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Offshore Drilling Riser VIV Suppression Devices – What's Available to Operators?

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ABSTRACT

VIV suppression and drag reduction are key issues for improved operation in offshore drilling. Properly designed helical strakes are effective in the mitigation of VIV fatigue damage for many riser applications. However such strakes tend not to be applicable to offshore drilling riser applications. This is due to increases in drag force due to increased apparent diameter as well as workability problems for drilling operations. For these reasons, effective devices are sought that would mitigate VIV and reduce, or at least not increase, drag for drilling applications.

Along with yielding good hydrodynamic performance, a drilling riser VIV suppression device must be compact and robust enough to be used in a drilling-rig environment. It needs to be deployable and recoverable in declared operational sea states. It must also be easy to store and assemble. Finally, and most importantly, it must be efficient to deploy and recover during normal riser operations. This last point is vital to drilling operations in deepwater in hurricane-prone areas. Weather conditions can change quickly and even a non-faired deepwater riser takes 2 to 3 days for a full retrieval.

BP continues to research and document suppression device types and to assess their practical performance. A supply choice in the market place is important so that the correct device can be used for particular situations. To this end, we have recently worked with cooperative partners to demonstrate the hydrodynamic performance of a handful of the most promising devices. This paper is a tailored synopsis of previous suppression concepts and the philosophical pathway toward what is available on the market today. At its core are recent circumstances which precipitated a need to quantify and qualify for operational acceptance the performance of two commercially available short aspect ratio fairing devices. (i.e. a dual-fin splitter and an airfoil-shaped fairing). This paper discusses the results of the large-scale model acceptance tests over prototype Reynolds number for these devices.

In addition to rigid devices, a relatively newer suppression product that "inflates" in the direction of the relative flow was also assessed by BP for expected hydrodynamic performance. This device shows particular promise for the mitigation of VIV during drilling operations surprises in high currents along with appearing potentially commercially viable.

INTRODUCTION

During 2005, industry wide offshore drilling operational efficiency in the Gulf of Mexico (GoM) was badly hit by a series of hurricane and loop current events. Managing drilling operations in GoM loop currents is challenging, but when combined with hurricanes the potential to severely decrease a drill rig's operability is magnified significantly; particularly in the case of moored rigs, which can neither evade a rough-weather situation nor use their relative motion to ease the process of retrieving a riser. Decreasing drill rig operability can equate to many tens of millions of dollars in unproductive costs given prevailing drill rig rates.

As such, BP considered it sensible to review equipment available to a production company and drilling contractor in helping to maintain drilling riser operational efficiency in high currents for future drilling operations. The work tended toward two main areas. The first being that of devices that can be attached to the drilling riser to decrease drag and suppress vortex induced vibration (VIV). The second was the development of an improved mechanical drilling riser centralizer system that could be used to expand the operational window for drilling riser recovery in high loop currents; this being of particular importance during the GoM hurricane season.

In this paper, we will address some of the work done in the area of available devices for reducing riser drag and vortex induced vibration (VIV) suppression with the intent of improving drilling operability.

FLOW DEVICES – SUMMARY HISTORY

Within the field of hydrodynamics a large amount of work has been done over the years in relation to fluid flow around many forms of bodies. (Ref. 1) For an operating company, a key question is: what types of flow improving device are presently available or could be available for use on deepwater drilling risers and how workable are they?

A comprehensive review was undertaken with the objective of identifying and evaluating the performance claims made for a range of flow device concept types. (Ref. 2) The review considered and subsequently classified a wide range of devices into the two broad classes; these being defined as 'passive' and 'dynamic'. *Passive* devices were defined as those devices that required no motive power; whereas the *active* class requires motive power, typically employing air or water pumps to disrupt vortex shedding mechanisms. Key to the operational evaluation of the workability and performance claims made was the recognition that a deepwater drilling riser needs to be deployed and recovered in the shortest time possible. As a benchmark, a typical deepwater drilling riser in 6,000ft of water is recoverable in a 72-hour period. Note the importance of such timings in hurricane season when event occurrence predictions can be of similar timings.

Within the 'passive' class the following types of flow influencing devices were investigated together with the associated performance claims made for the device. An abbreviated set of characteristic comments are listed against each. The aim being to identify and clarify what is available to the operator.

Fairings (rigid) - Figure 1 – Multiple designs of this device are commercially available and are in operational use. In some cases, the concept is proven in VIV suppression and drag reduction. However not all design forms (range of chord-to-diameter (C/D) ratios and form – Figure 2) function similarly with effective VIV suppression. Indeed, certain fairing forms have suffered from instability issues (Ref. 8). There is evidence that these devices are less sensitive than other devices to marine growth marring their performance. They require robustness in their mechanical design, particularly in their ability to weathervane. Depending on their design, they can introduce a significant penalty in terms of the time to install and remove them during deployment and retrieval of the drilling riser.

Deformable Shrouds/Fairings - Figure 16 – These devices are compliant and "inflate" down stream of the oncoming current. Their VIV suppression performance and associated drag reduction ability have been demonstrated in the laboratory. They, like rigid fairings, have relatively lower sensitivity to marine growth. Unlike fairings, their installation and removal during riser running and retrieval are potentially much easier and quicker, which would yield key operational benefits. Commercial development of a robust flexible device is progressing with prototype fabrication and field trials in the planning stages.

Buoyancy Module Distributions – Operationally, staggering of buoyancy elements or bare and buoyed drilling riser joints has been utilized as an approach to mitigate VIV. There is, however, limited data on its actual VIV suppression performance other than that which has been arrived at anecdotally. Nonetheless, buoyancy elements in both uniform and staggered configurations are used routinely on existing GoM deepwater drilling risers. If its efficacy could be demonstrated, a key advantage of this approach is that it incurs no time penalty during the running and retrieval of the riser.

Buoyancy Module - Helical Grooved (Inverted) Strakes – Figure 3 – The concept of helical grooves cut into buoyancy modules has been tested with significant VIV suppression recorded. Timely deployment and recovery are major prizes given that inverted strakes could form an integral part of buoyed deepwater riser joints. Not surprisingly, these devices' performance is sensitive to marine growth in the grooves. Development work is required to optimize groove geometry and to engage buoyancy element manufacturers in fabrication approaches.

Axial Rod Shrouds – Figure 4 **–** This concept has been model tested with significant VIV suppression recorded after the tuning of overall diameter geometry and number of rods. The use of rod shrouds is likely to require attachment and removal during deployment and retrieval with the associated time penalties. Marine growth is again envisaged as a potential detractor from hydrodynamic performance.

Perforated Shrouds – Figure 5 - While these devices have been used in air, there appear to be no products offered for drilling riser applications, despite the fact that they indeed appear to suppress VIV in water as well. The required extent of riser coverage and increased riser diameter over buoyed joints appear to be considerable hurdles for practical operational use.

Windings/helical wraps - Figure 6 – Helically wound ropes have been used to counter VIV in certain drilling situations when vibrations occurred unexpectedly. This has tended to be a temporary solution. Purpose-designed strake wraps internal to and external to auxiliary lines have been model tested with some success. (Ref. 3) However, at present, no such products appear to be available for full scale use. Key issues would be the robustness of the wrapped material and the deployment and retrieval time required for its installation and removal.

Hoops / spaced spoilers – Figure 7 – Hoops with spoilers discretely spaced along the length suppress VIV according to model tests, but introduce a major increase in drag loading. They also carry similar operational robustness, installation and timing issues to other devices with these drawbacks.

Fins / Bumper Bars – Figure 8 **–** These devices are currently employed on many drilling risers with the stated purpose of aiding in joint storage and protecting the auxiliary lines on slick (non-buoyed) riser joints. However, they have been demonstrated in the laboratory and in the field to suppress VIV. While they incur a slight drag penalty, since they are permanently installed on riser joints, they introduce no time penalty during deployment and retrieval. They can only be used on slick joints and a deepwater riser is typically predominantly made up of buoyed riser joints. However, it is surmised that relatively few VIV suppressed joints in the upper part of the water column where currents tend to be highest may be sufficient.

The range of 'passive' devices are at various stages of maturity while in the main the 'active' class of devices such as water jetting and air bubble pumping are at an earlier stage of development. Indeed, such active devices face major hurdles in terms of added operational complexity together with attaining acceptable operational economics. Thus, no further comment will be made on active devices herein.

THE OPERATOR'S OPTIONS

After an operational review of various suppression devices, considering performance testing, level of development and claimed operational status, nearer-term most favourable options appeared thus:

1. Fairings (rigid) - various designs in use
2. Fairings (flexible) - prototype construction underway
3. Fins/Bumper Bars - designs in use
4. Helical Wraps - previously used as temporary mitigation

Additionally, the staggered distribution of buoyancy elements along the riser can be seen on a number of deepwater risers configured for use in the GoM.

When considering the use of VIV suppression devices for drilling operations, the following typical physical working characteristics need to be considered for complete clarification and understanding of performance:

- Dynamic behaviour – motions, loads, stability, failure modes
- Robust mechanical design – fitness for a working drilling environment, storage, maintenance
- Marine logistics – container transfer and storage demand , hurricane evacuation
- Deployment/recovery efficiency - time management, GoM hurricane season interaction
- Mechanical handling - Crew resources, cross lifting, rig modifications
- Health/Safety/Environment – dropped objects, failure risks and consequence

The physical characteristics of the various VIV suppression devices have time and resource consequences that can be translated into overall operational efficiency. In turn, the comparative efficiency may be evaluated in terms of operational expenditure or costs. (i.e. OPEX) Typically fairings require attachment and removal while running and retrieving the riser. This can take much more time than when working with standard slick and buoyed joints. Real offshore deployment times have resulted in multipliers of 5 to 12 times longer for the handling of a faired joint over that of a slick joint. The actual time taken depends on the mechanical complexity of the fairing attachment design.

Other suppression devices, such as fins or bumper bars, are permanently attached but they also tend to increase drag which in turn impacts the riser top and bottom angles and hence drilling operations in currents.

Finally, operational risk and consequence need to be considered and fully understood when augmenting existing drilling riser running or pulling operations with additional operational duty steps. These along with failure of any attached devices present the risk of extending riser timings. This recognition is critical when operating in the GoM hurricane season when the prediction of such events typically allows only a 3 to 6-day window for preparation.

The final deployment decision needs therefore to be based on a risked comparative investment decision resulting from operability benefit analysis. A typical tool used to help make these decisions is the SLOOP computer program provided by BMT. (Ref. 4)

The hydrodynamic and dynamic performance of suppression devices - reducing drag with associated lower riser angles and/or suppressing VIV for improved riser and wellhead integrity - is central to quantifying the targeted improved operational drilling window. Over the years, many claims have been made in published papers regarding the hydrodynamic performance of fairings for drilling risers. Some report significant VIV and drag reduction benefits while others show that larger C/D fairings exhibit flutter instability. Shorter C/D fairings have also attracted varying behavioural performance claims.

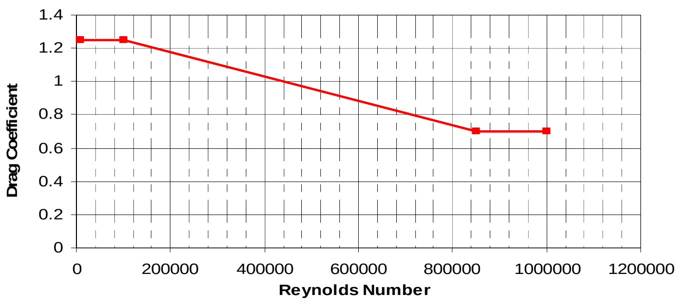
To help understand and clarify performance it was decided to invite fairing suppliers to submit their latest products for large scale model tests. Following the invitation, two suppliers came forward with products they were prepared to let BP test against a pre-declared set of acceptance criteria. The two companies were AIMS and Trelleborg. In addition, a third company, Allbrown requested that we perform initial proof-of-concept tests on a new product based on flexible fairing technology. We therefore had two products to gauge against specific performance acceptance criteria and a new concept to evaluate in terms of basic VIV suppression.

FAIRINGS - PERFORMANCE ACCEPTANCE CRITERIA

The following performance acceptance criteria on drag, VIV suppression and dynamic motion amplitudes were specified for the two rigid fairing devices.

Drag reduction:

- Performance equal to or better than assumed design curve for bare riser joints:



VIV Suppression, Stability, Motion Amplitude:

Less than Reynolds number = $3x10^5$

- At VIV frequency: No motion > bare pipe A/D
- At flutter frequency: - No motion > A/D = 2.5

Greater than Reynolds number = $3x10^5$

- At VIV frequency: No motion > 10% of bare pipe
- At flutter frequency:- No motion > A/D = 0.5

FAIRINGS – ACCEPTANCE MODEL TESTS

The AIMS and Trelleborg fairings were modelled at near quarter scale relative to a prototype buoyed drilling riser diameter of 1.33 metres. The AIMS fairing is a dual fin splitter (ADFS) design and is shown in Figure 11. The Trelleborg fairing design is more traditional in that it is a streamlined body section and is shown in Figure 12.

The large scale acceptance tests were performed at the Institute for Ocean Technology in St. John's, Newfoundland, Canada. The test apparatus has been used for many such model tests in recent years and the set up is fully documented in Ref. 5. Generally, the 90 tonne carriage spans the 12m wide by 7m deep tow tank and has a maximum speed of 10m/s. The carriage is rated for a maximum towing force of 20kN. The VIV model test apparatus has two basic modes of operation: forced vibration at defined frequency and amplitude and free vibration for ranges of frequency settings. The model test specimen is 6.328m long and 0.325m diameter and, as mentioned above, this provided a model scaling of 0.24 relative to full scale.

The carriage speed was varied from 0.5 to 4.5 m/s giving Reynolds numbers (Re) up to approximately 1.6 x 10^6. The model test apparatus allows for the variation in system stiffness by changing support springs. The resulting variation in stiffness give a reduced velocity range V_{RN} of 0.6 to 25.7 at model scale. The combined possible model test footprint of V_{RN} and R_e is shown in Figure 9.

To benchmark the fairing results, comprehensive fixed and freely vibrating roughened circular cylinder tests were conducted for direct comparison. Typical results from these tests are shown in Figure 10. The drag coefficient is seen to significantly increase with the vibrating amplitude. This once again confirms the importance of VIV motion on drag and hence drilling riser operations based on top and bottom angle management.

The model tests for both sets of rigid fairings produced positive results in each category of acceptance. The freely vibrating tests for both devices produced drag coefficients around 0.6. (Figures 13 and 14) In terms of VIV suppression, both Trelleborg and AIMS devices met the acceptance criteria. No flutter was observed for either device. As an example, the ADFS response amplitudes as a function of diameter are shown in Figure 15.

VT FAIRING – VIV SUPPRESSION PERFORMANCE

As previously mentioned, when potential fairing suppliers were approached a new flexible concept (Ref. 6) was tabled for assessment and it was decided to assess its drag and VIV suppression capabilities. This was based on the premise that if the concept performed hydrodynamically, then it appeared to have significant benefits in operational deployment and recovery and also swiftness for retro-fitting.

The device has been developed by the company Allbrown Universal Components and named the "VT". The flexible VT fairing net contains specifically shaped rodlets and deforms under fluid flow to take a streamlined fairing shape. (e.g. Figure 16)

The model tests were conducted in the modes of development and proof-of-concept, in contrast to the previous large scale acceptance tests previously reported. The model riser was 2.4m long and 0.093m in diameter. For these tests the model riser was sectioned along its length and tensioned via an axially running cable such that it had a natural frequency of approximately 4.2 Hz. The tests were conducted at the Southampton University tow tank.

The test matrix covered a nominal reduced velocity range of 4 to 9 with frequency based on the still water response. The associated Reynolds numbers were 4×10^4 to 1.4×10^5 with the VT fitted over the cylinder. (Figure 17) The proving tests also included varying net lengths and rodlet density to gauge any variation in response and VIV suppression.

During testing, the bare cylinder responded as expected with large amplitudes over the complete velocity range. Indeed, it was decided to limit tow speeds to lessen the risk of apparatus damage. The bare cylinder dynamic drag coefficient varied from 1.25 to 1.5. (Figure 18)

The VT was found to be effective at VIV suppression and produced a reduced drag characteristic compared to the bare cylinder results. The VT also increased damping over bare cylinder values. The proving tests showed differing response for varied net length and differing rodlet density configurations. In the optimum geometric arrangement VIV response was reduced to less than 0.1D (Figure 20) with reduced drag loading. (Figure 18)

It was concluded the VT is a promising solution and a full scale field trial is being constructed to address mechanical handling and deployment development.

FAIRINGS - FULL SCALE OPERATIONAL EXPERIENCE TO DATE

BP has been measuring and monitoring the behaviour of deepwater drilling risers for a number of years and certain VIV findings are being presented in another paper at this conference. (Ref. 7)

It is worth noting that full scale measurement has taken place on two deepwater GoM drilling risers that have had fairings fitted. These fairings were of differing designs (i.e. full wrap and tail-fin) and both sets were supplied by Shell Global Solutions, Inc. (SGSI). Unfortunately neither of these fairing types was made available for BP's acceptance model testing. However it can be said in summary from the full scale monitoring results (Ref. 7) that the fairings appeared to suppress VIV behaviour in higher currents.

WHAT NEXT?

VIV and the associated amplification of drag can influence drilling operations in high loop currents. Via the suppression device acceptance testing described we have arrived at a technically supportable position that as an operator we can more confidently use certain fairing designs that are presently available to suppress VIV and lower the drag on the drilling riser string. The final decision to use fairings for a particular drilling campaign is driven by the cost-benefit analysis that was previously mentioned.

It is also pleasing to see that the industry is being offered new devices that could ease the deployment decision while reducing the time penalty associated with rigid fairings. We intend to continue to encourage the development of such solutions and document this progress at a later date.

ACKNOWLEDGMENTS

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REFERENCES

1. Hoerner, S.F. (1965). "Fluid – Dynamic Drag." Self – published.

2. King, R. (2006). "Practical Hydrodynamic Solutions/Devices for Retrievable Risers in High Currents." BP Internal Report.

3. MARINTEK/NDP. "VIV suppression tests on retrievable riser systems, CWOR." MARINTEK Report No 580061.00.02.

4. BMT. (2006). "BMT Sloop Users Manual and Reference Manuals."

5. Spencer, D. (2004). "High Reynolds Number cylinder vortex induced vibration test apparatus." *Oceanic Consulting Corporation*. Rpt. No.: INT062-01.

6. King, R. and Brown, A. (2007). "Model test of the VT suppressor." Report No AB-BP-VT 01- March 2007.

7. Tognarelli, M.A., Campbell, M., Taggart, S. (2008). "Actual VIV fatigue response of full-scale drilling risers: With and

without suppression devices." *Proc. 27th Int'l. OMAE Conf.*, Estoril, Portugal.

8. Slocum, S.T., Ding, Z.J., Frank, W.R., Cox, M.R. (2004). "Flutter instability in riser fairings." Offshore Tech. Conf., *OTC 16342*, Houston, TX.

FIGURES

Figure 1: Full Wrap Fairings on Deepwater Drilling Riser

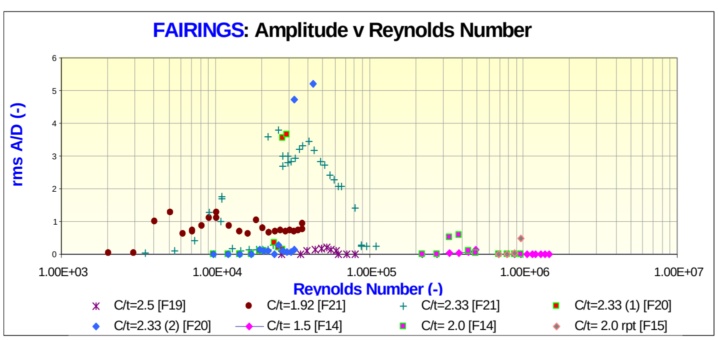

Figure 2: Summary graph of Fairing experimental results from literature reviewed. Flexible cylinders (A/D vs Re)

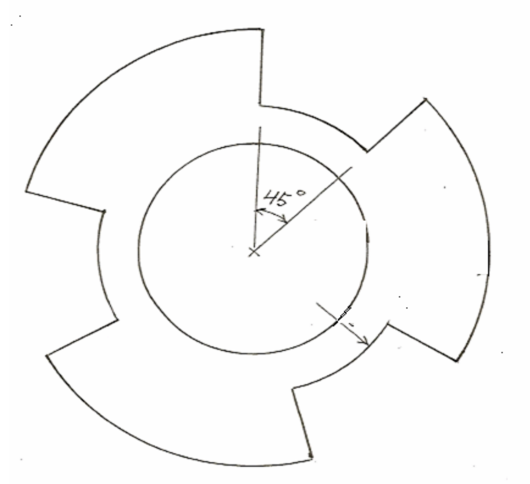

Figure 3: Inverted Grooved Helical Strakes

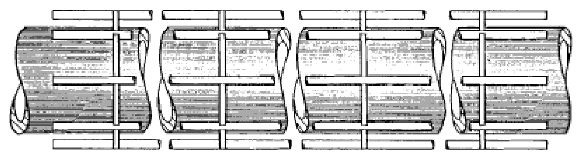

Figure 4: Axial rod shrouds

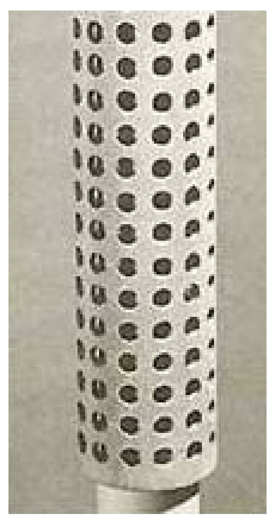

Figure 5: Typical Perforated Cylindrical Shroud form

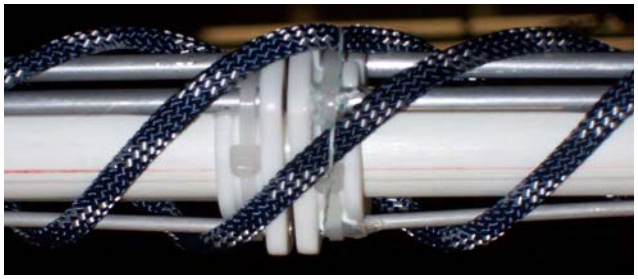

Figure 6: Helical Rope Wrap over auxiliary lines

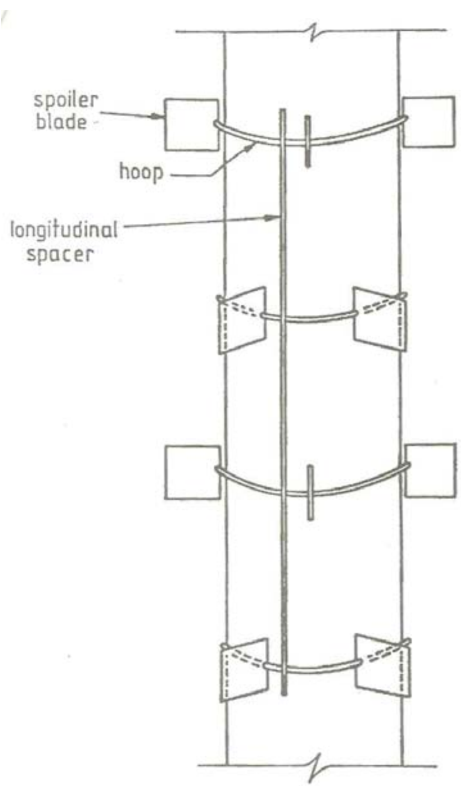

Figure 7: Hoops / Spaced Spoilers

Figure 8: Lankhorst Fins on Drilling Riser

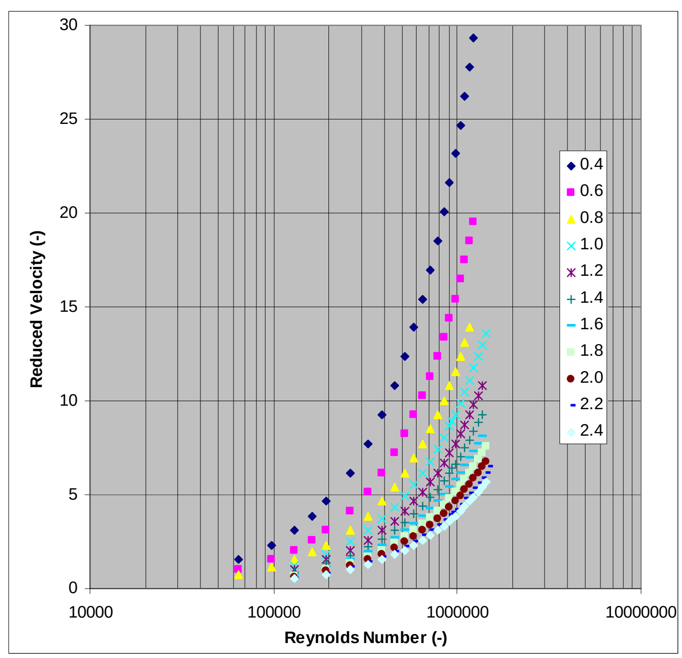

Figure 9: Re vs Reduced Velocity – 0.24 scale Model Test Matrix Footprint (varied frequency Hz)

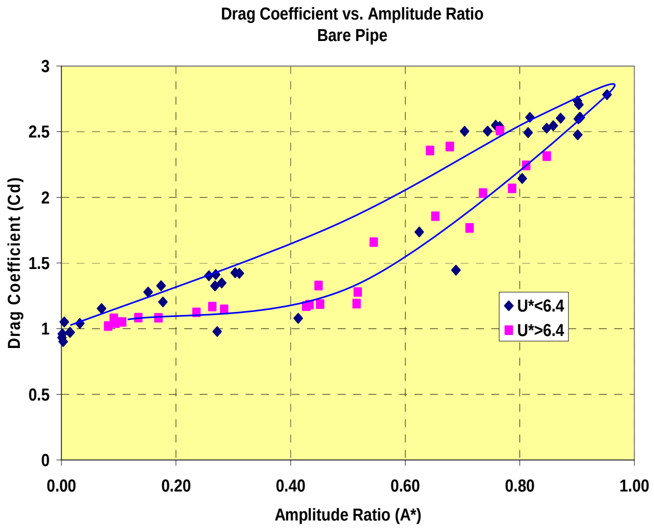

Figure 10: Drag Coefficient, CD, versus Amplitude Ratio, A*, for the Bare Pipe

Figure 11: AIMS Dual Fin Splitter fairing Installed on Dynamometer

Figure 12: Trelleborg Fairings installed on Dynamometer over tow tank

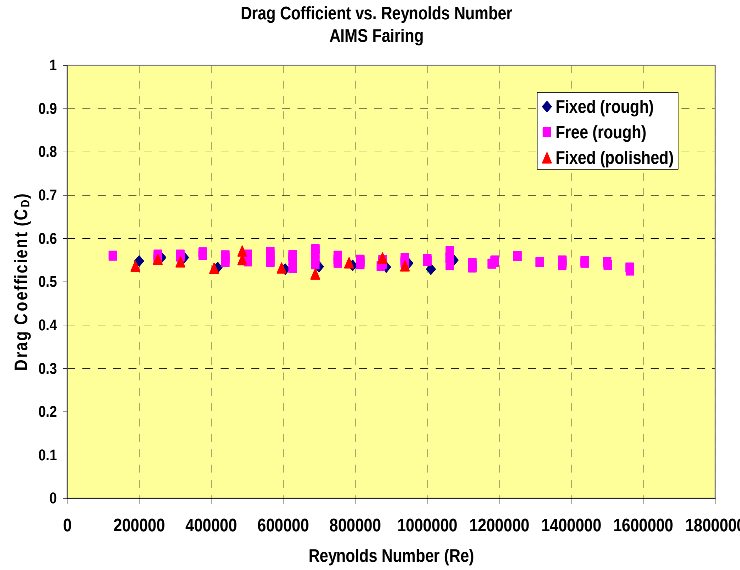

Figure 13: Drag Coefficient, CD, for Freely Vibrating ADFS

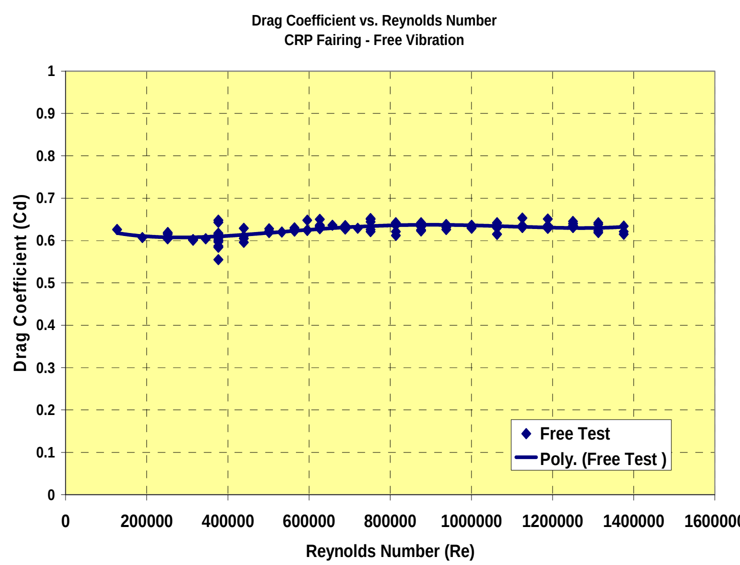

Figure 14: Drag Coefficient, CD, for Freely Vibrating Trelleborg Fairing

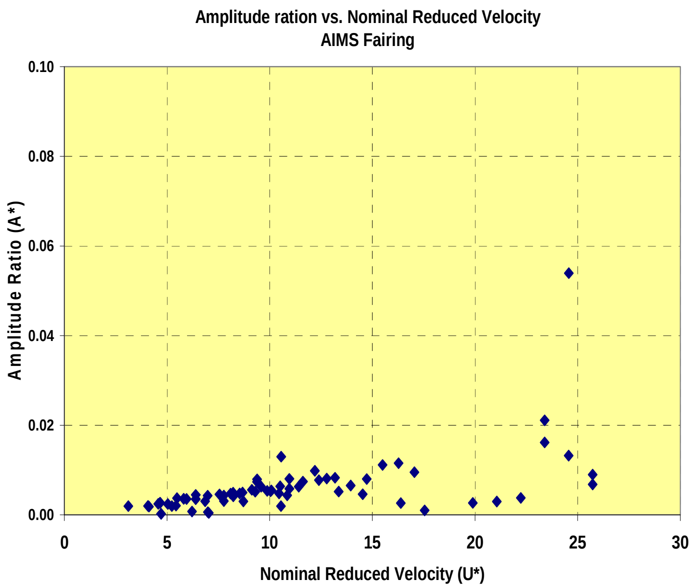

Figure 15: Amplitude Ratio versus Nominal Reduced Velocity for the ADFS

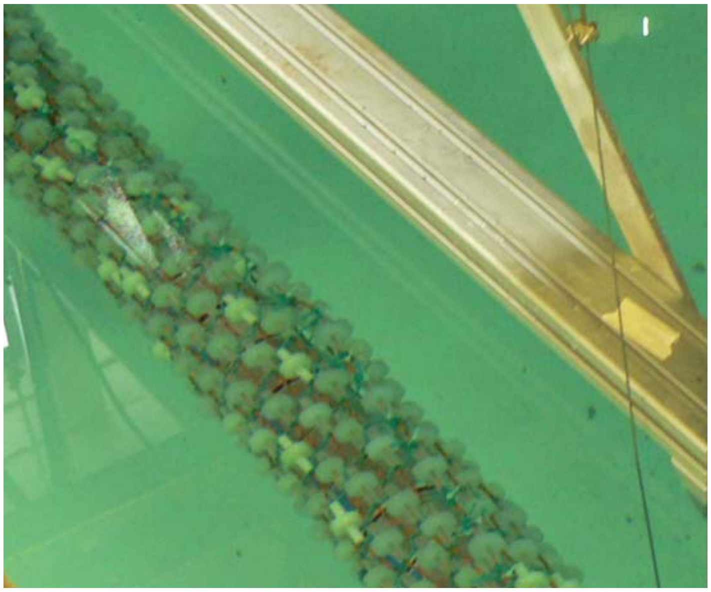

Figure 17: The VT Suppressor fitted on the model riser

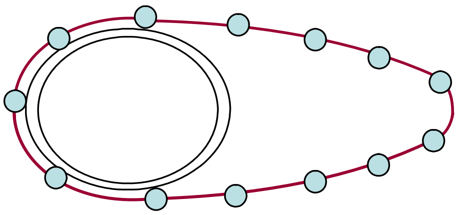

Figure 16: The VT net form for the low drag hydrodynamic shape

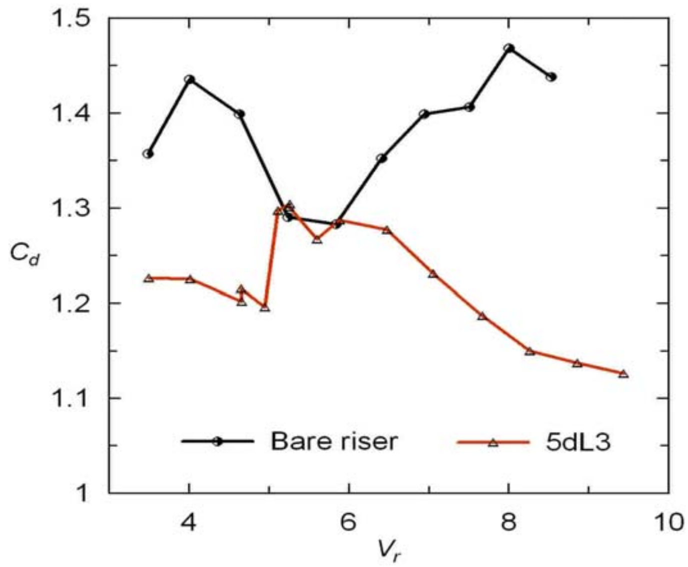

Figure 18: VT Drag coefficients as functions of Reduced Velocity

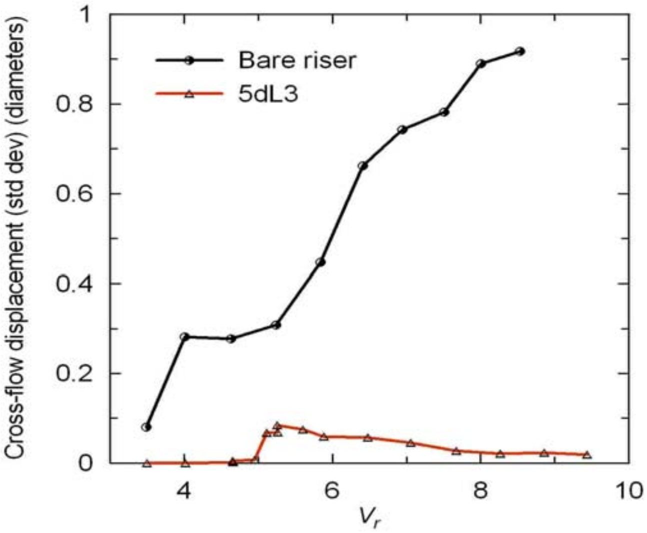

Figure 19: VT Standard deviations of cross-flow displacements as functions of Reduced Velocity