risers in the Gulf of Mexico" and so on.

Deepwater Risers

Flexible 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.

The installation of flexible risers in deepwater is often limited by the collapse resistance of the pipe as it 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 to a reel for efficient and quick transportation and installation. Installation speeds can average 500 metres per hour. 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 riser installation can be conducted almost year round and so installation schedules are generally quite flexible. For harsh environments suitable weather windows are small and risers are often pre-installed in the 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 is limited. 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. 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.

Single Line Offset Risers

Although relatively new in the market, the single line offset riser (SLOR) design has been proven or is planned on a number of projects including Kizomba A & B and Petrobras P52. The SLOR 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 SLOR 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 SLOR can be used with any floating vessels and is suitable for deepwater and ultra-deepwater applications in all environments.

The SLOR 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 SLOR may be procured using established contractual framework. 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 SLOR must be performed using a J-Lay derrick barge. The installation window is determined by the vessel response whilst the riser joints are fixed during welding. However, the SLOR can be pre-installed and left free standing before the host vessel arrives. Some SLOR 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 SLOR 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 hybrid risers consist of a number of small diameter steel pipe strings and umbilicals that are grouped together, usually around a buoyant 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 SLOR arrangement, and the riser strings can be configured in a number of ways, usually around the periphery of the structural core pipe. In the first application of bundled hybrid riser offshore Angola, the pipes are shrouded in syntactic foam buoyancy.

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. Fabrication facilities for assembly and tow-out of bundled hybrid risers are already established in the Gulf of Mexico and West Africa.

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.

The tow methods commonly adopted are surface tow and near-surface tow.

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

Riser Installation Analysis

For riser installation analysis the computer program Abaqus, Shear7, Orcaflex and OFFPIPE may be used.

ABAQUS is a general purpose finite element program from Hibbit, Karlsson and Sorensen Inc. It has a large element library and is capable of analysis of a variety of problems. A large class of stress analysis problems can be solved with ABAQUS.

SHEAR7 is a mode superposition program, which evaluates which modes are likely to be excited by vortex shedding and estimates the steady state, cross-flow, VIV response in uniform or sheared flows. It is capable of evaluating multi-mode, non-lock-in response, as well as single mode lock-in response.

OrcaFlex is the world's leading package for the dynamic analysis of offshore marine systems. With over 50 man-years of development, OrcaFlex is renowned for its breadth of technical capability and user friendliness. OrcaFlex also has the unique capability in its class to be used as a Windows DLL, allowing ready integration into 3rd party software. It can do the most aspects of riser analysis, including time domain dynamic analysis, modal analysis, non-linear large displacement analysis, fatigue analysis, vessel manoeuvres (forward speed and turn rate) and so on.

OFFPIPE is a finite element method program specifically developed for the modeling and analysis of non-linear structural problems encountered in the installation of offshore pipelines.

An analysis of the riser-laying operation is to be performed, taking into account the geometrical restraints of the anticipated laying method and lay vessel, as well as the most unfavorable environmental condition under which laying will proceed. The analysis is to include conditions of starting and terminating the operation, normal laying, abandonment and retrieval. The analysis is to ensure that excessive strain, fracture, local buckling or damage to coatings will not occur under the conditions anticipated during the pipe-laying operation.

Strength analysis is to be performed during laying and installation. The strength analysis is to account for the combined action of the applied tension, external pressure, bending and dynamic stresses due to laying motions, when applicable.

Installation conditions regarding sea state and current are to be specified to avoid any overstressing of the pipe and joints. Contingency procedures are to be specified to cover dynamic positioning system breakdown, anchor dragging and anchor line failure. Safety of subsea operation is to meet the requirements of the National Authorities.

Risers Installation Projects Recently Completed

SCR for Independence Trail Pipeline (2006)

At a record water depth of 7,912 fsw in the Gulf of Mexico, the 138 mile long Independence Trail Pipeline (ITP) is the deepest pipeline ever to be laid. ITP initiates from West Delta Block 68 at a water depth of 118 feet and terminates at Mississippi Canyon Block 920 at a water depth of 7912 feet. At the deep end, a Steel Catenary Riser (SCR) connects the pipeline to the floating production facility.

C & C Technologies Autonomous Underwater Vehicle (AUV) performed the detailed survey along the preliminary route, shown in Figure 2. This system provided exceptionally high data quality, navigational accuracy, speed, survey design flexibility, and digital data delivery which allowed for almost real time pipeline span assessment. During the detailed survey, both major and minor adjustments were made to the optimize routing. Interpretation of the AUV data allowed large sections of the pipeline route to be finalized. However, a number of areas of concern were also identified. Hence, a reconnaissance visual survey was undertaken using a remotely operated vehicle (ROV) to investigate these areas and allow the route to be finalized.

Figure 2 C&C's Survey AUV

Should an accidental buckle occur, it will propagate at high speed until it reaches either shallow water or a stronger pipe section or stiffeners, also known as buckle arrestors. Integral-ring type buckle arrestors (Figure 3) are used on ITP due it their high efficiency in restraining a propagating buckle. Buckle arrestor spacing influences the length of pipeline that is damaged and hence how much spare line pipe is needed for repairs. Hence, the optimization of the buckle arrestor spacing is best done at the same time as the optimization of the line pipe sparing.

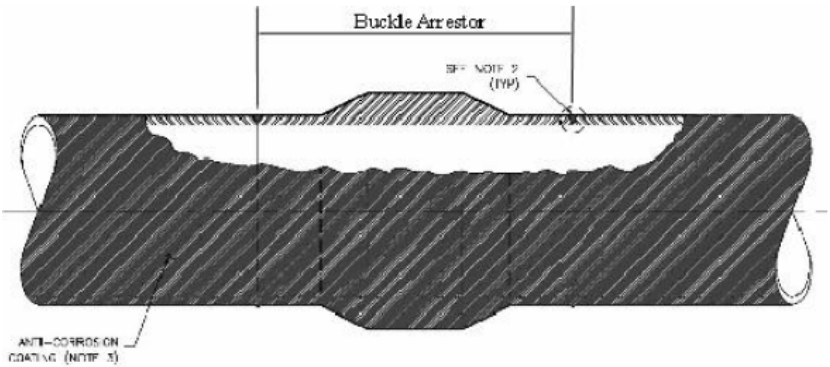

Figure 3 Integral Buckle Arrestor Make-up

Few vessels are capable of installing the ITP pipeline and SCR in this water depth in either configuration. Allseas Solitaire S-lay vessel (Figure 4) was selected for ITP due to the company's long and successful track record in laying large diameter pipeline in deep water. Nevertheless, upgrades to its tensioning system, stinger and abandonment and recovery system were necessary to execute the work. Test and qualification trials are planned for the vessel and for the main and ancillary equipment before starting the laying process to ensure that the systems are compatible and that the capacity meets project requirements.

Figure 4 Allseas Vessel Solitaire (after upgrades)

Installation of an SCR is an extension of the pipe lay operations. However, it is complex and typically progresses at a far slower rate as it does not allow weld repair and requires a stringent weld defect acceptance criterion. Further, the SCR is installed after the floating production unit is in place. Therefore pre-laying the SCR within a pre-defined corridor within the floating production facility mooring is typically performed if the SCR is installed prior to the floating production facility using S-lay. The hanging of the SCR on the floating production facility involves a complex handover operation between the heavy lift vessel and the floating production unit, where the vessel is working in close proximity to the floating production unit. This situation greatly increases the level of risk associated with this operation.

SCRs for Prince Project (2002)

The Prince SCRs represent a leap in the SCR applications by having many firsts in the industry. They have been designed and installed for less than 1500 ft water depth that represents the shallowest water for SCRs so far, breaking Morpeth SCR's water depth record of 1670 ft. The Prince SCRs had the largest departure angle of 24 degrees and FlexJoint angle variation of +/-20 degrees to accommodate the TLP motion in such relatively shallow water depth. The VIV strakes are the first to be pre-installed on the SCR pipes during an S-lay operation.

The design of the Prince SCRs was a challenge since these SCRs represent the first to be implemented for water depth of less than 1500 ft. In general, for catenary shape wires, ropes or pipes the deeper the water the less the curvature and thus the less stresses. As such an optimization process was undertaken to minimize the level of stresses at the touchdown area, where the largest curvature occurs. As obvious, in order to minimize the curvature at the touchdown point, a larger departure angle for the top of the SCR at its connection to the TLP is required. However, larger departure angle may also affect the design and construction of other components such as the flexible joint itself

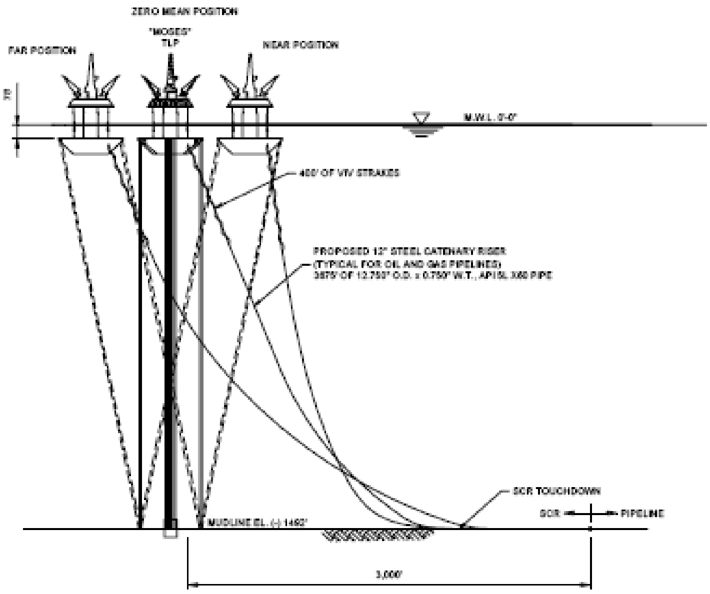

Figure 5 The Prince SCR's Configuration

and its supporting structures (i.e. receptacle and porch) and the TLP hull body due to the large horizontal force components. In addition, having a large departure angle will require longer horizontal projection for the suspended section of the SCR as well as longer section on the seabed to accommodate the large surge and sway offsets of the TLP.

Figure 5 shows the Prince SCR configuration in the TLP mean, far and near design positions. After having all the parties including the hull and the SCR porch designer, the FlexJoint and the receptacle designer and the export pipeline system designer agree to the basic elements of the aforementioned configuration, the design of the receptacle and the porch of the SCRs proceeded with several cycles of discussions and transformation of information so that all the parties would finalize their design to the satisfaction of all involved.

SCR pipe specification, procurement and manufacture were coordinated with SCR installation contractor. SCR welding procedure qualification, SCR weld acceptance criteria, automatic ultrasonic inspection procedure and fatigue test welds were mutually developed. Fatigue testing was performed as a contract variation by SCR installation contractor at The Welding Institute in England.

Another activity performed by SCR installation contractor as a contract variation order was testing of the robustness of the proposed VIV-suppression strakes to ensure that they could withstand the passage over lay vessel pipe ramp and stinger rollers.

Figure 6 The Prince SCR during Hang-Off Installation showing the Pre-Installed VIV Strakes

SCR installation contractor coordinated the design of FlexJoint A/R protection shrouds and A/R rigging with the Prince hull installation contractor to ensure hull installation contractor's ability to employ the same rigging for lifting and hang-off of SCRs. Figure 6 displays the SCR during hang-off, showing the pre-installed strakes.

Reeled PIP SCR for CSO Deep Blue

The contribution of plastic strains resulting from reeling on the relative pipe tensions is presented. The technique is applied to a dynamic installation analysis and used to quantify the influence of wave motions, temperature and pressure cycles on strains, inner pipe shape and shake down of residual stresses. Technip-Coflexip have developed a suite of user defined FORTRAN subroutines, included within ABAQUS, to increase functionality and simulate the complex cyclic elastoplastic material effects, resulting from the reeling process. These subroutines are further utilized to superimpose a residual inner pipe shape and a non-symmetric residual stress/strain state on a dynamic PIP SCR riser.

Reel installation analysis presents a method to calculate the development of stresses and strains in both pipes from initial reeling on through reeling off and subsea installation. The analysis tracks the non-uniform distributions of stress and strain in the longitudinal direction. PIP installation starts with initiation of a pipe end and continues through to development of a full catenary plus pipe on the seabed. The first part of the analyses consists of a finite element model that analyses the pipe stress and strain response to reeling loads and curvatures. The ABAQUS-ELBOW element is used and although this element appears as a beam type element it has a full shell element formulation, thus it can take cross sectional pipe deformation into account. ABAQUS-DESIGN is used for parameterization of key input variables to accurately describe the pipe elastoplastic cross sectional behavior during the reeling process. The second part of the analyses is an analytical PIP static catenary model (including the pipe span on the vessel), developed to determine the PIP tension variation at any stage of installation between initiation and continuous lay. Figure 9 represents the tension distribution for a PIP during unreeling from seabed to reel.

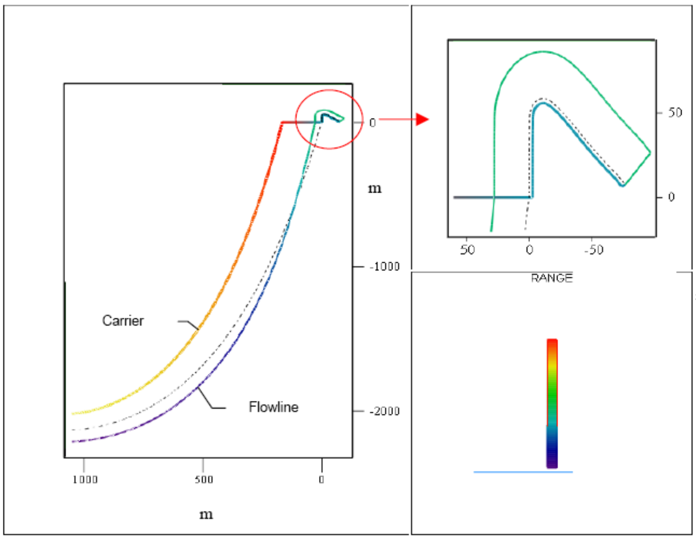

Figure 9 Reel Installation Analysis detailing carrier and flowline tension distribution during unreeling from the CSO Deep Blue

Installation of the Na Kika Export Risers (2004)

These systems are in record water depths and several significant "worlds-firsts" were achieved during installation. The 74-mile-long 18-inch oil export pipeline to Shell's Main Pass 69 pump station is the deepest pipeline ever installed in the flooded condition, thereby achieving significant reductions in wall thickness and associated costs. The 74-mile-long dual diameter 20"/24"gas export pipeline, from the host to Main Pass 260 is the deepest and largest pipeline installed by the S-lay method. In addition, a large 24"x20"in-line Wye assembly was installed by J-lay. This gas export pipeline forms part of the Okeanos pipeline system, which connects not only Na Kika but also the future Thunder Horse facility to the Destin pipeline system. The subsea flowline system design posed significant flow assurance challenges that were solved by a combination of pipe-in-pipe insulation, an electric-heating-ready hydrate remediation system, and an innovative gas lift riser system. In total approximately 100 miles of intra-field flowlines were installed. All flowlines, including pipe-in-pipe flowlines and risers on the South side fields were installed by the reel method-an industry first for reeled pipe-in-pipe risers. The pipe-in-pipe flowlines on the North side were installed by the J-lay method. Because the 10 wells that comprise the Na Kika subsea system (12 wells including the Coulomb field) were all dispersed, no subsea manifolds were installed. Instead some 23 sleds, many with multiple well connection hubs, were installed. The sleds connected flowlines and wells with jumpers. A total of 11 Steel Catenary risers were installed, for which a special bridge equipped with a 1.5 million pound chain jack had to be constructed across the open area in the center of the semi-submersible host. Total cost of the export pipeline, flowline and riser system, including subsea sleds and jumpers exceeded $350 MM.

Figure 10 ROV deployed Synthetic Sling Riser Transfer Rigging

Installation of the risers required a unique solution.Riser weights in the accidentally flooded condition approached 1300 kip. In the past for Shell projects, SCR's were transferred using a chain jack with the chain being connected to the riser pull head onboard the pipelay vessel, and the riser then being lowered on an abandonment cable from the lay vessel until the chain would take over the tension, at which time the vessel's abandonment cable would fall away and the riser could be pulled up to the riser support receptacle. In its most simplistic form, the host accommodation for the chain jack was simply a set of pad eyes at strategic locations to hang the chain jack from, with some clear space around it for auxiliary and diving equipment. On Na Kika, a completely different approach was required. Risers would be transferred from three directions, often in rapid succession. The deck structures could simply not be designed to handle the weight of the risers, nor would it have been possible to relocate the chain and chain jack from one pad eye to the next one. Thus, a dedicated riser pull-in bridge was built. This bridge allowed the chain jack to be moved to be quickly moved to the best position for the riser lift and minimize the lateral riser pull-in force. In addition, the semi submersible was actually ballasted between 1.5 and 3 degrees during various stages of the riser transfer and pull-in, to avoid contact between chain and pontoon and also reduce lateral pull-in forces. Finally, an innovative method was used by the pipelay contractor to achieve an underwater connection between chain and riser pull head, using a 2000 metric tonnes synthetic sling, transferred by ROV (Figure 10). Nine risers were installed between the end of August and early October 2003 without any incidents or significant difficulties.

Installation the Mardi Gras Transport System SCRs (2004)

During 2004 HMC utilized their Deep Water Construction Vessel (DCV) Balder for the installation of four of the eight SCRs for the Mardi Gras Transport System. The DCV Balder is specialized in installing complex deepwater field architecture and was well suited for the installation.

Figure 11 Spar under Construction

The Mardi Gras Transport System ties-in to each of the four deepwater production facilities and utilizes sets of two SCRs; one for oil one for gas. Three facilities have 24"and 16"SCRs and one facility has a 24"and 20" SCR. The SCRs range in waterdepths from 4500 to 7100 ft of water.

Two sets of SCRs are connected to truss SPAR type of platforms (Figure 11), while the other two sets connected to semi-submersible type of platforms. The SCR design also required that with the exception of two, the SCRs had to be installed with VIV suppression strakes along their entire length. In addition, two of the SCRs are equipped with a fiber optic SCR monitoring system.

Figure 12 a: VIV suppression strake installation platform; b: Pre-installed strake area; c: Strap installation

Approximately 70%of the VIV strakes were installed on a specially designed platform on the port side of the DCV Balder (Figure 12-a). These strakes were installed off the critical path. The remaining 30%were installed in the J-lay tower (Figure 12-b). As the riser design required strakes from hang-off until touchdown, an efficient installation method was required. The strakes were client supplied material; however, during the design phase, HMC was involved to optimize the design from a transport and installation perspective. The weight of the strakes was chosen such that two men could handle them horizontally and vertically. For that purpose, special handling holes were provided at each end of each strake section. The length was dictated by the aforementioned weight requirement but in addition, chosen such that two layers of strakes could be transported in a closed 20ft container. Onshore tests resulted in the preference of pre-cut straps above endless coils (Figure 12-c). The handling was much easier and installation faster. As the pre-cut straps were rounded off; no cutting Hazards were expected nor reported.

Freestanding Risers in the Gulf of Mexico

Freestanding risers have become an increasing familiar riser solution for deepwater field developments in West Africa and more recently Brazil. A total of 4 field developments in West Africa will utilize the freestanding riser concept by the end of 2007, with a total of 14 risers installed that includes a combination of bundled risers and single pipe or pipe in pipe arrangements. To date, the Gulf of Mexico market has focused on the use of deepwater dry tree units with direct access vertical risers, or with flowlines and steel catenary risers to tieback subsea developments to the host facility.

Free standing hybrid risers, such as the 2H developed Single Line Offset Risers (SLORs) are becoming more frequently considered and installed in deepwater developments around the world. They are considered to be an enabling technology for deepwater and ultra deepwater field developments due to the robustness and flexibility inherent with the design. The figure below shows the arrangement of the SLOR.

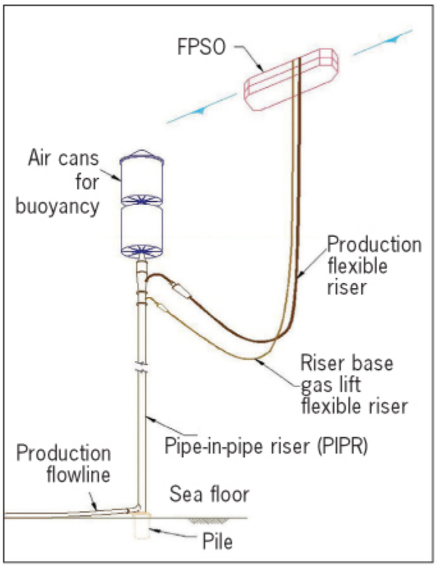

Figure 13 Sketch for SLOR

The SLOR 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.

It is inherent that riser steel weight increases proportionally with water depth, which has a significant effect on the tension requirements of the installation vessel. As field developments approach water depths in excess of 6,000ft with thick wall HPHT production risers and large diameter export risers, the number of installations vessels capable of installing such risers diminishes, creating limited availability. The freestanding SLOR can be installed from a variety of vessel and with the use of high strength steels in excess of 100ksi, the riser weight is reducing such that an increased number of installation vessels are capable of installing the risers, even in water depths beyond 8,000ft.

Sub-Project of Chinese National 863 High-Tech Program

"Technology Research of Deepwater Risers Installation"

According to the urgent need of the deepwater oil/gas exploitation for the South China Sea, a series of national-level research is being carried on both in oil companies and in some other research organizations, which includes the sub-project of Chinese national 863 Hi-tech program "Technology Research of Deepwater Risers Installation". This project is in the charge of Offshore Engineering Technology Centre (China Offshore Oil Engineering Co.) and Offshore Oil/Gas Research Centre (China University of Petroleum, Beijing). Through one year's effort, the study has been done in the aspects of the recent advance in deepwater risers installation, SCRs and TTRs VIV analysis and suppression devices, static and dynamic global analysis for deepwater risers installation, local components analysis for flexible risers and SCRs, and so on.

Using Shear7 and Abaqus, we studied 12" TTR in the water depth of 1500m and 14" SCR in the water depth of 1852m.

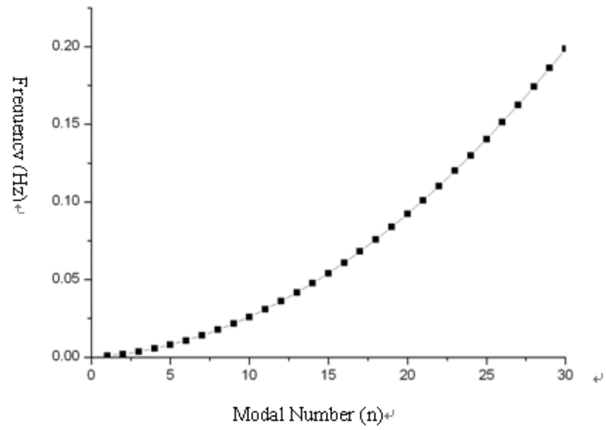

Figure 14 Frequency for each modal of in-plane direction of 1852m water-depth SCR

We also simulated the SCR laying procedure, and the course using the ROV pull-in the SCR to the floater. The figure below describes the riser stress distribution on the stinger of pipelay vessel during installation.

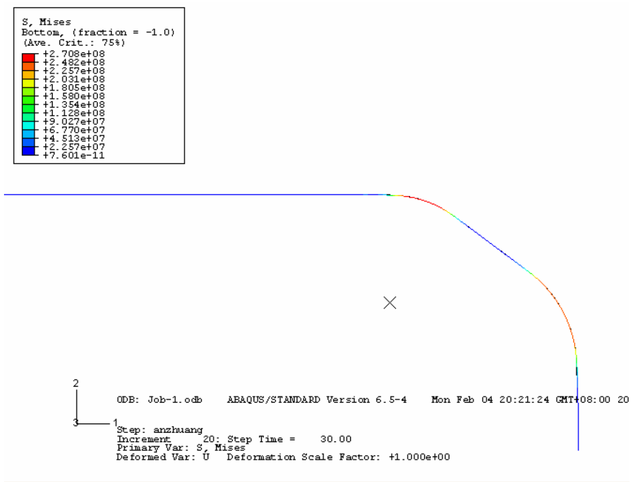

Figure 15 Riser stress distribution on the stinger of pipelay vessel during installaion

Besides, the static and dynamic analysis for the deepwater risers has been done using Abaqus/Aqua.

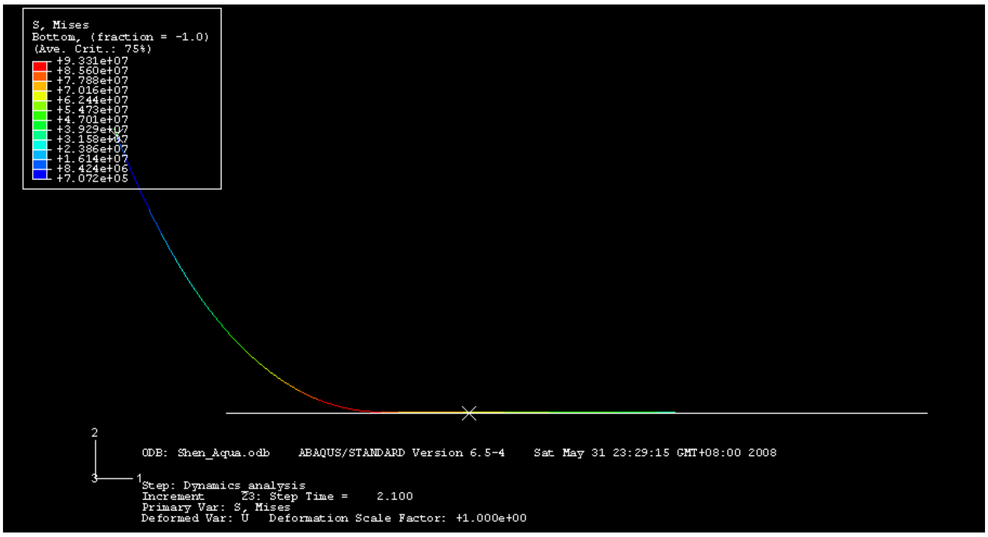

Figure 16 Global analysis for SCR under the effect of the changing current

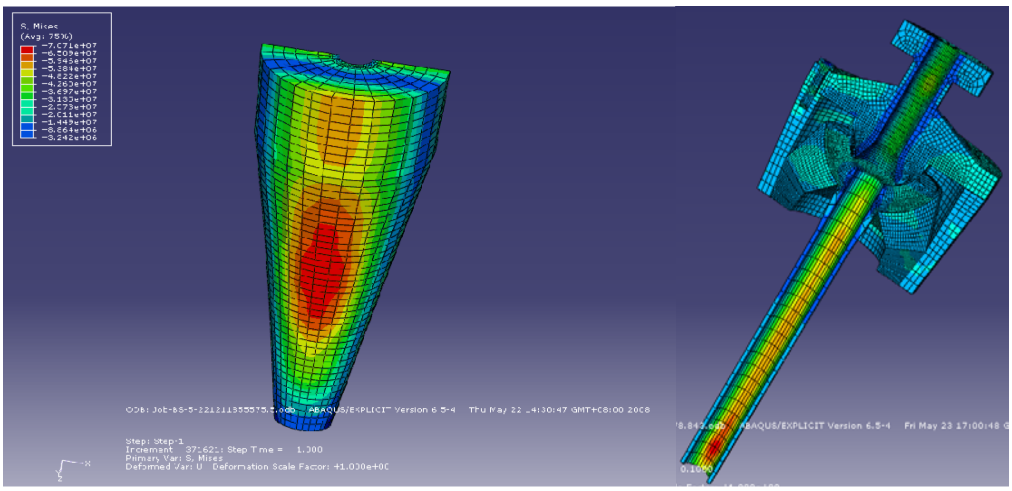

Figure 17 Bend stiffener and flex-joint analysis

Bend stiffener for flexible riser and flex-joint for SCR are also been studied.

Conclusion

As the petroleum industry moves into deeper water, installation of deepwater risers will meet many tough jobs. The challenging projects recently done can give a consideration, when concerning the oil/gas exploitation of the South China Sea.

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