

ANALYSING THE PRACTICALITIES OF MOVING TO STEEL CATENARY RISERS IN THE ATLANTIC FRONTIER

by

Dr Hugh Howells
2H Offshore Engineering Limited
Woking, Surrey, UK

Presented at DEEPTEC '96, Aberdeen, January 1996

ABSTRACT

Steel catenary risers have been implemented on the Auger TLP and are proposed for other developments in the Gulf of Mexico and the Marlim field, offshore Brazil. This riser concept offers a number of benefits for deep water floating production systems which cannot be realised with alternative riser systems. The applicability of steel catenary risers to the harsher West of Shetland environment and use with other vessels is evaluated. Differences in riser arrangements are described and changes to installation procedures and costs are assessed.

INTRODUCTION

Steel catenary risers have been implemented on the Auger TLP in the Gulf of Mexico and are proposed for other TLP's currently under development for the same location. In these applications the steel catenary riser configuration offers solutions to difficult deep water conditions, simplifying riser design and offering cost advantages. In the shallower water depths of the North Sea steel catenaries may have limited benefits, except when used for fixed platforms, but for the deeper waters West of Shetland steel catenaries may provide a viable alternative to flexible risers [1,2].

The conditions under which catenary risers would be implemented West of Shetland are different from those of the Gulf of Mexico. The extreme environmental conditions are significantly more severe and current developments are focused around ship-shaped production vessels as opposed to TLP's. These differences could limit the feasibility of using steel catenary risers for West of Shetland applications. However, riser arrangements have been developed which perform satisfactorily. The differences in design conditions are evaluated and their effects on riser arrangement, installation methods and costs are assessed.

STEEL CATENARY APPLICATIONS

Gulf of Mexico Catenary Riser Arrangement

A summary of current and planned applications of steel catenary risers is given in Table 1. All these risers consist of a simple catenary which forms an extension of the flowline, attached to the vessel by way of a flex-joint. These SCR's have a number of design conditions in common:

- * Deep water
- * High surface currents
- * Moderate wave heights
- * Small vessel motion envelopes

The moderate wave heights and small vessel motion envelopes enable a simple catenary shape to be adopted. The high surface current velocities can generate vortex induced vibrations (VIV's) which can give rise to unacceptable fatigue damage over a large part of the riser length. VIV suppression strakes are therefore implemented, over a short length near the surface where currents are high.

| Development | Line Function | Size (inch) | Pressure (psi) |
|----------------------|---------------|-------------|----------------|
| Auger TLP, 1994 | Oil Export | 12 | 3000 |
| | Gas Export | 12 | 3000 |
| Mars TLP, 1996 | Gas Export | 18 | 2400 |
| | Oil Export | 14 | 2160 |
| | Import | 5 | 5000 (7300) |
| Ram-Powell TLP, 1997 | Gas Export | 14 | 2220 |
| | Oil Export | 12 | 2500 |
| | Gas Import | 8 | 6200 |
| Marlim Semi, 1996 | Gas Export | 10 | 2350 |

Table 1 Current and Planned Steel Catenary Riser Systems

Conventional v Steel Catenary Risers

To understand the reasons for implementing steel catenary risers, the alternatives to the riser systems listed above can be assessed. The TLP risers could take the form of flexible lines or vertically tensioned risers. The alternative to the Marlim steel catenary is a flexible line. Taking the vertically tensioned riser alternative, the steel catenary offers the

advantages of reduced deck space, elimination of riser base and tensioner and a fixed valve stack. These changes provide a simpler arrangement at reduced cost. The loading applied to the platform is similar for tensioned or catenary risers though the catenary riser has a small lateral load component.

There is limited scope for using flexible lines as alternatives to many of the steel catenary risers listed. The Auger export lines are near the current maximum diameter/internal pressure combination of flexible risers. Lines larger than 12 inches exceed the maximum flexible riser size produced to date which would limit the possibility of using flexibles for the Mars export lines. Furthermore, the water depth of all the developments would result in novel application of flexible risers with diameters of 10 inches or more. Hence, the only viable flexible pipe alternative to the steel catenaries of 10in diameter or more is the use of a larger number of smaller diameter lines.

DESIGN APPROACH

Before examining the differences between steel catenary risers for the Gulf of Mexico and West of Shetland, the key riser design issues and their influence on design configuration are briefly described.

Key Design Issues

The key design issues which determine riser arrangement are listed below.

- * Dynamic loading and vessel motions
- * Tension applied to platform
- * Resistance to fatigue from waves, slow drift and VIV's
- * Interference with adjacent risers and mooring lines

Riser arrangements are typically developed in two phases: extreme load analysis, giving a basic arrangement which has satisfactory maximum stress levels, followed by fatigue analysis which may require minor modifications to the basic arrangement and determines the quality of details needed to meet design life requirements.

Extreme Load Response

Critical loading occurs when the waves and current lie in the same plane as the catenary. "Far" loading, in which the platform moves away from the catenary gives maximum tension at the vessel and in the flowline. "Near" loading, in which the platform moves towards the riser gives maximum bending in the riser just above the seabed touchdown point. The greater the offsets which must be accommodated, the greater the nominal angle at which the vessel must be inclined to the vertical in order to accommodate near loading and consequently, in far loading conditions, the greater becomes the tension applied to the platform and the flowline. Transverse loading, in which waves and current have components normal to the plane of the catenary has less effect on riser stresses but determines the length of riser on the seabed on which abrasion resistant coating, such as neoprene, must be applied and the required spacing between risers of different types and

between risers and mooring lines.

Fatigue

Fatigue damage is generated by first order wave action and associated platform movements, platform drift effects and vortex induced vibration. First order fatigue damage in steel catenary risers is generally greatest in the wave zone and at touchdown point on the seabed. Catenary geometry may need to be modified to improve response and local improvements in fatigue details may be required in extreme cases. Second order motions affect of distribution of fatigue damage at the touchdown point, the beneficial effects of which must be accounted for to avoid undue design conservatism. Vortex induced vibration behaviour due to currents determines the need for use of vibration suppression devices such as strakes.

GULF OF MEXICO AND WEST OF SHETLAND COMPARED

Two main differences between Gulf of Mexico and West of Shetland applications are the environmental conditions and type of production system.

Environmental Conditions

The environmental conditions in the West of Shetland are significantly harsher than those of the Gulf of Mexico. The main differences which affect riser system design are:

- * Shallower water
- * Larger mid-depth currents
- * Larger waves
- * Longer waves (larger wave period)
- * Larger long term average wave height

Each of these factors adds to the difficulty of steel catenary riser design. The shallower water, larger waves and larger currents increase extreme loading. The larger currents may require the use of vortex induced vibration suppression strakes over longer lengths. The greater average wave height increases fatigue damage. Further difficulties arise when considering the change in environment together with change in vessel type.

Production Vessel Effects

Proposals for steel catenary risers in the Gulf of Mexico involve use of a TLP. There do not appear to be any current plans for a TLP West of Shetland though such a development may be used in the future. Currently, however, the development trend is towards ship-shaped vessels. The feasibility of steel catenary risers for West of Shetland applications is therefore assessed on the basis that a catenary moored vessel such as a tanker or semi-submersible is used.

One significant difference in riser design requirements between TLP's and catenary moored vessels is vessel drift offset. Maximum TLP offsets are expected to be less than 10% of water depth. For catenary moored platforms, offsets of up to 20% and 25% water

depth may need to be accommodated for intact and damaged mooring systems respectively. Thus the riser compliancy needed when moving from TLP's to moored vessels is increased.

Combination of Environment and Vessel

The combination of more severe environment and different dynamic motion characteristics of floating platforms produce very different riser attachment point motions West of Shetland from those of the Gulf of Mexico. A comparison of the attachment point motion envelopes for different platforms in Gulf of Mexico and West of Shetland environments is attached. This shows that moving to a floating platform introduces heave and pitch induced heave motions being applied to the riser. In the Gulf of Mexico this motion is significant, but simple catenary geometries are nonetheless sufficiently compliant to accommodate vessel motions. i.e. the same basic riser arrangement can be used with TLP's and catenary moored vessels. The vessel motion envelopes are considerably greater West of Shetland for two reasons: the first is the greater extreme wave heights and second the longer wave periods, at which vessel heave and pitch RAO's are greater.

West of Shetland SCR Arrangements

To accommodate the large vessel offsets and dynamic motions of catenary moored production vessels buoyancy can be used. Typical arrangements of a 12in steel catenary riser in 400m and 800m water depths West of Shetland are given. The buoyant riser arrangements are similar to those used for flexible risers. Loads applied to the vessel are less than would be found with flexible risers as flexible risers are some 20 to 40% heavier than equivalent steel risers in production mode. The suspended length of riser extends a greater distance from the vessel than a flexible riser, but it still lies within the radial span of the mooring lines. The greater suspended length coupled with the large mid-depth currents West of Shetland increases the possibility of clashing with the mooring lines. However, for the 12 inch riser in 400m water depth shown, interference can be avoided by placing the riser at an angular spacing of 15 degrees from the mooring line.

INSTALLATION

Conventional Methods

Installation of steel catenary risers and attached flowlines can be carried out using all conventional methods of flowline installation including S-lay, J-lay and reel-lay. In order to minimise installation cost, risers and attached flowlines would be installed in one operation, eliminating the need for a subsea tie-in between riser and flowline. Seabed terminations can be effected by the same methods used for flowlines. However, seabed tie-ins for steep wave arrangements and attachment of buoyancy needed to form lazy wave arrangements may be more difficult to achieve using S-lay vessels. For these reasons J-lay or reel-lay are considered preferable.

The procedures required for vessel tie-in are akin to those used for flexible riser installation. This is the most difficult aspect of steel catenary riser installation and greater

care is required to control curvature than needed for flexible risers. The additional controls required are not expected to have a significant cost impact. In this respect, it is worth noting that the submerged weight of flexible risers may be between 40% to 80% heavier than steel lines during installation (assuming lines are air filled). Consequently, lifting equipment load capacity is no more severe.

Alternative Installation Methods

The use of mechanical connectors for steel catenary risers offers a number of attractions. Two such systems have been implemented for flowline installation, though for different reasons:

- * Hunting Snap-Lay - to avoid damage to internal coating by elimination of offshore welding [4];
- * Hydril Series 2000 - to enable use of lower cost materials which cannot be welded offshore [3].

Mechanical connectors also offer other benefits for steel catenary risers. The ability to produce well controlled connection details offers improved fatigue performance by reducing stress concentrations and improved fatigue classification. Fracture performance may also be improved by reduction or elimination of residual stresses. Other mechanical connection systems, such as premium threaded couplings used for TLP rigid riser systems, could be used to provide the same benefits as the two systems described above. Furthermore, the use of systems of this type offers potential for using lower cost installation vessels and achievement of faster lay rates.

COSTS

Due to the more complex riser arrangement, the steel catenary riser systems proposed for West of Shetland applications are more costly than those implemented in the Gulf of Mexico. The buoyant steel catenary riser system nonetheless offer cost advantages compared to alternative riser systems for similar applications. As riser system costs can vary significantly from one application to another the differences in cost components of steel catenary risers and alternative riser systems are evaluated in order to illustrate the potential benefits. For this purpose it is necessary to consider both the riser and its interface with the flowline.

A significant proportion of flowline and riser costs comes from installation. As similar methods are required for both steel catenary and flexible riser installation, costs may be similar. However, the ability to continue the flowline to the vessel avoiding the need for a subsea tie-in between flexible riser and rigid flowline may offer cost advantages in some applications. The level of benefit depends on many factors including number of bases required, the need for additional vessels and loads applied to the tie-in from the riser and flowline. Typical savings are expected to be around £100,000 per riser. Riser base and flowline tie-in costs also are saved in this way when using a steel catenary as opposed to a rigid riser for export from a TLP.

Further cost differences between steel catenary and flexible risers may be found by comparing component costs. Steel catenary risers require a flex-joint at the vessel interface, which is expected to be of similar cost to a bend restrictor required for a flexible line. Steel catenary risers need buoyancy applied over a longer length but as the pipe weight is less than that of an equivalent flexible line it is not expected that the total upthrust requirement and hence buoyancy costs would be significantly different. Significant cost savings are made in the pipe itself which, in greater water depths, or where the riser forms a continuation of the flowline, becomes more significant.

CONCLUSIONS

The steel catenary risers being implemented for TLP's in the Gulf of Mexico can be used in a similar form with TLP's West of Shetland. Whilst simple catenaries can also be used with semisubmersible and ship-shaped platforms in the Gulf of Mexico the harsher environment and greater vessel motions experienced West of Shetland require buoyant steel catenary riser arrangements such as lazy and steep wave geometries similar to those employed for flexible risers.

Installation of steel catenaries can be achieved using the same techniques employed for flowlines and flexible risers. Greater care is required to limit stresses when connecting steel catenary risers to the production vessel, but this can be achieved by specification of suitable controls. As a direct alternative to flexible risers steel catenaries offer distinct cost advantages. Steel catenaries also offer extended depth/diameter/pressure ratios which may assist in deeper water developments and potential benefits for difficult applications such as HP/HT fields.

REFERENCES

- [1] Howells, H. - "Advances in Steel Catenary Riser Design". The 2nd Annual International Forum on Deepwater Technology, DEEPTTEC '95, Aberdeen, March 1995.
- [2] Hatton, S.A. - "Rigid Risers for Tanker FPSO's". FPSO World Congress, Aberdeen October 1995.
- [3] Sikes, J. and Roche, J. - "J-Laying Deepwater Pipelines with Drillship and Threaded Connections". Offshore, October 1995.
- [4] Dick, M. and Craig, M. - "Debut for Snap Laid Pipeline". Offshore Engineer, October 1995

| Environmental Parameter | GoM | WoS |
|-------------------------------------|------------|------------|
| Water depth (m) | 800+ | 300+ |
| 100 yr wave height (m) | 23 | 30+ |
| Wave period (sec) | 14 | 20+ |
| 100 yr current (m/s) | | |
| surface | 2.3 | 1.7 |
| mid-depth | 0.1 | 1.0+ |
| bottom | 0.1 | 1.0+ |
| Average significant wave height (m) | 1.16 | 3.0+ |

Table 2 Comparison of Gulf of Mexico and West of Shetland Environmental Conditions