

HYBRID RISERS

A Cost Effective Deepwater Riser System ?

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INTRODUCTION

Ship shaped and semi-submersible floating production systems have been shown to be highly cost effective field development solutions. Flexible risers have been widely adopted on these developments since their flexibility allows large vessel excursions to be accommodated without overstressing.

Flexible riser technology is now well established however, costs are relatively high due to the complex pipe manufacturing process and materials used. As water depth increases, flexible riser costs become an increasing proportion of the total development cost. Additionally, flexible pipe may be considered limited with respect to high temperature and pressure capability.

This has led to the development of a number of deepwater riser concepts that utilise all or a majority of rigid pipe. The main objective of these developments has been to reduce the length of flexible pipe required, which is up to 10 times the cost of steel pipe, in order to reduce total riser costs.

The hybrid riser is one of these concepts. Whilst a number of hybrid configurations have been developed over recent years only one has been installed. This was by Placid Oil Company in 1988, in the relatively calm waters of the Gulf of Mexico (Green Canyon 29, Water depth 469m).

Evaluation of alternate hybrid riser configurations and design approaches clearly shows that cost effectiveness, when compared to flexible risers in the water depth range 400-600m, can only be achieved by careful design optimisation.

The following paper discusses an approach to hybrid riser design and presents a design, developed by 2H Offshore Engineering Limited, that is cost effective in water depths as low as 400m and is also suitable for an extreme environment typical of the Atlantic Frontier.

BASIC HYBRID ARRANGEMENT

Hybrid risers utilise a vertical bundle of relatively low cost steel pipes extending from a seabed template up to a point near the sea surface from where short lengths of flexible pipe are used to connect to the vessel, figure 1.0.

This arrangement does not eliminate flexible pipe but minimises the length required, to short jumpers approximately 40 to 80 m long. Due to the large cost differential between steel and flexible pipe, significant cost savings can be made by this approach. Additionally the arrangement locates the flexible jumpers near the surface where they can be reliably inspected and replaced as necessary.

The riser bundle is vertically supported by tension generated by syntactic foam and air can buoyancy which resists environmental and vessel loading and prevents overstressing.

DESIGN APPROACH

Design Spiral

Hybrid riser designs are sensitive to weight. Increased weight requires increased buoyancy which in turn results in a higher drag diameter and hydrodynamic loading. This leads to an increase in riser deflections and stresses. Thicker pipe sections are therefore required which further increases the weight and buoyancy requirements. A negative design spiral is entered and the net result is reduced performance and higher material costs.

Conversely, a positive design spiral is entered if the weight of the riser is reduced, resulting in improved riser response and lower material costs.

Construction and Installation

Hybrid risers may be assembled offshore from a series of individual joints, in the same manner as a large drilling riser. This approach was adopted by Placid on their Green Canyon development. The connectors required to assemble each joint are heavy, costly and time consuming to make up. Additionally each connector introduces possible failure modes eg. bolt failure and seal failure.

Alternatively, the riser may be fabricated onshore and towed to site as a single welded structure. This approach eliminates over 600 connectors, in a typical 500m design, saves considerable weight and reduces offshore installation durations. The reduction in weight allows the positive design spiral to be entered.

Emergency Disconnect

Hybrid risers have typically been designed with sufficient self buoyancy to ensure that the riser can free stand without external support. This allows the vessel to disconnect from the riser in an emergency situation, such as mooring failure, without the riser being over stressed.

However, developments in mooring system technology shows that high levels of reliability can be achieved, such that the need to disconnect the vessel from the riser is not anticipated during the life of the field. (Note that a failed mooring line scenario must still be considered.)

Elimination of the emergency disconnect requirement means that the riser does not need to be capable of free standing ie. the riser may be supported at all times by tension applied from the vessel. This allows the volume of riser buoyancy to be reduced, further reducing riser cost and weight, and improving riser response.

Applying tension from the vessel also helps to modify and control the riser response relative to the vessel. This reduces out of phase motion and thus helps to reduce flexible jumper lengths and hence costs.

In summary the following design approach is recommended to minimise costs and maximise performance:

- **Welded construction**
- **Installation by tow out and up ending**
- **No emergency disconnect**
- **Tension riser from vessel**

2H HYBRID RISER CONFIGURATION

A typical arrangement of the 2H Offshore hybrid is shown in figure 2.0. This riser was developed for a BP prospect in 500m of water West of Shetlands using the above design approach.

Line Sizes and Numbers

Figure 3.0 shows a cross section through the riser bundle which is typical along the riser length. The bundle consists of a large diameter central pipe with smaller peripheral lines arranged around its circumference. Syntactic foam buoyancy, is attached around the central member in half shells. These are moulded with longitudinal glass fibre tubes to support the peripheral lines. Depending on water depth and current profile, vortex suppression strakes are attached to the outside diameter of the buoyancy modules. The outer buoyancy diameter is 2200mm and the total riser steel weight (in air) is approximately 800 Te.

Riser Base Configuration

A gravity riser base is proposed, constructed from reinforced concrete, figure 4.0. The riser base is floated out to the offshore site and deballasted onto the seabed. Flowline porches and pipework is pre-installed on the base, with temporary pipe supports to ensure accurate alignment during riser installation.

A taper joint is provided at the base of the riser to accommodate the high loads experienced at this location. The connection between the riser and base is made via a modified wellhead connector which connects onto a forged mandrel integral with the riser base. Riser bending loads are transmitted by a machined spigot, integral with the lower connector, which also assists in alignment and orientation during installation.

Peripheral lines are arranged with radial flow spools, each with its own collet style connector. High integrity connectors are considered essential for long term system reliability. Preloaded, metal to metal AX type sealing is proposed in conjunction with connectors capable of providing substantial preload to accommodate long term dynamic loading and pipework thermal expansion.

Riser base pipework is arranged radially, connecting to diverless flowline connection porches located on the periphery of the riser base.

Gooseneck Assembly

The gooseneck assembly is located approximately 36m below the mean sea level, figure 5.0,

Each peripheral line is terminated with a 180 degree gooseneck, terminating in a flange to facilitate connection of the flexible jumpers. A fabricated frame is designed to support the individual goosenecks and react jumper hose loading into the central riser member.

A forged support spider is provided immediately below the gooseneck to support the weight of each peripheral line.

Top Assembly

The top assembly consists of an extension of the main central member of the riser bundle. It is connected to the riser via a flange located immediately above the gooseneck assembly. The top assembly allows tension to be applied to the riser via a drilling riser tensioner system and provides a continuous bore which allows internal inspection by intelligent pigs or with minor modifications, may be used as a large diameter riser.

Material Selection

API X65 grade material is selected for all tubulars providing a good compromise between strength, weldability and availability.

All pipework is protected from corrosion by a thermally sprayed coating of aluminium.

Installation

The riser is fabricated and assembled at an onshore site using facilities and procedures developed for flowline bundles or at a dock side depending on length. Once assembled, the riser can be fully pressure tested prior to launch.

The riser is launched using trollies or mobile cranes, taking advantage of tidal movement. Once launched the riser is trimmed by flooding a predetermined number of peripheral lines such that a near neutrally buoyant state is achieved. A surface or near surface tow is proposed similar to that used for the Heidrun tether elements.

The riser is towed to site at a speed of approximately 4 knots. At site the riser is upended, by removal of buoyancy modules from the lower end whilst supporting the upper end of the riser from the production vessel. Note that no offshore ballasting or deballasting is required. The upending operation is expected to take 20-30 minutes. Once in the vertical orientation, the top of the riser can be lifted into the moonpool of the vessel and the riser top assembly can be attached.

After connection of the top assembly, tensioners and flexible jumpers, the riser is lowered and connected guidelineless to the riser base. Following an overpull test, each peripheral line is individually connected to the riser base pipework and pressure tested.

Analysis

Detailed dynamic analysis has been conducted using time and frequency domain analysis software. The scope of analysis includes:

- In place storm response
- Failed mooring line response
- First order fatigue
- Vortex induced vibration fatigue
- Installation
- Thermal

Analysis work confirms feasibility of the proposed design West of Shetlands, which is subject to current velocities of 2.0 m/s and wave heights of 30m. The analysis work has considered a range of water depths (350m-1000m) and vessel types (FPSO and Semi).

Riser stresses are maintained within allowable levels for all load cases. Design allowables of 0.6, 0.8 and 1.0 for functional, extreme and abnormal loading conditions respectively are assumed, in accordance with international design codes. (DnV, NPD and API).

A mean top tension of 500 Te is concluded, which is within the capacity of conventional drilling riser tensioner systems. Extreme base reactions are as follows:

Bending moment	12110 KNm
Shear	725 KN
Effective Tension	5202 KN

These are within the capacity of existing connector designs.

The taper joint is 15m long, forged from 65ksi yield material. An internal diameter of 450 mm and a wall thickness variation of 140-38 mm is proposed.

Peak stresses occur at two locations, immediately above the taper joint and at the connection between the gooseneck and top assembly. Extreme 100 year storm load conditions dominate the design rather than abnormal load conditions ie. mooring line failure.

Vessel offsets up to 12% water depth were considered in the development. This may be increased up to 15-18% but would require a slightly longer taper joint, manufactured from a material with a higher yield strength.

Fatigue analysis highlights the requirement for vortex suppression devices to meet a service life of 25 years. The lowest first order wave frequency damage is calculated to be 250 years and occurs at the top of the taper joint. VIV damage is potentially high and would lead to failure around the mean water level within less than 2 years if suppression devices are not employed. With helical strakes, giving 80% suppression of vortex induced vibrations, a fatigue life of 250-300 years can be achieved.

Double sided C class welds, or equivalent, are required on the central structural member with a maximum stress concentration factor of 1.3 to achieve the quoted life. Peripheral lines can be fabricated with single sided F2 class or equivalent weld details.

The response of the riser under surface tow is shown to be acceptable but obviously sensitive to installation sea state. A significant wave height of 2.5 m is shown to be acceptable.

Cost Analysis

A cost analysis for the 500m Atlantic Frontier design estimates a total installed cost of £16 million. A summary cost break down is given in Table 1.0. This compares very favourably with an equivalent flexible riser system for the specified water depth and environment.

Description	Cost
Engineering/Procurement	£1.0m
Hardware	£10.0m
Fabrication/Assembly	£2.8m
Installation	£2.2m
Total	£16.0m

Table 1.0 Cost Break Down

The effect of doubling the water depth, to 1000m, is to increase the riser cost by only £4 million (25%). Hence the cost effectiveness of the hybrid is improved for increasing water depths.

Cost effectiveness is not significantly affected by reductions in the number of peripheral lines since the high cost items are the buoyancy, flexible jumpers and base connectors, which would all be reduced. A break even point, with flexibles is expected to be between 6 and 8 peripheral lines for a 500m water depth.

Risk Assessment

The low development flexibility of the hybrid riser is considered to be its main disadvantage. Unlike a flexible riser development, where individual risers may be installed over a number of seasons, the hybrid riser must be fabricated and installed in one shot.

The numbers of lines and their pressure rating need to be specified during the initial design phase. Once installed, it is difficult to add additional lines and therefore contingency lines to meet future requirements must be considered during the design phase. This may reduce the cost effectiveness of the concept if contingency lines are not subsequently used.

Alternatively, if the probability for future lines is small, conventional flexible risers may be considered, providing vessel connection porches are available or can be provided.

CONCLUSION

The design approach developed by 2H Offshore results in a cost effective riser design suitable for harsh environment floating production developments

- Comprehensive analysis confirms the design approach and long term structural integrity
- The design is competitive with flexible risers in water depths as low as 350m.
- The cost advantage of the hybrid riser improves significantly as water depth increases.
- For developments in 750m of water, the concept should be less than half the cost of a flexible riser system.
- The technology and hardware specified in the design and manufacture of the riser is well proven.
- The installation method may be considered novel however, the approach has been successfully used for TLP tether elements and installation analysis results are positive.
- The arrangement allows provision of a large diameter export (upto 36 inches) if required.