Alternative Buoyancy Systems For Deepwater Drilling

Buoyancy systems designed to reduce vortex-induced vibration (VIV) and lower overall drag offer minimal improvements when compared to devices like fairings which streamline the flow past a tubular.

An older alternative buoyancy concept for mitigating vortex-induced vibration (VIV) in high currents consists of staggering buoyancy so that slick and buoyed joints are alternated.[1] This method can sometimes provide modest suppression but further testing has shown it to be unreliable for most high current situations.[2] Recently alternative buoyancy systems such as those based upon helical grooves or Saguaro cactus-type longitudinal protrusions (axial ridges) are concepts that have been proposed for reducing drag and VIV of drilling risers.[2,3] The problem with these concepts is that the fundamental physics of high Reynolds number vortex shedding from long tubulars contradict marketing claims about the efficiency of their products.

One of the challenges with testing VIV suppression and drag reduction for drilling risers is that they normally encounter very high (super-critical) Reynolds numbers. Since Reynolds number is proportional to both diameter and current speed, the ocean currents of greatest interest produce very high Reynolds number flow which is difficult to test with a flexible cylinder under controlled laboratory conditions. While some have attempted to promote devices based upon low Reynolds number and short cylinder tests, the information below illustrates why these test results can be misleading.

Sub-Critical Flow

- $Re \leq 100{,}000$ (less than 0.2 knots)
- Boundary layers are laminar
- Alternative buoyancy designs (helical grooves or axial ridges) can trip the boundary layer into turbulence, thereby simulating moderate Reynolds numbers which result in lower drag; however, the Reynolds numbers are still substantially lower than actual risers and the results can be deceptive

Critical Flow

- $100{,}000 \leq Re \leq 1$ million (up to 2 knots)
- Boundary layers are turbulent and stay attached to the riser further downstream before separation occurs, resulting in possible lower drag and reduced VIV
- As with sub-critical flow, most rigs can continue drilling even with some riser vibration at these lower currents and no VIV mitigation present (i.e., with standard riser buoyancy)

Super-Critical Flow

- Re ≥ 1 million (above 2 knots)
- Boundary layers remain fully turbulent
- Increased flow inertia forces boundary layers to separate further upstream, causing high VIV and high drag
- Vortices correlate easily along the riser span and thus short cylinder tests can be misrepresentative
- Alternative buoyancy concepts that simply cause more turbulence in the boundary layers will be ineffective in this range and may cause more harm than good
- Fairings can keep the boundary layers attached thereby reducing both drag and VIV

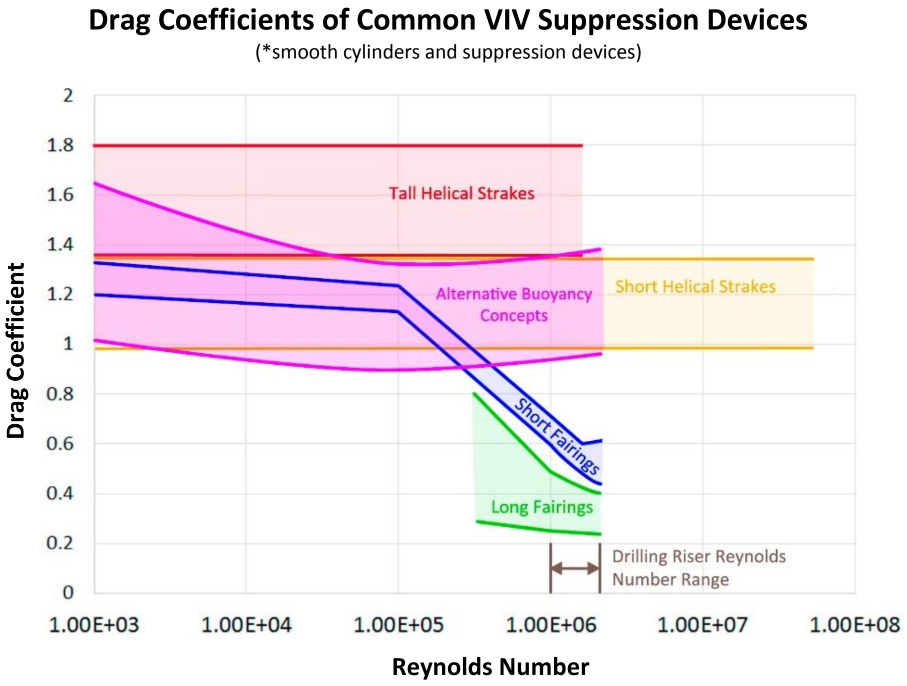
Both helical groove and axial ridge buoyancy modules are able to trip a boundary layer at lower Reynolds numbers so that the laminar boundary layers become turbulent and the critical Reynolds number range is shifted to lower current velocities. Since drag (and possibly VIV) decrease as the critical Reynolds number range is entered, this gives a premature (and inaccurate) indication that the alternative buoyancy systems may be effective. This phenomenon can be likened to dimples on a golf ball which trip the laminar boundary layers such that they become turbulent and stay attached to the ball over more of its surface, thereby reducing drag and insuring a straighter path of travel. However, deepwater risers experience Reynolds numbers that are much higher than those experienced by a golf ball. This is why testing at super-critical Reynolds numbers on a flexible cylinder is important for accurate prediction of how risers with grooved buoyancy or axial ridges will behave on drilling risers in the ocean.

Deepwater drilling risers experience peak currents that reside in the super-critical Reynolds number range (Re ≥ 1 million). At this level, the flow has so much inertia that it separates more easily causing higher drag and VIV (note that Reynolds number is essentially the ratio of inertial forces divided by diffusion forces). The only viable solution is a fairing that streamlines the flow so that the boundary layer stays attached to the fairing for a longer period of time and delays large vortex-shedding until the flow has passed the fairing tail.

Buoyancy systems with helical grooves (such as an inverted helical strake) behave similarly to a very short helical strake, in that (if they are effective at all) the grooves cause the flow to separate at the groove location much like protruding helical strake fins. By controlling flow separation in a helical fashion, the vortices cannot easily correlate along the riser span and thus are weaker, thereby reducing VIV. However, it is well known that helical strakes suffer from high drag due to this forced early separation. The early separation causes a larger wake with lower pressure in the wake. If short helical strakes (or grooves) are able to control flow separation, then they produce lower VIV at the expense of higher drag. If short helical strakes or grooves cannot control flow separation, then they will have very little effect at the super-critical Reynolds numbers of interest for drilling risers.

Buoyancy modules with axial ridges can produce results similar to those of inverted helical strakes at lower Reynolds numbers in that they can convert laminar boundary layers to turbulent boundary layers and thereby lower drag and slightly reduce VIV. However, at high Reynolds numbers which are important for actual risers, pipelines, and tendons, the turbulent boundary layers are much more resilient. More recent testing has shown drag coefficients for this concept of over 0.8 on a spring mounted rigid cylinder (larger drag coefficients would thus be expected on a long flexible riser).[4] While this represents a modest reduction in drag relative to standard buoyancy, this is still lower than what will most likely be experienced in the field, primarily because the test consisted only of a short spring-mounted cylinder where half of the ridges were rotated relative to the other half of the ridges to attempt to reduce the correlation length of the vortex shedding. On a long slender cylinder such as a drilling riser in the ocean, the vortices can correlate over much longer lengths (and can even be enhanced by the axial ridges), thereby generating a significant increase in vibration and drag. Thus, in the field there are other sets of ridges along the riser that promote correlation length whereas these were absent in the experiment. The result is that the vibrations and drag coefficients for an actual riser with this type of buoyancy could be quite large. It is possible that this type of device could actually enhance drag and VIV rather than suppress them.

It is useful to compare common VIV suppression devices across the Reynolds number range for their ability to reduce drag on risers. The graph below presents this information for tall helical strakes, short helical strakes, short chord fairings, long chord fairings, and alternative buoyancy systems such as those with helical grooves or axial ridges. The data ranges are taken either from test data or from field measurements and are approximate for illustration purposes.



This graph illustrates why fairings are still the best solution for reducing both drag and VIV for drilling risers. Helical strakes (or grooves), when effective, can reduce VIV but do so at the expense of high drag. Axial ridges or helical-groove solutions can be effective for low Reynolds number tubulars (umbilicals, cables, etc.) but do not possess any physical mechanism to suppress VIV or reduce drag once the boundary layers become fully turbulent.

In contrast to alternate buoyancy methods, fairings act to streamline the flow so that, even at supercritical Reynolds numbers, an effective fairing can provide both low VIV and low drag. The turbulent boundary layers stay attached to the fairing surface and only a very small wake is formed immediately downstream of the fairing. (The wake will grow further downstream due to the sheets of vorticity being shed off of the fairing but this is inconsequential to the drag and VIV on the fairing and riser.) This results in a reliable solution for controlling drilling riser VIV and drag with drag coefficients of around 0.5.[5,6]

VIV Solutions' fairing products are well tested and field proven for over two decades. The latest generation of tail fairings for drilling risers are very fast to install and reliably reduce both drag and VIV. VIV Solutions also has numerous fairing devices that can be adapted or customized for a variety of drilling situations.

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