

CHOOSING THE MOST APPROPRIATE RIGID CATENARY RISER DESIGN FOR VARIOUS DEEPWATER AND HARSH ENVIRONMENTS

by

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INTRODUCTION

As operators commence the development of deep water fields, the interest in cost effective riser solutions increases. Some of these fields have particularly severe design conditions such as harsh environments and high temperature and pressure. These factors make riser design particularly challenging and may be beyond the scope of riser systems traditionally used in shallow water applications. One emerging technology is the use of steel pipe configured in compliant catenary arrangements. Medium grade steel pipe has a low cost compared to flexible pipe, but since it has a much larger minimum bend radius, careful consideration must be given to optimising the riser arrangement to achieve an acceptable performance.

Several types of steel catenary riser have been developed, each having characteristics which make it better suited for particular applications. This paper discusses these characteristics and the applications appropriate to each type of riser.

STEEL CATENARY RISER TYPES

Four types of steel catenary riser are considered and are illustrated in Figure 1, these are:

- Simple Catenary Riser
- Buoyant Wave or Lazy Wave Riser
- Steep Wave Riser
- Bottom Weighted Riser

Although not a true catenary, the bottom weighted riser has very similar characteristics to a simple catenary.

Simple Catenary Riser

This is a simple drape starting at the vessel and curving through nearly 90 degrees to a horizontal orientation on the seabed. A flex joint is required at the vessel interface and some length of the pipe is

required on the seabed before any seabed termination/flowline connection. This length allows for any movement caused by changes in vessel position with the actual length required dependent on the amount of vessel drift. Alternatively, the riser can extend to become part of the flowline without any end termination or pipeline connection.

Buoyant Wave Riser

The buoyant wave riser is similar to the simple catenary except that it has additional suspended length supported by a buoyant section. This forms an arch prior to the touch down point on the seabed. The buoyant wave riser also requires a length of pipe on the seabed before (if any) the seabed termination.

Steep Wave Riser

The steep wave riser is similar to the buoyant wave riser in that it also has an arch formed using buoyancy. The steep wave riser is not orientated horizontally on the seabed as the other catenary risers are but terminates vertically into a structure fixed to the seabed. This riser type requires a stress joint or flex joint at the base where bending loads can be high. The seabed interface is closer to the vessel compared with the other catenary risers and is fixed, whereas the touch down point for the simple and buoyant wave catenaries can move.

Bottom Weighted Riser

The bottom weighted riser is similar to a simple catenary and consists of a vertical and a near horizontal section joined by a rigid elbow and flex joint arrangement. The near horizontal section is made of titanium and has flex joints at either end, the lower end is connected to a piled end termination. A small amount of buoyancy is added to make the near horizontal section neutrally buoyant, and a tether is used at the elbow to help stabilise the vertical section.

The bottom weighted riser has the capacity to accommodate higher vessel motions and current loading than the buoyant wave or simple catenary risers, making it particularly suited to large diameter export lines (>20in) connected to an FPSO in shallow water depths (400-800m).

Selecting Catenary Type for Vessel

Simple catenary risers have a limited amount of additional length available to accommodate platform motion. Changes in the suspended length are achieved by the riser either being picked up or laid down on the seabed. Limitations are reached when either the riser tension at the vessel becomes too great as the vessel drifts away from the touch down point (far load case, Figure 2), or when the bending stresses near the seabed become too great as the vessel drifts towards the touch down point (near load case). These limitations mean that simple catenaries are appropriate for TLP and SPAR applications which have limited vessel offsets. Simple catenary risers are less appropriate for FPSO applications where vessel offsets are considerably higher.

Two types of vessel motions contribute to changes in the suspended length of a catenary, these are first order motions and slow drift. First order motions are the vessels response to each wave that passes such as heave, surge and pitch etc. Slow drift motions are lateral motions, which occur over a longer

period of time (typically 200-600 seconds) as the vessel moves about its mooring system. Typical slow drift motions of up to 9% of water depth are quoted for TLP and SPARs. FPSO slow drift motions can be 20% - 30% of water depth depending on mooring stiffness. These values are for failed mooring line conditions and can result in large top angles and extreme tensions at the vessel.

In benign environments such as West Africa and the Gulf of Mexico where changes in catenary length due to first order vessel motions are small, the catenary has greater capacity available to accommodate vessel slow drift motions. This means that simple steel catenary risers and bottom weighted risers should not be discounted for FPSO applications where waves and corresponding first order vessel motions are small. Steep wave and buoyant wave risers are much more compliant than the simple catenary riser and can more easily cope with large vessel drift motions (Figure 3).

Selecting Catenary Type for Water Depth

The feasibility of steel catenary risers is dependent on many factors including water depth, diameter, pipe size and weight, vessel motions and environmental conditions. Studies [2] have developed catenary risers in 400-1200m water depths for the West of Shetland environment and 1200-2000m water depths for the Northern Norway environment.

Buoyant wave risers can be configured for similar water depths as simple catenaries of the same pipe size, but steep wave risers need deeper water to accommodate the geometry.

Risers which have a relatively low weight in water may not have enough tension at the vessel in shallow water (400-800m) to cope with high first order vessel motions. Ballast weights or thicker walled pipe may be needed to overcome this. In deeper water the riser may have sufficient tension to work without additional ballast weights.

Bottom weighted risers have been developed for large diameter export risers connected to FPSO's in shallow water (400-800m) where large diameter buoyant wave risers are not feasible. In greater water depths, it is more economical to use a buoyant wave riser than a bottom weighted riser.

Effects of Current

Current has two major effects on catenary risers. These are hydrodynamic drag effects and vortex induced vibrations (VIV).

The effects of hydrodynamic drag cause the suspended part of a catenary to move downstream. This is not a problem at the vessel where a rigid connection resists the motion. At the seabed however, there is no rigid connection for simple catenaries and buoyant wave risers and the catenary touch down point on the seabed will move. To account for this, the effects of current should be considered from 3 directions:

- In line with the riser from the touch down point towards the vessel (far load case)
- In line with the riser from the vessel towards the touch down point (near load case)
- Normal to the plane of the riser (transverse)

Near and far current loading has only minor effects on the simple catenary riser due to its geometry and cause a small amount of pipe to be picked up or laid down on the seabed. Transverse current loading has a more significant effect on the riser and causes sliding on the seabed (Figure 4). In addition, the floating platform may drift with the current and cause additional deflection of the riser.

Buoyant wave and steep wave risers have increased drag due to the increased diameter of the buoyant sections and their longer lengths. Coupled with lower tensions which occur in the buoyant sections, higher deflections result compared with a simple catenary riser. Hence, buoyant wave risers will experience more sliding on the seabed, particularly with transverse currents. Risers which slide laterally along the seabed may not return to their original positions when the lateral loading is removed.

Careful planning is needed when positioning multiple catenary riser systems on a floating platform to ensure that risers will not interfere with each other, particularly if risers of different sizes are placed next to each other.

Riser interference is also affected by wake interference and VIV. Wake interference is caused by an upstream riser shielding a downstream riser from the current flow. This results in the downstream riser deflections and hence the riser clearance being reduced. Vortex induced vibrations have a relatively small amplitude of motion and do not have a significant effect on riser clearance. However, a vibrating pipe has a greater drag coefficient than a stationary one and this will affect clearance of adjacent risers.

In locations where highly sheared current profiles exist, the effects of current can be reduced by keeping the arch as low as possible. Careful optimisation of the design is required to ensure that the sag bend does not impact the seabed in the near load case.

The steep wave and bottom weighted risers interface with the seabed at a single point and experience no sliding on the seabed. This is beneficial where a large number of risers are required and space is limited. High bending stresses can occur at the base of the steep wave riser due to platform motions and current loading requiring the use of a flex joint and/or stress joint.

The bending stresses at the base of a steep wave riser can be minimised by using sufficient buoyancy to provide a high tension at the base. The amount of buoyancy required will need to be applied over a long length, putting the arch higher in the water column than for a buoyant wave. In locations where the current profile is highly sheared, the arch of a steep wave riser will experience high current velocities and may not be suitable in this type of environment.

Vortex Induced Vibrations (VIV) are caused by vortices shedding from alternate sides of the riser and resulting in a cross flow vibration of the riser. If the vibration frequency matches any of the risers natural frequencies high fatigue damage can occur.

Much research has been undertaken to understand VIV and its effects on risers, but this research has focused mainly on vertical risers. The effects of VIV on catenaries and pipes inclined to the flow are not well understood at present, but it is known that VIV fatigue damage on catenary riser systems will be high. VIV suppression devices such as helical strakes or fairings can reduce VIV fatigue damage by up to 80% and require a coverage of 50% - 100% of the catenary suspended length. However, the use of VIV suppression devices introduces other difficulties such as more complex installation.

Effects of Wave

Wave action itself does not have a significant effect on steel catenary risers as the riser tension is high in the wave zone, also the length of riser in the wave zone is small compared with the overall suspended length. However, platform motions due to wave action do have a major influence on riser response.

Catenary risers do not have tensioner systems and rely on their self weight to provide tension. Platform vertical motions cause fluctuating increases and decreases in tension. As vertical motions increase, tension may be reduced to a point where instability and buckling may occur.

Catenaries which are relatively light because of thin wall, thick coating or low density internal fluid will experience this instability with smaller vertical motions than a heavier catenary. Similarly a lightweight catenary may be suitable for a heave restrained platform such as a TLP or SPAR where tension fluctuations are small. A heavier catenary may be required if an FPSO is used in the same conditions.

Vertical motion at the top of a catenary is caused by vessel heave, and can also be caused by pitch and roll if the riser is not at the vessel C of G. Risers connected to a turret moored FPSO's, in which the riser is positioned some distance from the C of G, can experience large vertical motions at the riser interface.

Conclusion

Several types of steel catenary riser exist and each has characteristics affecting its suitability for a particular application. There are many factors which influence the response of the selected catenary and these should be considered carefully during the riser design.

In harsh environments such as West of Shetland and Northern Norway, simple catenary risers are suitable for heave restrained TLP and Spar platforms. Buoyant wave risers are more suitable for FPSO applications where vessel offsets are larger (20%-30% water depth). Bottom weighted risers are suitable for large diameter export lines in shallow water depths (400-800m).

Both simple catenaries and buoyant wave risers can be used in a wide range of water depths. However, shallower water depths (400-800m) present difficulties which may require slight modifications of the riser in places such as the use of increased pipe weight or higher grade material. In benign environments such as the Gulf of Mexico or West Africa less modification is required.

Some issues such as VIV and catenary seabed interaction require more research to enable a better understanding of these phenomena to be established. Studies are being undertaken at present to achieve this.

There are many design difficulties associated with steel catenary risers but with careful engineering a workable solution can be found.

REFERENCES

- [1] Hatton S. and Willis N. – “Steel Catenary Risers for Deep Water Environments”. Paper OTC 8607, Houston, May 1998.
- [2] 2H Offshore Engineering Ltd. – “Stride JIP - Extreme Storm Analysis, Simple Catenaries”. 1094-RPT-0008, Rev 01, September 1997.
- [3] 2H Offshore Engineering Ltd. – “Stride JIP - Catenary Riser VIV Analysis”. 1094-RPT-0009, Rev 01, September 1997.
- [4] 2H Offshore Engineering Ltd. – “Stride JIP - Extreme Storm Analysis, Bottom Weighted Risers”. 1094-RPT-0011, Rev 01, September 1997.
- [5] 2H Offshore Engineering Ltd. – “Stride JIP - Extreme Storm Analysis, Buoyant Wave Risers”. 1094-RPT-0014, Rev 01, September 1997.
- [6] 2H Offshore Engineering Ltd. – “Stride JIP - Buoyant Wave VIV Analysis”. 1094-RPT-0016, Rev 01, October 1997.
- [7] 2H Offshore Engineering Ltd. – “Stride JIP – Thermal Coating Parametric Study”. 1094-RPT-0021, Rev 01, November 1997.
- [8] 2H Offshore Engineering Ltd. – “Stride JIP – Steep Wave Configuration Study”. 1094-RPT-0028, Rev 01, December 1997.

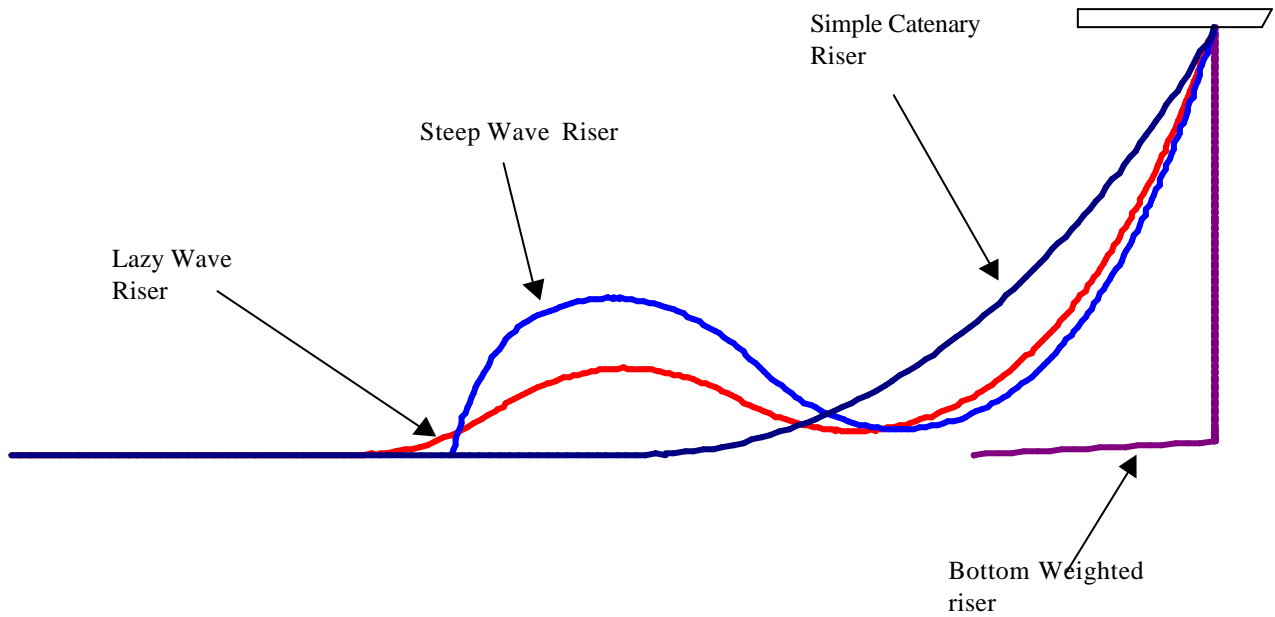


Figure 1 Simple Catenary, Buoyant wave, Lazy Wave and Bottom Weighted Risers

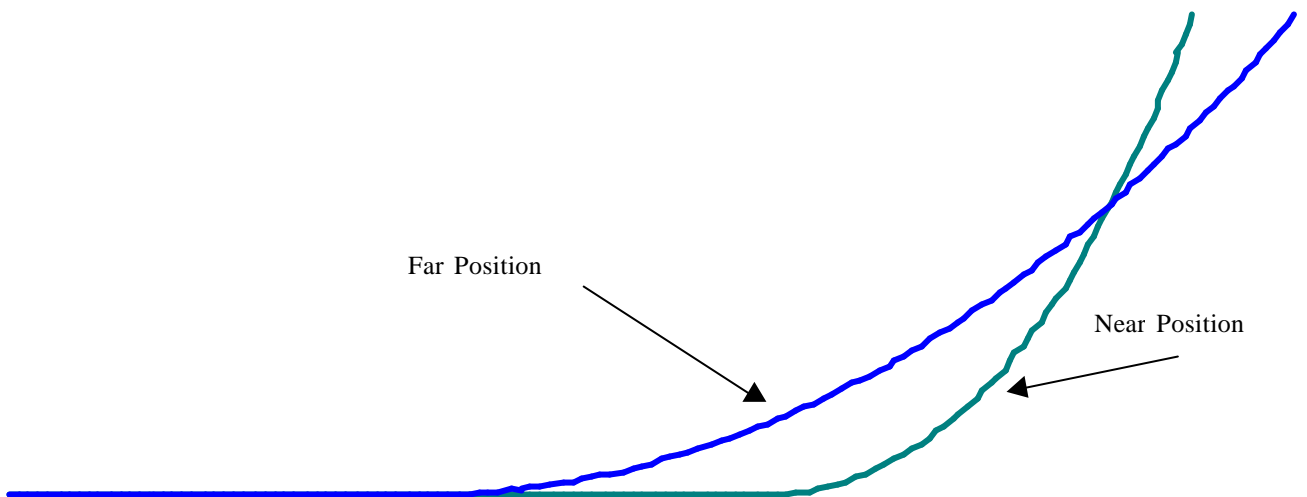


Figure 2 Simple Catenary Riser in Near and Far Positions

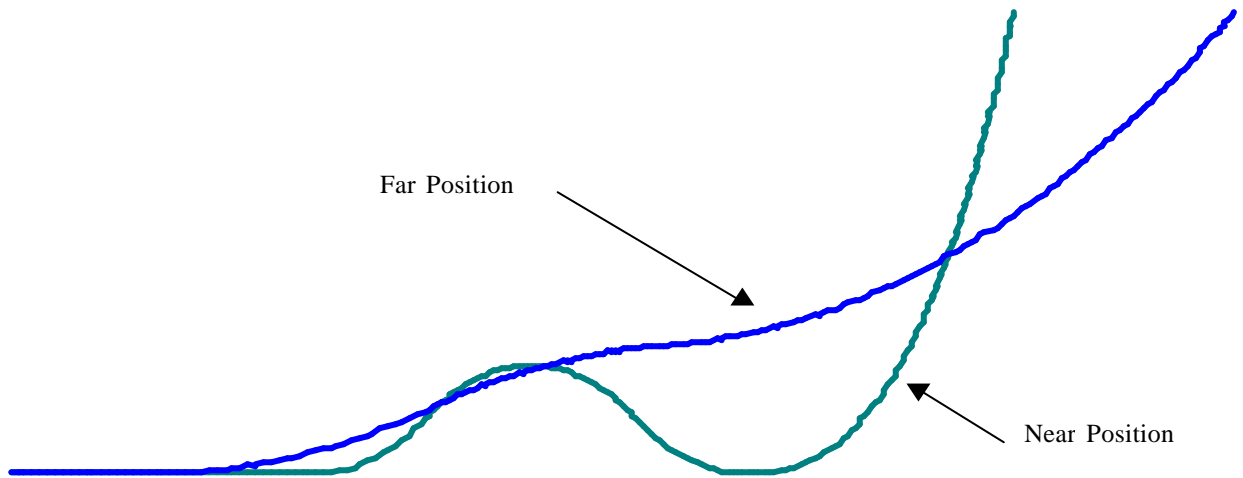


Figure 3 Buoyant Wave Riser in Near and Far Positions

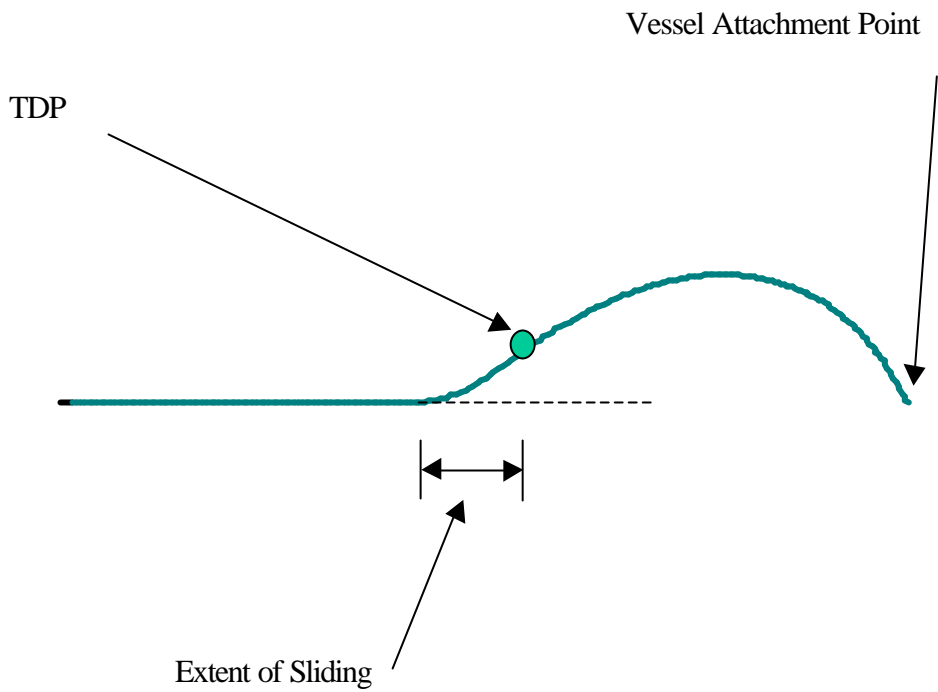


Figure 4 Current Directions