INSTITUTO ARGENTINO DEL PETROLEO Y DEL GAS

IMPROVING OPERABILITY AND REDUCING COSTS OF DRILLING RISER OPERATIONS THROUGH THE USE OF LGS VIV AND DRAG SUPPRESSION TECHNOLOGY

A Tovar, P Kurts, D Johnstone, H Marcollo, A Potts; andres.tovar@amog.consulting; AMOG Consulting

Abstract

Vortex-Induced Vibration (VIV) has long been recognized as a significant challenge facing the offshore oil and gas industry globally. Many types of infrastructure are adversely affected by VIV and the associated increased drag, leading to increased fatigue damage and reduced operability. Specifically, drilling riser deployment, operation and retrieval is one area of the industry that has been in need of new VIV suppression technology for a number of years.

Many drilling risers have large sections covered in cylindrically shaped buoyancy modules, which can result in significant VIV response, which amplifies the drag experienced by the riser. This can cause suspension of operations as the top and bottom angles during high current speeds surpass allowable limits. Operations can be delayed, and in some cases complete disconnection and retrieval of the riser string may be necessary. Although some suppression technologies do exist to reduce the VIV response itself (such as helical strakes and fairings as shown in Figure 1 and Figure 2), these have significant shortcomings including poor reliability, lengthy installation times, safety concerns related to their fitment below the drill deck floor, and other practicality issues. All of these issues have significant associated costs.

An innovative new technology, named Longitudinally Grooved Suppression (LGS), has recently been developed, tested and deployed multiple times in drilling campaigns in the Gulf of Mexico. Numerical modeling of full scale risers in measured current conditions from around the world has also been conducted. What separates LGS from other suppression technologies is its optimized balance of VIV suppression, drag reduction and design for practical handling. Inspired by the Saguaro cactus, LGS attempts to mimic nature's perfection with its uniquely-shaped profile which exhibits low VIV and drag characteristics. When applied to buoyancy modules, the result is a product that is fully integrated into the modules themselves during the manufacturing process, with no moving parts and no need for additional installation or fitment time in the field.

This paper provides a brief overview of the results of physical model testing before describing the methodology and analysis of a full scale riser specifically deployed offshore South America. It will report the results of the riser's drag and fatigue performance in a range of measured current profiles from South America. This paper ultimately illustrates that, by applying LGS technology to a South American-deployed drilling riser, significant financial savings can be achieved through increased operability and increased fatigue lifetimes.

Introduction

Vortex-Induced Vibration (VIV) is a significant challenge for the offshore oil and gas industry globally. It occurs when the frequency of the vortices shed from a cylindrical structure exposed to fluid flow is similar to a natural frequency of the structure. VIV affects many types of offshore infrastructure, and oil and gas production in deeper water increases the susceptibility of many structures to VIV. Of particular interest is the VIV response of drilling risers. Limitations on the acceptable top and bottom flex joint angles lead to VIV having an impact on drilling riser operability. In high currents, VIV amplifies the drag forces on the riser, resulting in unacceptable deflections. Operations may need to be suspended and in some cases the riser must be retrieved to prevent damage. In addition, drilling risers accumulate fatigue damage as a direct result of VIV oscillations. Together, the impacts of VIV on operability and fatigue damage carry significant cost implications for drilling contractors and operators. Drilling projects in South America have in the past been aborted due to high currents and the effects of VIV [1].

In order to reduce the riser tension, deepwater drilling risers are typically covered with Drilling Riser Buoyancy Modules (DRBMs) over most of their length. In order to provide effective buoyancy, DRBMs must have the maximum practical cross sectional area. This is constrained by the limited space available at the drill floor.

Helical strakes (as shown in Figure 1) are used in many applications throughout the offshore industry as a VIV suppression device. They are used to almost completely eliminate the VIV response, at the cost of significant additional drag. They are not typically used on drilling risers because the size of the helical strakes required to effectively suppress VIV (approximately 15% of the total outer diameter) significantly reduces the available buoyancy. If they were to be used, the slender shape of the helical strakes would make them susceptible to damage.

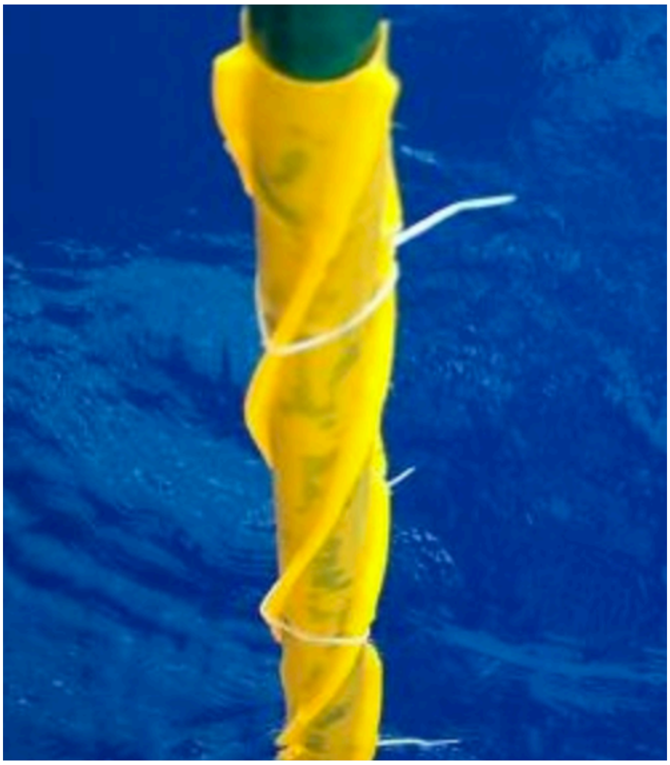

Figure 1: Example of Helical Strakes [2]

Drilling risers with VIV suppression fitted typically use weathervaning (i.e. able to rotate to align with the flow direction) fairings. Fairings present a streamlined geometry to the flow which produces little VIV excitation. However, the need for fairings to be aligned with the flow direction (weathervaning) introduces additional complexity into their design. Fairings are fitted on top of the DRBMs and are susceptible to failure of the weathervaning mechanism. This can result in jamming of fairings which, unable to rotate, may not be aligned with the flow. The performance of fairings in this condition is unknown, despite it being a common occurrence. Fairings may also break free of the riser during operation, and anecdotally up to 20% of the fairings have been known to fall off. Most significantly, fairings require additional time for deployment and retrieval of the riser. Fairings must be fitted below the drill floor, as they are too large to fit on the riser during deployment. The manual installation of fairings below the drill floor exposes personnel to additional risk, delays deployment of the riser and can add enough time to the retrieval of the riser to prevent the drilling vessel from quickly relocating to avoid storms. Because of these drawbacks, when fairings are used they are typically only installed on the part of the riser most likely to be exposed to high currents.

Figure 2: Example of weathervaning fairings [3]

Longitudinally Grooved Suppression (LGS) is a VIV suppression technology that can be integrated into DRBMs. The technology is optimized for drilling risers, and balances the competing requirements for VIV suppression, low drag, buoyancy and ease of handling. LGS can be used on DRBMs without significant loss of buoyancy, and the handling of the riser for deployment and retrieval is unchanged. Because LGS is integrated into the DRBMs, VIV suppression and drag reduction can be achieved over the entire length of the riser.

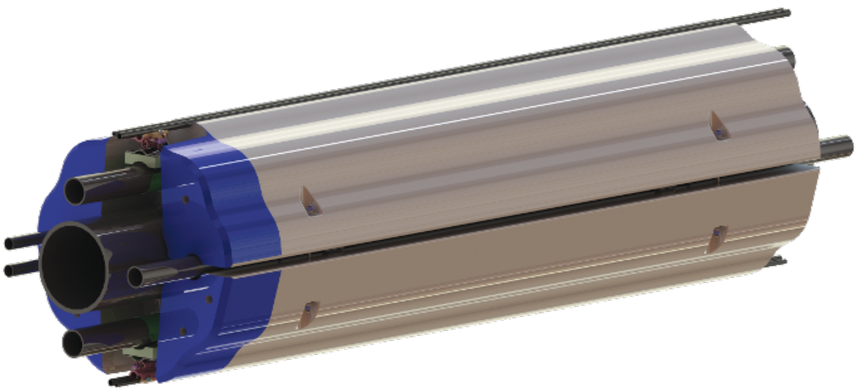

Figure 3: Longitudinally Grooved Suppression (LGS) [4]

LGS was developed using physical model tests to measure the hydrodynamic performance of the geometry. This paper presents the hydrodynamic properties measured during the physical tests, and the results of analysis of drilling riser systems in realistic South American current conditions.

Development

The design of LGS was inspired by the Saguaro cactus, which has evolved to withstand strong winds by growing in a shape which has lower drag than a regular cylindrical shape.

The initial development of LGS made use of small scale model testing at Monash University in Melbourne, Australia. 3D printing technology was used to test over 50 different variants of the LGS concept. Once a design was reached which presented optimal characteristics for drilling riser applications, high Reynolds number testing was conducted at the National Research Council tow tank in St. John's, Canada.

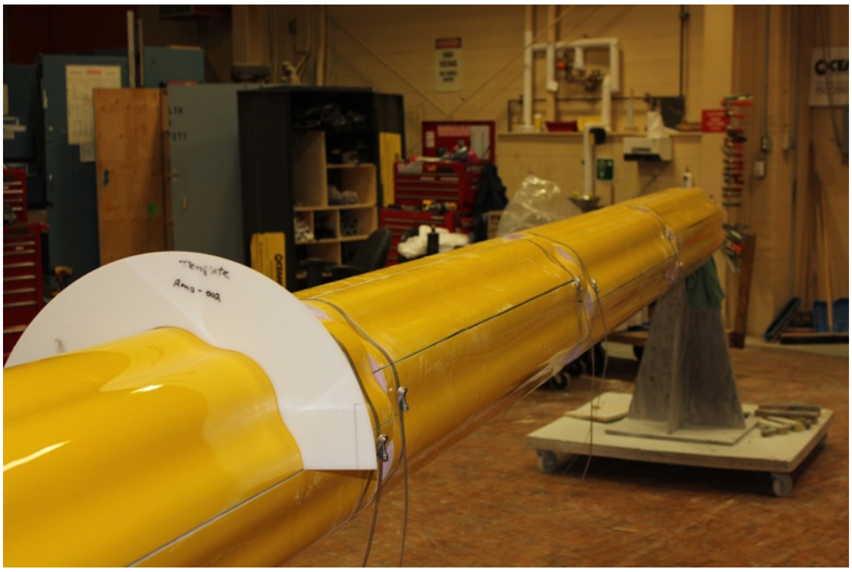

Figure 4: High Reynolds Number Test Model

The results obtained from the testing have been reported previously [5]. In summary, the drag coefficient was found to be consistently less than 0.6, and both the lift coefficient and the drag amplification when VIV occurs were found to be significantly lower than a bare cylinder. Maximum amplitudes of vibration were measured to be less than 0.25 diameters. These results indicate the suitability of LGS for use in drilling riser applications, as both VIV excitation and total drag will be significantly lowered, improving both operability and fatigue life.

South American currents

The prevailing currents offshore South America are often characterized by undercurrents which run in the opposite direction to the current at the surface (otherwise known as countercurrents) [6][7][8]. This introduces unique challenges for maximizing fatigue life and operability of drilling risers in conditions which cause VIV. While a previous analysis [9] investigated the effectiveness of LGS DRBMs in measured currents from Brazil, the current profiles analyzed did not include any countercurrent acting at depth. In order to understand the effect of countercurrents on the performance of drilling risers with VIV suppression, current profiles for a South American location have been used to perform a similar analysis. The results are compared to the previous results for measured Brazilian currents. The current profiles simulated in the two sets of analysis are shown in Figure 5. As shown in the graphs, the notable features of the South American currents investigated in this paper compared with those previously analyzed are as follows:

- Maximum current speed at the surface, as opposed to at 200-300 m depth.
- Countercurrents of significant strength deep in the water column.

Two different currents were considered for the analysis, a Long Term Current (typically expected to exist at the site for the majority of a year) and an Extreme Current (representing an event expected to occur once in several years). Both of these currents were modeled with and without countercurrents known to exist at the site, giving four current profiles in total.

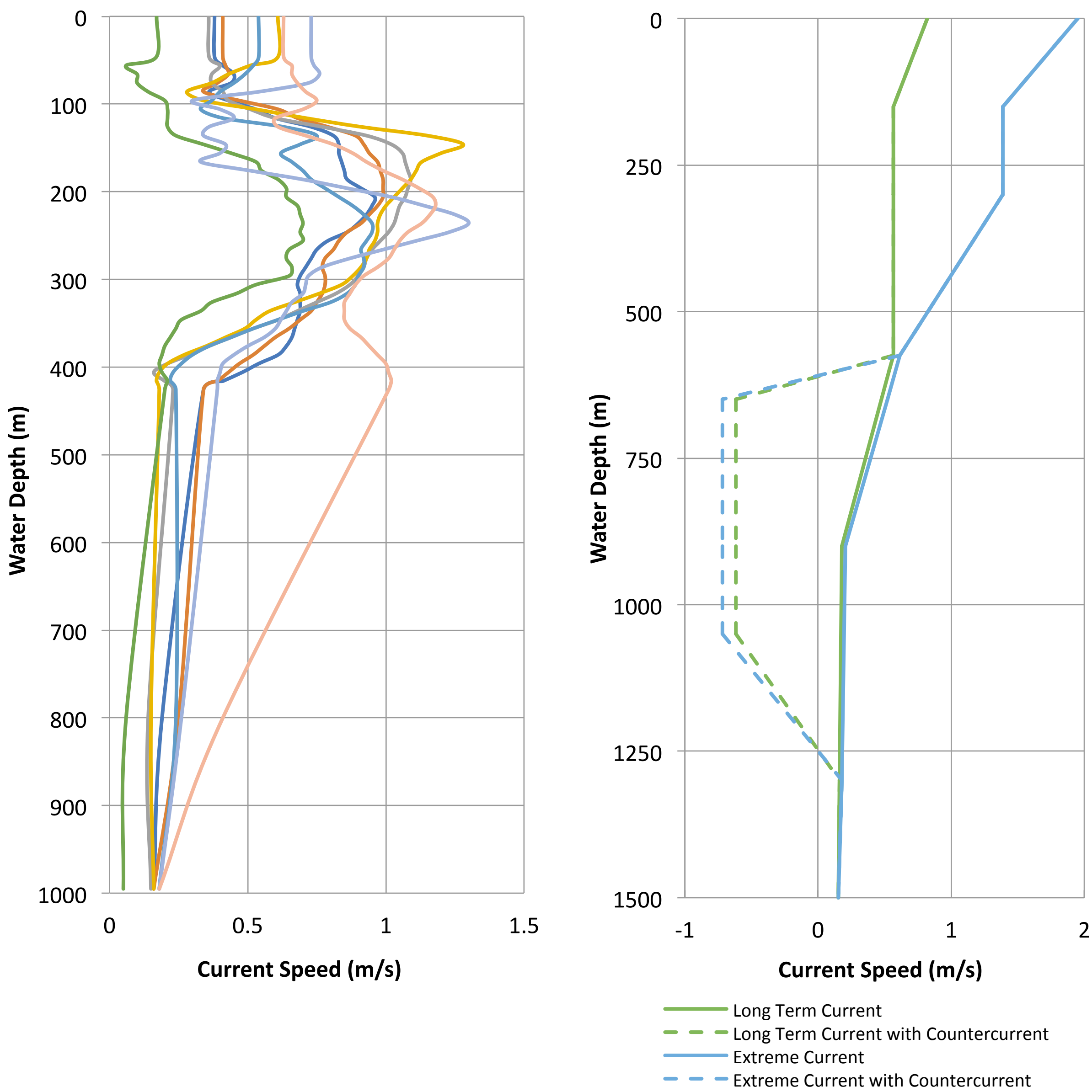

Figure 5: Analyzed Current Profiles
Previously analyzed Brazilian current profiles (left) and South American currents with countercurrents (right)

A summary of the water depths and riser tensions used in the analysis for each set of current profiles is also provided in Table 1. The modeled riser arrangements are shown diagrammatically in Figure 6. Where fairings were modeled, they were included over the top 183 m of the buoyancy modules in the previous analysis, and 274 m of the buoyancy in the present analysis. This was a result of the increased water depth in the analysis for this paper. It should be noted that while increasing the number of fairings applied to the riser may improve VIV suppression, doing so requires considerable additional time during deployment and retrieval of the riser.

Table 1: Analyzed Water Depths and Riser Tensions

	Previous analysis of Brazilian currents	Analysis of South American currents with countercurrents
Water Depth (m)	1000	1500
Riser Tension (kN)	2370	5980

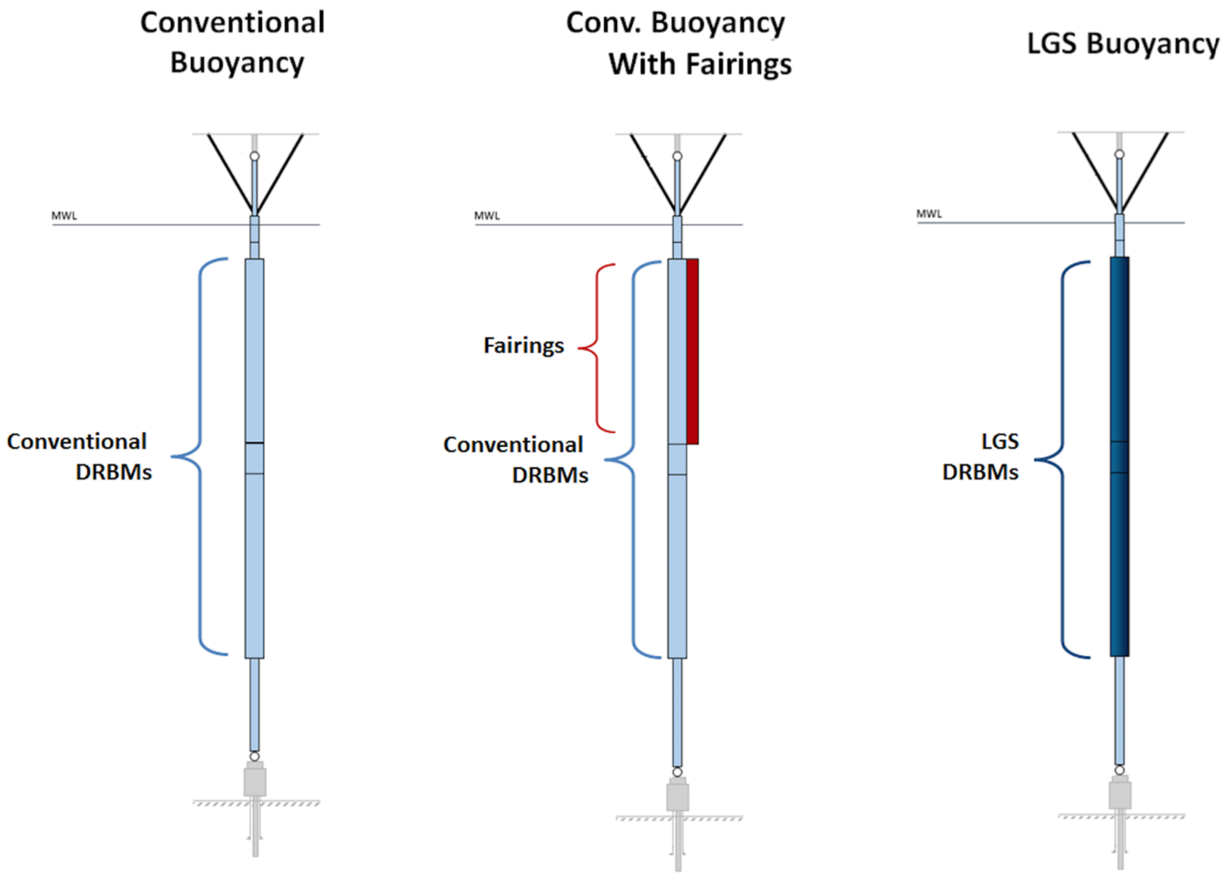

Figure 6: Modeled Riser Arrangements

In order to accurately model the performance of LGS DRBMs, the analysis was performed using the methodology developed for previous investigations [10]. In short, a customized version of SHEAR7 was used to predict the VIV response, accounting for the fundamentally different behavior of LGS, fairings and conventional cylindrical modules.

Results

In the Long Term Current profiles, the modeled LGS equipped drilling riser was found to exceed the performance of conventional buoyancy modules and fairings in terms of riser offset and the resulting top and bottom angles. Riser offset graphs, which show the deflection of the riser string down its length, are shown for the four modeled currents in Figure 7 to Figure 10. The performance benefits of LGS DRBMs are particularly significant when a countercurrent is considered, as the presence of VIV suppression over the entire depth of the riser suppresses the VIV response in all locations. In contrast, the typical fitment of fairings in the upper section of the riser means that no VIV suppression is placed in the countercurrent region. The fairings were shown to be most effective (although still less effective than LGS) in the Extreme Current (without countercurrent), as the highest current speeds are in the region with fairings.

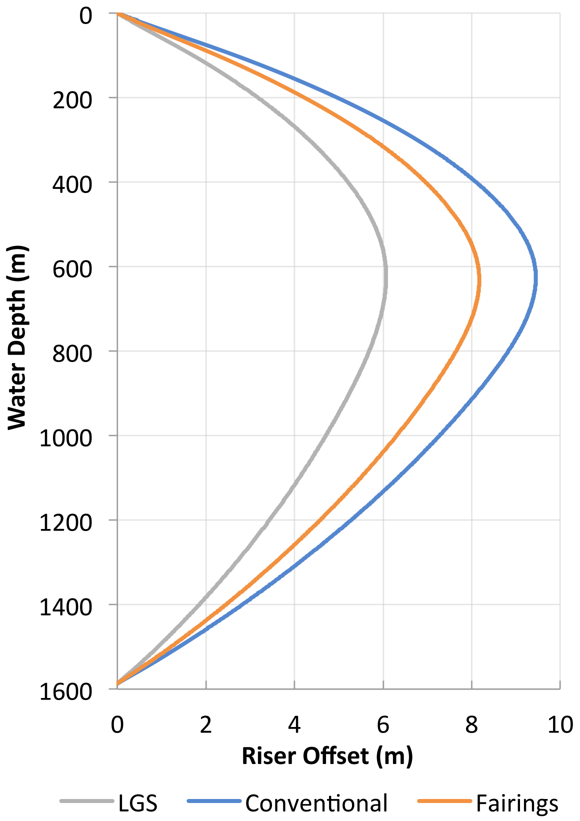

Figure 7: Offset Results for Long Term Current

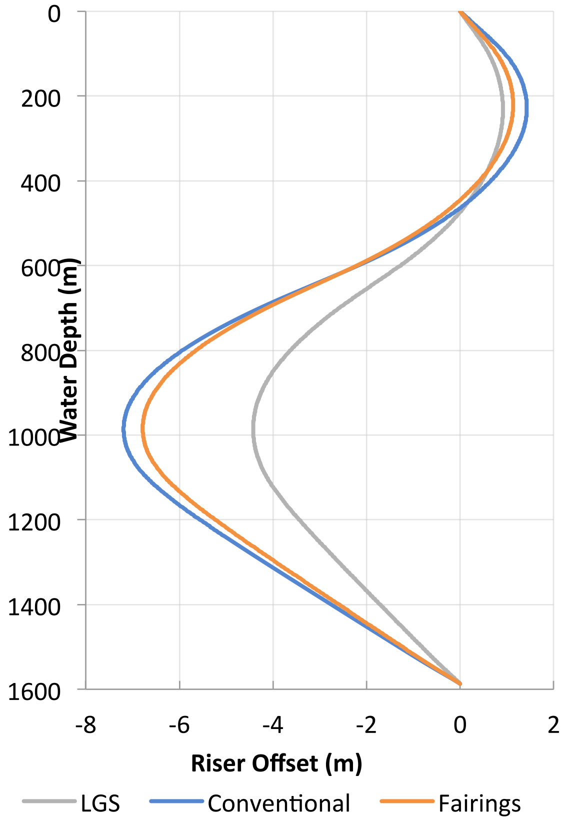

Figure 8: Offset Results for Long Term Current with Countercurrent

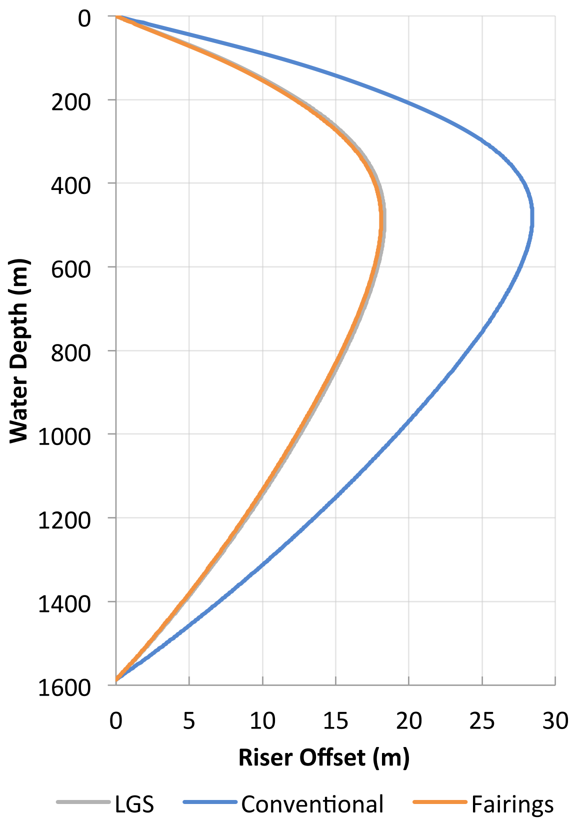

Figure 9: Offset Results for Extreme Current

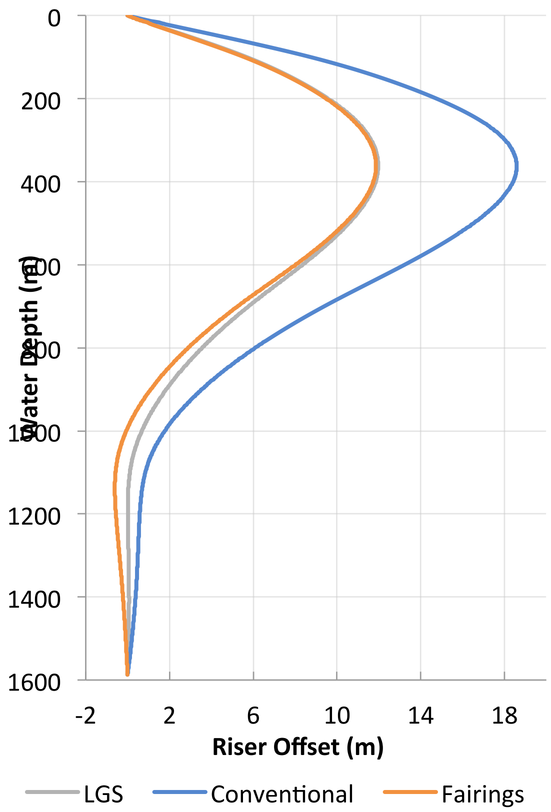

Figure 10: Offset Results for Extreme Current with Countercurrent

The top angles predicted for the three risers in each of the currents modeled are shown in Table 2. In the Long Term currents, the LGS equipped riser was predicted to have significantly lower top and bottom angles than the riser with fairings. On average, the reduction in top angles achieved by the LGS equipped riser in the Long Term currents was approximately 35%. Previous analysis of Brazilian current profiles indicated 25% reduction [9]. This indicates that the benefits of the LGS technology are increased in current profiles similar to those modeled for this paper. In the extreme current cases the LGS equipped riser was predicted to perform similarly to fairings, and provided a significant benefit compared to a traditional riser.

The corresponding bottom angles are shown in Table 3. In the cases with countercurrents, fairings did not reduce the bottom angle of the riser compared to conventional buoyancy modules. In both cases, the LGS equipped riser provided a reduction in bottom angle. While the angle at the top of the riser typically governs operability, it can be seen that in cases with strong currents at depth (e.g. the Long Term Current with Countercurrent) the bottom angle may reach or exceed the top angle. In certain cases, depending on the acceptable lower flex joint angle, the bottom angle may be governing.

Table 2: Riser Top Angles (degrees)

	Conventional	**Fairings**	**LGS**
Long Term Current	1.6	1.3	1.0
Long Term Current with Countercurrent	0.6	0.5	0.4
Extreme Current	6.6	4.1	4.3
Extreme Current with Countercurrent	5.3	3.4	3.5

Table 3: Riser Bottom Angles (degrees)

	Conventional	**Fairings**	**LGS**
Long Term Current	0.9	0.8	0.6
Long Term Current with Countercurrent	0.8	0.8	0.5
Extreme Current	2.2	1.4	1.5
Extreme Current with Countercurrent	0.1	0.1	0.0

The calculated fatigue life for each riser in each current profile is shown in Table 4. The values provided do not include a factor of safety, and assume constant operation of the riser. In each case LGS provided a significant fatigue life benefit compared with a conventional riser. While for the Extreme Current cases the predicted fatigue life enhancement was less for LGS than for fairings, the fatigue life is likely to be governed by exposure to prevailing currents (i.e. the Long Term Current cases). Furthermore, if the total fatigue life, considering the statistically average exposure to each individual current profile throughout a typical year, was to be higher for the riser with fairings, previous analysis has shown that this benefit is unlikely to materialize in reality [10]. This is because the fatigue life of an LGS equipped riser (including the appropriate factor of safety) is likely to exceed the expected service life of the riser. It should be noted that the figures presented in Table 4 assume continuous operation, and that the extreme currents modeled are expected to occur approximately once every 10 years. As a result, the actual fatigue life of a drilling riser used under the modeled conditions is likely to be considerably higher than the reported figures.

Table 4: Fatigue Life in Years (unfactored)

	Conventional	**Fairings**	**LGS**
Long Term Current	65.5	267	2461
Long Term Current with Countercurrent	30.9	80.4	1812
Extreme Current	2.35	93.6	33.9
Extreme Current with Countercurrent	3.59	24.8	19.2

Conclusions

The results obtained for South American current profiles including countercurrents demonstrate the benefit of including VIV suppression over the entire length of the riser. Traditional VIV suppression by weathervaning fairings is limited to specific sections of the riser, owing to the lengthy process of installing and removing the fairings. In conditions where the sections of the riser which are exposed to severe currents may change depending on the presence of countercurrents or other phenomena at depth, the use of LGS DRBMs provides VIV suppression which will remain effective in all current conditions. This can be achieved without any additional handling time, and without risk of degraded performance as occurs when fairings fall off or fail to rotate. In terms of operability, LGS was shown to be more beneficial in the current profiles investigated for this paper than previously reported for Brazilian currents.

The results reported in this paper, and those previously published, demonstrate that the physical model testing program generated a VIV suppression design which performs consistently for a wide range of current profiles, water depths and riser arrangements. The final step in confirming the performance benefits of the technology will lie in measurement of actual risers in the field. One such riser, deployed with LGS DRBMs, has been instrumented, with preliminary results from the data measurement and analysis campaign showing that the predicted performance of LGS is being observed as expected.

Acknowledgements
The authors would like to thank Matrix Composites & Engineering for their supporting the high Reynolds Number model testing and field trials.

References

[1] Gardner, T. & Cole, M. 1982 “Deepwater Drilling in High Current Environment” OTC 4316, Houston, Texas. May 3-6 1982.

[2] MIT, n.d. “MIT Research: Vertex-Induced Vibration” http://web.mit.edu/shear7/experiments.html. Accessed May 31st 2017.

[3] Offshore Magazine 2007. “Riser fairings bring improvements in VIV, drag suppression” http://www.offshore-mag.com/articles/print/volume-67/issue-7/sweden/riser-fairings-bring-improvements-in-viv-drag-suppression.html. Accessed May 31st 2017.

[4] Matrix Composites & Engineering n.d. “Matrix LGS – VIV + drag reduction” http://www.matrixengineered.com/oil-plus-gas/riser-buoyancy-systems/matrix-lgs-viv-plus-drag-reduction/. Accessed May 31st 2017.

[5] Marcollo, H. et. al. 2016. “Drag Reduction and VIV suppression behavior of LGS Technology integral to drilling riser buoyancy units” OMAE 2016-54689, Busan, South Korea, June 19-24, 2016.

[6] Strub, T. & Mesias, J. 1998 “Coastal Ocean Circulation Off Western South America” https://ceoas.oregonstate.edu/people/files/strub/1998_Strubetal_TheSea_color-s.pdf. Accessed June 1st 2017.

[7] National Imagery and Mapping Agency n.d. “Ocean Currents” http://msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/APN/Chapt-32.pdf. Accessed June 1st 2017.

[8] Bonhoure, D. & Rowe, E. & Mariano, A. & Ryan, E. 2014. “The South Equatorial Sys Current” http://oceancurrents.rsmas.miami.edu/atlantic/south-equatorial.html. Accessed June 1st 2017.

[9] Johnstone, D. et al. 2017 “Drilling Riser Case Studies Comparing the Drag Performance of LGS Technology to Conventional Buoyancy Units and Fairings” OMAE2017-62219, Trondheim, Norway. June 25-30 2017.

[10] Kurts, P. et al. 2017 “How the Application of LGS Technology for Drilling Risers Reduces Drilling Costs Through Improved Operability” OTC-27692-MS, Houston, Texas. May 1-4 2017.