# SHEAR7 v4.10
# Calibration Report

*A calibration of VIV Solutions' helical strake and fairing products using proprietary long cylinder pipe data leads to improved modeling capabilities in SHEAR7.*

VIV Solutions has conducted a calibration exercise using data obtained from a controlled experiment with well-known directly-measured inputs. Results from this test program are presented alongside trendlines generated using either SHEAR7's default input coefficients[1] or new coefficients recommended by VIV Solutions, respectively. The information is applicable for Reynolds numbers ranging from 150,000 to 360,000, which is representative of most production risers and large umbilicals. Values can also be extrapolated for higher Reynolds numbers applications such as tendons or drilling risers with a moderate level of confidence.

The ultimate objective this endeavor was to produce a better method for modeling VIV Solutions' suppression devices in SHEAR7. In recent years, we have made significant enhancements to our products to further improve their robustness and performance in the field. We have also endeavored to design products that better match the test data for which this calibration exercise is based. As such, the calibration information presented herein is <u>strictly for use with VIV Solutions' helical strakes and fairings</u>. This is especially important for fairings since small changes in design or geometry can significantly impact their performance.

Raw test data was collected by four bi-axial accelerometers, with accelerometers 1 and 2 located near the low-velocity inner end of a linear sheared flow and accelerometers 3 and 4 at the high-velocity outer end. For the datasets utilizing suppression devices, the strakes or fairings were installed at the outer end of the pipe since this is most representative of field conditions where current speeds are highest near the top of the water column.[2,3]

The following comments should be carefully considered before attempting any modeling in SHEAR7:

1. A smooth tubular was used during testing to generate the measured datasets. In the field, a build-up of marine growth will likely render a suppression device less effective. (Input parameter values for fouled tubulars may be provided by VIV Solutions in the future.)

2. The plots were generated using data from isolated tubulars in a low turbulence environment. Tandem or offset tubulars may experience different vibration and suppression performance relative to that of isolated tubulars.

3. Many of the coefficients used in SHEAR7 are rounded to the nearest 0.05 or 0.1 value. Since adjustments to input parameters only produce minor changes in the response predictions, no further effort was undertaken to refine the values at this time.

4. Some of the parameters may not make complete physical sense. In the past, this was done intentionally to keep the results conservative and adequately robust. (For example, the reduced velocity damping coefficient for the bare riser condition is 0.0.) In general, it should be noted that the coefficients derived from this exercise have an improved physical basis relative to the default values, especially in the common.CL files for fairings and helical strakes.

5. The helical strake calibration requires different values for the bare tubular portion than a completely bare tubular or a bare section of a tubular with fairings. This is like attributable to helical strakes' ability to influence damping, correlation length, and vortex input frequencies, although the physical basis for this is not entirely understood.

6. The data assumes that all regions of the tubular experiencing current velocities greater than 60% of the maximum current value are covered with VIV Solutions' helical strakes or fairings. For example, a 1,000-meter tubular with a monotonically-varying sheared current profile of 3 m/sec at the surface would be covered with suppression devices beginning at the MWL to a water depth at which the current no longer exceeds 60% of the surface value (1.8 m/sec). Furthermore:

   a) For helical strakes, a minimum suppression coverage density of 85% is required (allowing some gaps for appurtenances, field joint coatings, etc.).

   b) For fairings, a minimum suppression coverage density of ~70-75% is required (allowing some gaps for appurtenances, field joint coatings, etc.).

7. Some calibration work was attempted for reduced coverage lengths but the results were not always conservative, therefore the revised coefficients are unlikely to produce conservative results when lower coverage lengths or coverage densities than those stated above are used.

8. Stress concentration factor inputs for the tubular are subject to the user's discretion and are design dependent. It may be appropriate to divide various regions (i.e., those with suppression) into multiple regions to properly address the stress concentrations.

9. Safety factors should be employed during a VIV analysis, whether by increasing the stress concentration factor, utilizing a conservative fatigue curve, applying a safety factor to the fatigue damage rate, or a combination thereof. This is especially important when performing an extreme event analysis (i.e., 100-year current).

10. For higher harmonics, the program defaults were utilized during the calibration exercise. This is an area of ongoing industry research. The user may want to consider even more conservative input values for higher harmonics, especially for structures that are tension-dominated at the modes of greatest concern.

It should be noted that this data is not meant to be a definitive calibration but rather an improvement in the overall understanding of SHEAR7 and its use in modeling VIV.

Future calibrations efforts require knowledge of suppression length coverage density and length to better predict spanwise correlation and suppression device damping. VIV Solutions endeavors to undertake this exercise at the request of interested clients.

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**Release Date:**
March 2019



[1] User Guide for SHEAR7 Version 4.10a, January 2018.

[2] Allen and Liapis (2014), The Effect of Coverage Length and Density on the Performance of Helical Strakes, OMAE2014-23107, Proceedings of the ASME 2014 33rd Annual International Conference on Ocean, Offshore and Arctic Engineering, June 8-13, 2014, San Francisco.

[3] Allen and Liapis (2014), The Effect of Coverage Length and Density on the Performance of Fairings, OMAE2014-23108, Proceedings of the ASME 2014 33rd Annual International Conference on Ocean, Offshore and Arctic Engineering, June 8-13, 2014, San Francisco.

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# SHEAR7 v4.10 Input Parameters

**Table 1 – Coefficients**

| | User Manual Defaults | | | VIV Solutions Calibration | | | | |
|---|---|---|---|---|---|---|---|---|
| | Tubular Region | | | Bare Area | Helical Strakes | | Fairings | |
| | Bare Area | Area with Strakes | Area with Fairings | Bare Area | Bare Area | Area with Strakes | Bare Area | Area with Fairings |
| Added Mass | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 | 2.0 |
| Strouhal Number | 0.18 | 0.1 | 0.1 | 0.18 | **0.16** | 0.1 | 0.18 | **0.11** |
| Bandwidth | 0.40 | 0.25 | 0.00 | 0.40 | **0.65** | 0.25 | 0.40 | **0.12** |
| CL Table | 1 | 5 | 5 | 1 | 1 | **6** | 1 | **4** |
| Beta Control Number | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Damping | | | | | | | | |
| Reynolds Number Still Water | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | **2.0** | 1.0 | 1.0 |
| A/D Still Water | 0.2 | 0.4 | 0.4 | 0.2 | **0.1** | 0.4 | 0.2 | 0.4 |
| Low $V_r$ Regions | 0.18 | 0.5 | 0.5 | **0.00** | **0.2** | 0.5 | 0.18 | 0.5 |
| High $V_r$ Regions | 0.2 | 0.2 | 0.4 | **0.05** | 0.2 | **0.35** | 0.2 | 0.4 |
| Axial Flow Regions | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Power Ratio Cutoff | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Primary Zone Amplitude Limit | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Lift Coefficient Reduction Factor | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Power Ratio Exponent | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Non-Orthogonal Damping | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Higher Harmonics Threshold | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| Higher Harmonics Factor | 3.33 | 3.33 | 3.33 | 3.33 | 3.33 | 3.33 | 3.33 | 3.33 |
| Stress Concentration Factors | TBD | TBD | TBD | **TBD** | **TBD** | **TBD** | **TBD** | **TBD** |

**Table 2 – Common.CL File**

| Common.CL |
|---|
| **Bare Riser and all Bare Areas (same as user manual default)** |
| *** CLtype 1 = mimic old SHEAR7 (v4.2f) data *** |
| 1 ** number of non-dimensional frequencies |
| 1.0000 1.1000 0.3000 0.7000 0.3000 -1.0 Ndfreq, aCL0, aCLmax, CLmax, CLa0, CLfloor |
| **Helical Strake Region** |
| *** CLtype 6 = VIV Solutions Helical Strakes, 25% hi, 17.5 pitch in good condition *** |
| 1 ** number of non-dimensional frequencies |
| 1.0000 0.2500 0.090 0.150 0.100 -1.5 Ndfreq, aCL0, aCLmax, CLmax, CLa0, CLfloor |
| **Region with Fairings** |
| *** CLtype 4 = VIV Solutions Standard Teardrop Fairings |
| 1 ** number of non-dimensional frequencies |
| 1.0000 0.2500 0.045 0.15 0.100 -1.0 Ndfreq, aCL0, aCLmax, CLmax, CLa0, CLfloor |

# Bare Cylinder

For the bare cylinder, VIV Solutions' calibration makes a small but important change to the damping coefficients. The modification incorporates higher Reynolds number data than that used for the default coefficients and is therefore more representative of field conditions for production tubulars. While the default coefficients produce significantly under-conservative results at the inner end of the pipe (i.e., the "seafloor") as shown in Figure 1, VIV Solutions' coefficients are relatively accurate over the entire length of the tubular. This is because the VIV Solutions' coefficients produce less spatial attenuation.

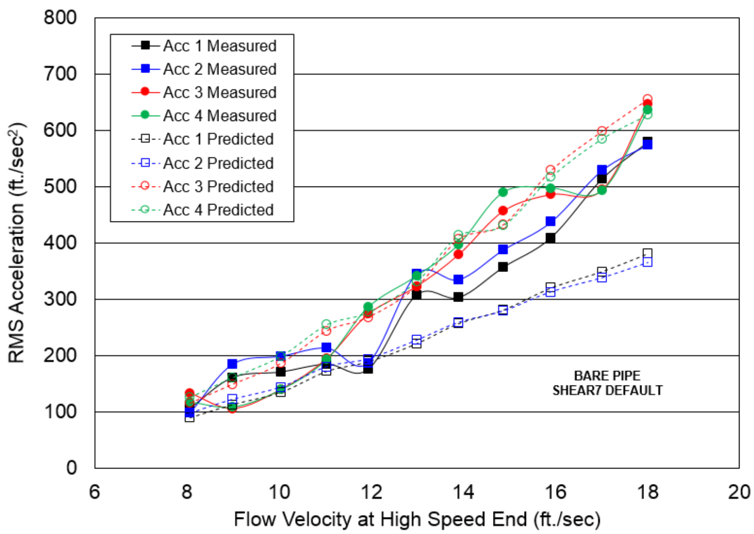




**Figure 1 – Long Bare Pipe Data Using SHEAR7 Default Coefficients**

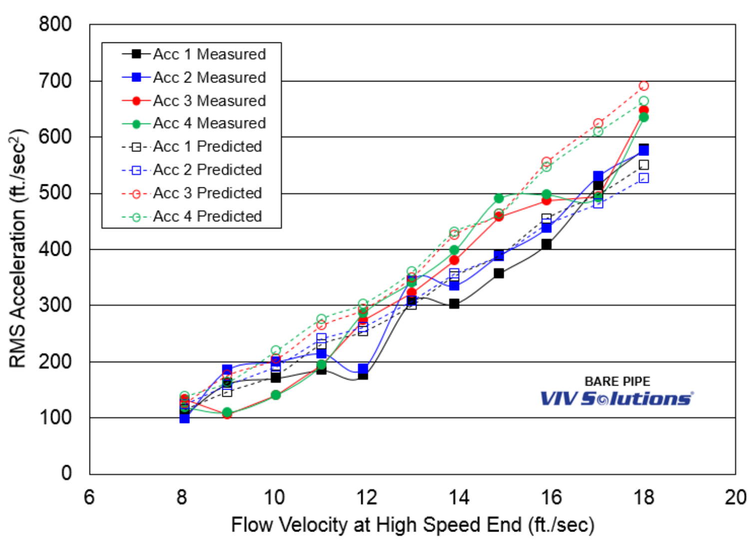
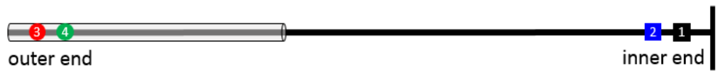



**Figure 2 – Long Bare Pipe Data Using VIV Solutions' Recommended Coefficients**

## Cylinder with Helical Strakes

Helical strake models are relatively easy to calibrate because the devices are inherently designed to control correlation length. The default coefficients for SHEAR7 produce a reasonable, though conservative, set of results despite having a common.CL table that does not have a strong physical basis. VIV Solutions' coefficients improve upon the default values primarily by better modeling both the overall level of vibration as well as increasing the accuracy of spatial attenuation. It should be noted that VIV Solutions helical strakes are designed to closely match the test models (e.g., a near-continuous fin with minimal slots for strapping bands).



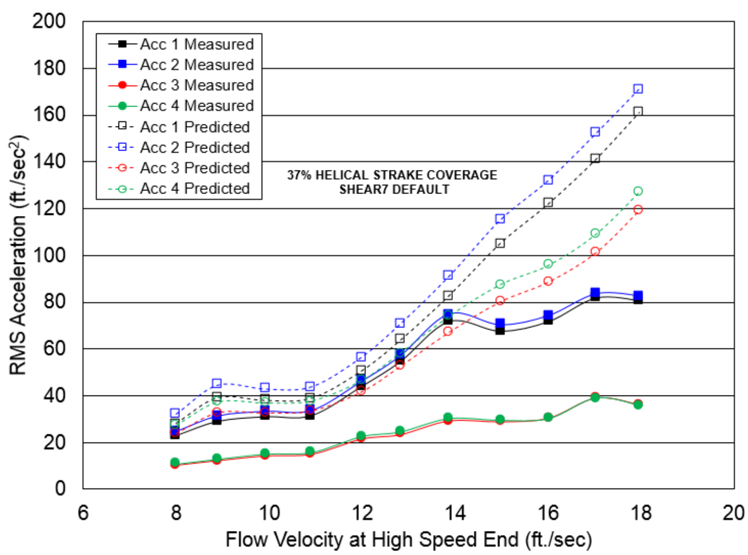




**Figure 3 – Long Pipe Helical Strake Data Using SHEAR7 Default Coefficients**

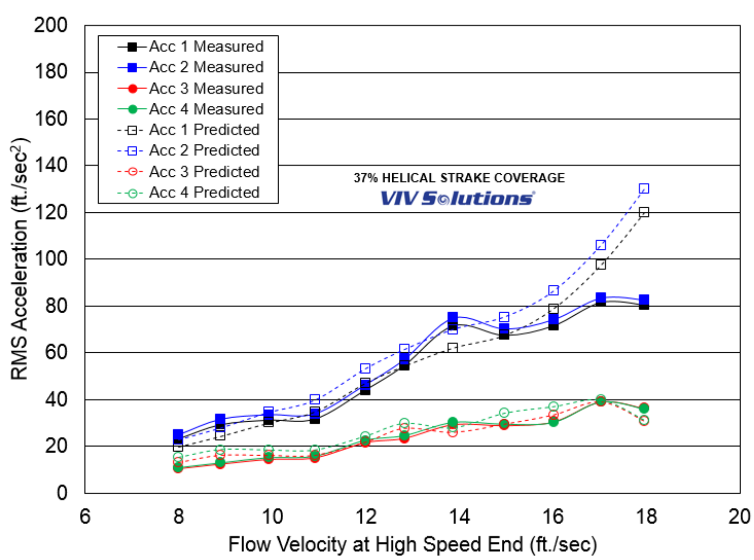
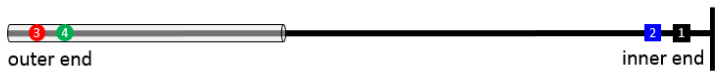



**Figure 4 – Long Pipe Helical Strake Data Using VIV Solutions' Recommended Coefficients**

# Cylinder with Fairings

The SHEAR7 program has physical limitations which restrict it from accurately modeling fairings. This was observed during analyses of various fairing coverage cases and warranted a coverage length of at least 40% to generate reasonably accurate coefficients. Note that there are still some significant differences between the measured and predicted values. Ultimately, VIV Solutions chose coefficients that are a better fit over the entire length of the test pipe even though some over-conservatism remains at the inner end of the test cylinder. It should be noted that VIV Solutions' coefficients have a much better physical basis than the default coefficients.



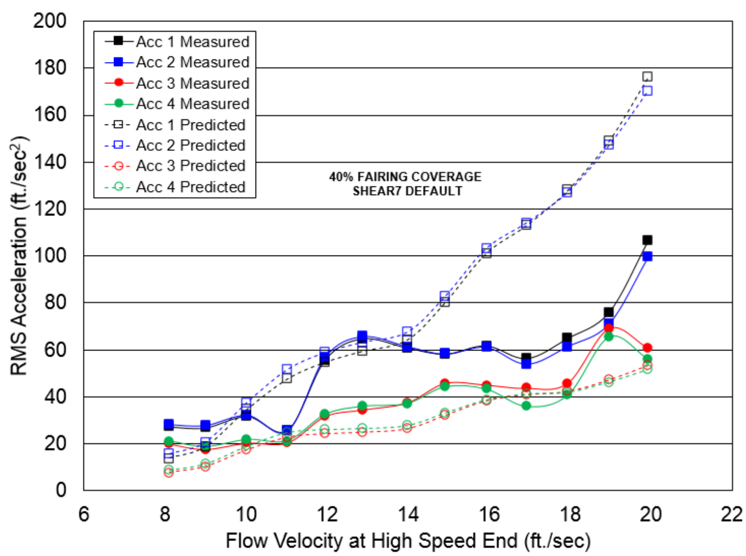




**Figure 5 – Long Pipe Fairing Data Using SHEAR7 Default Coefficients**

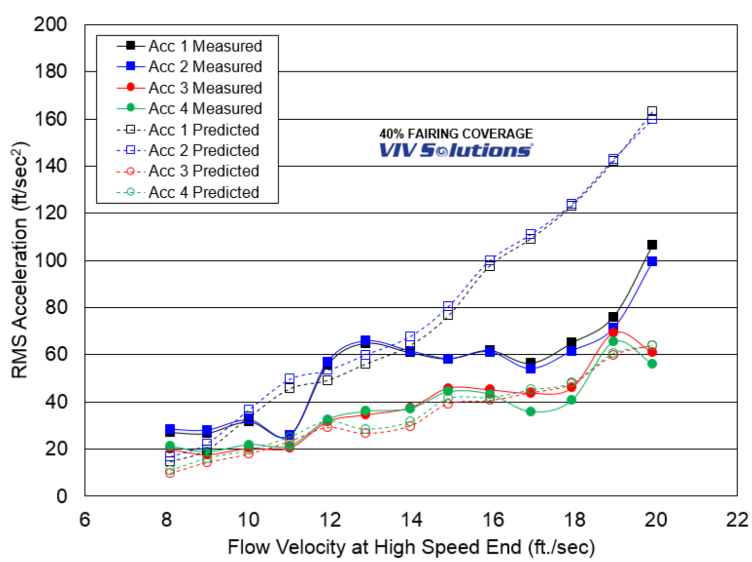



**Figure 6 – Long Pipe Fairing Data Using VIV Solutions' Recommended Coefficients**