

## **UNCERTAINTIES REGARDING VIV IN THE DESIGN OF DEEP WATER RISERS**

by

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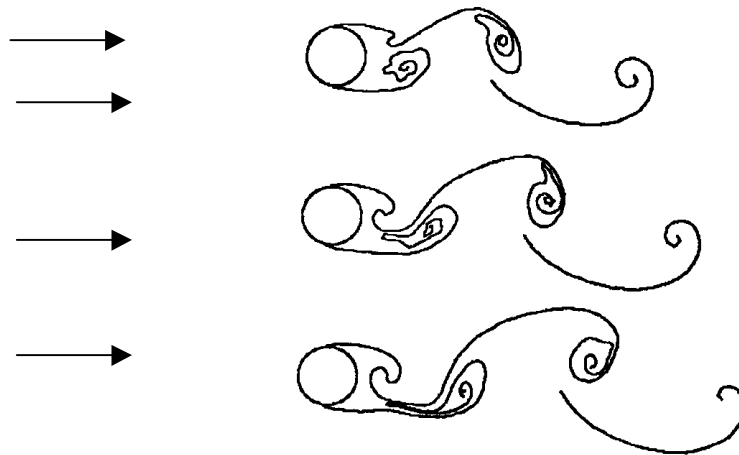
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### **INTRODUCTION**

Exploration and production in the Gulf of Mexico and West Africa is moving into water depths of over 2000m, and in the harsher areas of West of Shetland and Voring Basin, depths of over 1000m are being considered. The increased water depth and severe currents experienced in most of these areas place more severe design requirements on riser systems. A key aspect is Vortex Induced Vibration (VIV), which can lead to high frequency cyclic stresses, resulting in high rates of fatigue damage. This effect is important for drilling risers, and even more so for production risers where service lives in excess of 25 years are often required.

**Figure 1 – Alternating Vortices Shed from a Cylindrical Member**



Analysis of vortex induced vibrations in riser systems is widely carried out using the program SHEAR7 [1], developed at MIT under a joint industry research study. The program enables prediction of riser VIV response under uniform and sheared current flows and has been extensively validated for vertically tensioned risers by model tests.

**STRIDE JIP**

The industry has shown considerable interest in steel catenary riser technology as an alternative to flexible risers for deep water floating production systems. 2H Offshore is in the process of completing Phase I of the Stride JIP, which is supported by 14 operators, and 6 Engineering Contractors. The Phase I scope covers steel catenary risers in the range of 10-30inches installed to a TLP, Spar and FPSO platforms, in water depths up to 2000m. The main thrust of the project is harsh environments typical of the West of Shetland and Voring Plateau but benign environments such as the Gulf of Mexico and West Africa are also considered.

Results from the work show that in harsh environments steel catenary risers are highly fatigue sensitive with damage arising from first order dynamics, second order vessel motions and VIV. VIV is shown to be a primary design aspect, as it has a significant effect on the riser configuration, hardware, materials, fabrication and installation methods.

The Stride results show that damage contribution, resulting from VIV response, for simple catenary and wave catenary risers can be high with failure predicted in months rather than years. In these cases it is necessary to consider VIV suppression devices. Many systems have been proposed [2] although experience is limited. Two systems that provide high levels of suppression and have been used in previous operations are helical strakes and fairings [3-5]. Both strakes and fairings can reduce VIV fatigue damage by over 80%, but both systems also introduce handling difficulties. Strakes have the added disadvantage of increasing riser drag, whereas fairings can reduce drag loading. However, fairings need to rotate with current direction and design complexity may limit use of these devices particularly if they are required over a large portion of the riser length.

The requirement to use suppression systems over large portions of the riser length is very costly, both in terms of the capital cost and installation. Additionally, the higher drag caused by most suppression devices leads to higher extreme storm stresses and the need for heavier and higher-grade pipes.

However, whilst there is a high level of confidence in SHEAR7 for vertically tensioned risers there are a number of program limitations which introduce uncertainty for catenary riser shapes. It is therefore possible that the predictions made by SHEAR7 are overly conservative and there would be considerable benefit in quantifying areas of conservatism and benchmarking/validating the program for catenary shapes. VIV is considered the most important issue for further development within Stride phase II, aimed at addressing the following areas of uncertainty:

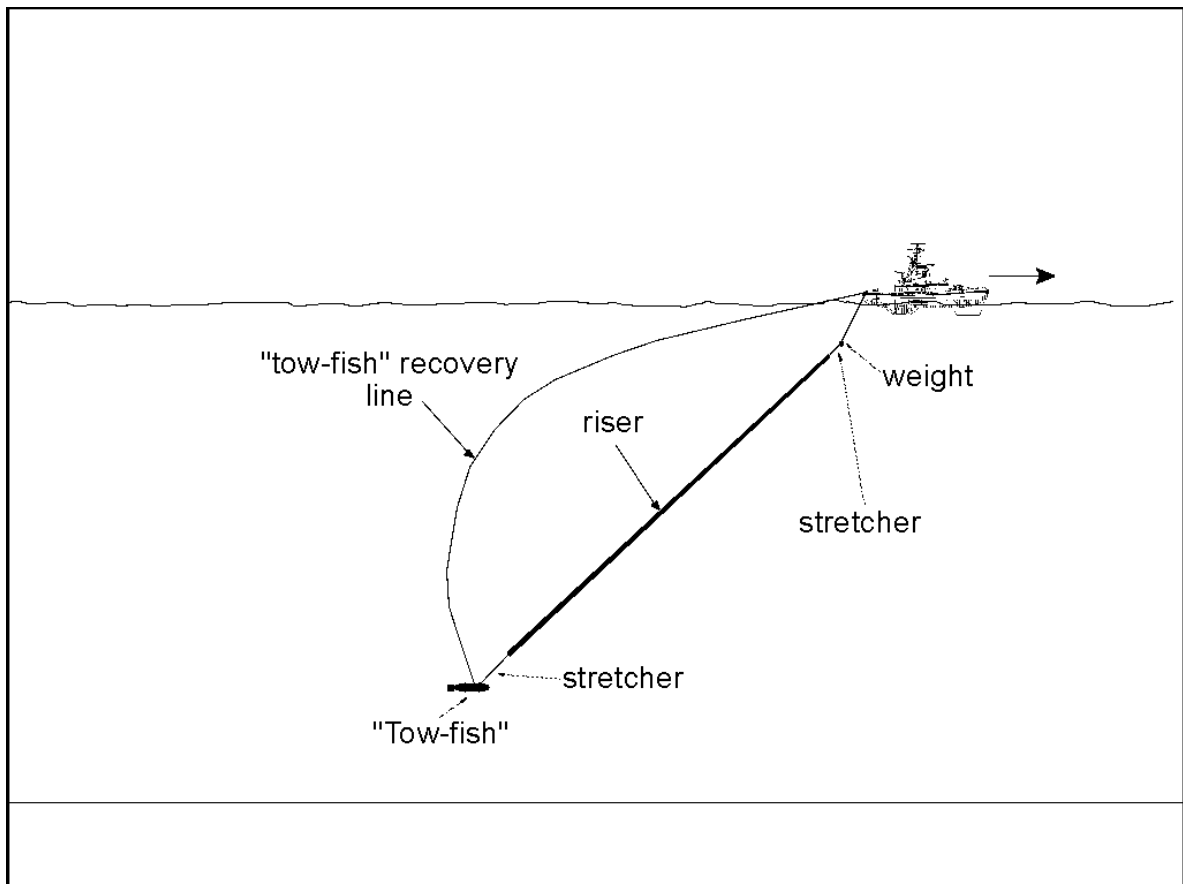
- VIV software simplifies catenary riser structures to vertically tensioned columns - this has little or no verification
- There is little or no VIV test tank data at applicable Reynolds numbers ( $Re > 5 \times 10^5$ )
- VIV response of inclined, skewed and curved pipes has very little documentation - it is possible that non vertical pipes may not be as susceptible to VIV
- Facilities for modelling VIV suppression devices are limited, not well understood or verified
- The effect of inclination on strake and other suppression device effectiveness is not documented for the parameters of interest within STRIDE.

- End effects in deep water, TDP interaction and seabed proximity are not fully understood particularly for applications in mildly sheared profiles
- The effects of first order vessel surge and heave on VIV response of bare and suppressed catenary risers is not known. Current references are TLP's and drilling risers, not FPSO's.

The proposed scope for Stride Phase II addresses these issues, with the objective of providing increased confidence in VIV response prediction. A stepwise approach is recommended, whereby significant benefit can be gained at small scale, low cost, with results feeding into and focussing more sophisticated larger scale testing.

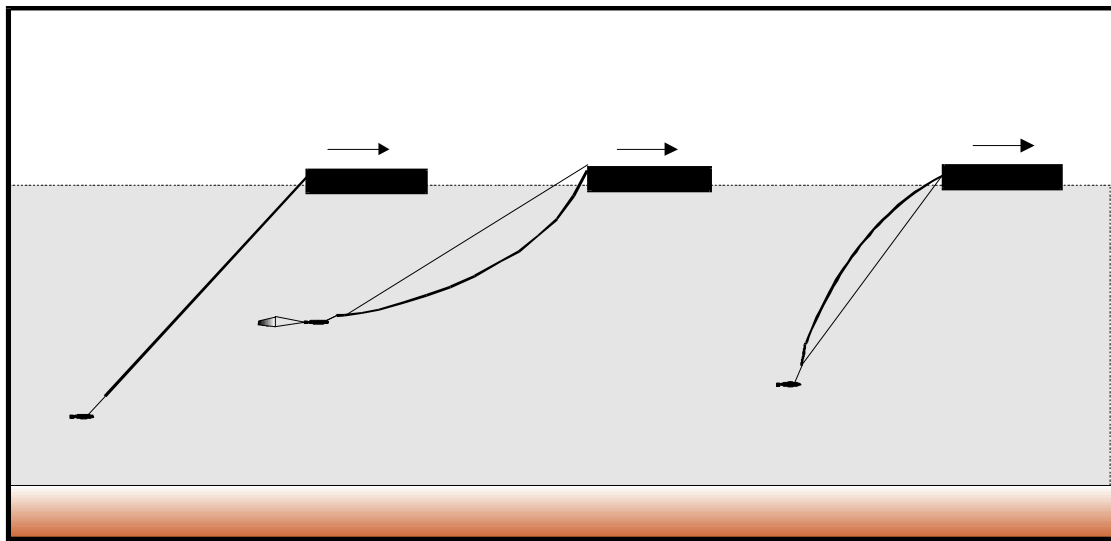
**Tow tank VIV testing** - Testing is proposed in a 270m long linear tow test tank. Towing is performed on a horizontally mounted pipe, 3m long, 10 inches diameter, velocity up to 3 m/s, with and without various VIV suppression devices. The pipe is mounted on springs sized to simulate a section of a buoyant wave riser, and will be towed at different angles of inclination to the flow. High angles will be simulated with elliptical pipes. This will produce valuable data on riser response at representative Reynolds numbers, in particular the effects of inclination, and different VIV suppression systems.

**Large scale VIV testing** - Results from tow tank testing will feed into a large-scale test at a medium depth, sheltered water location (fjord or lake). It is proposed to tow a 10 inch diameter riser, 200m long, from the stern of a rental vessel.



**Figure 2 – Open Water Testing Arrangement**

A tow-fish attached at the bottom of the riser provides the necessary degree of end restraint for modal VIV to occur. By varying the tow speed and riser weight, the inclination of the riser in the water can be adjusted. In addition, catenary shapes can be induced by use of tensioning wires attached between the vessel and the bottom of the riser (Figure 3). VIV response would be monitored using accelerometers and inclinometers located along the riser length. This arrangement allows a range of riser shapes, inclinations, VIV suppression systems/distributions to be evaluated at representative Reynolds numbers.



**Figure 3 – Open Water Riser Arrangements (Riser Length 200m)**

The importance of the above test program is that it will provide quality data which will allow better understanding of the VIV phenomena and benchmarking of programs such as SHEAR7. Analysis input parameters can be defined for different riser configurations based on test results rather than worst case conditions. It is hoped that test results will allow the conservatism and uncertainties, inherent in the present VIV analysis approach, to be eliminated allowing simplification of steel catenary riser design and installation. Whilst the cost impact of this is difficult to accurately estimate, it is probable that savings may be up to 40%.

## **REFERENCES**

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