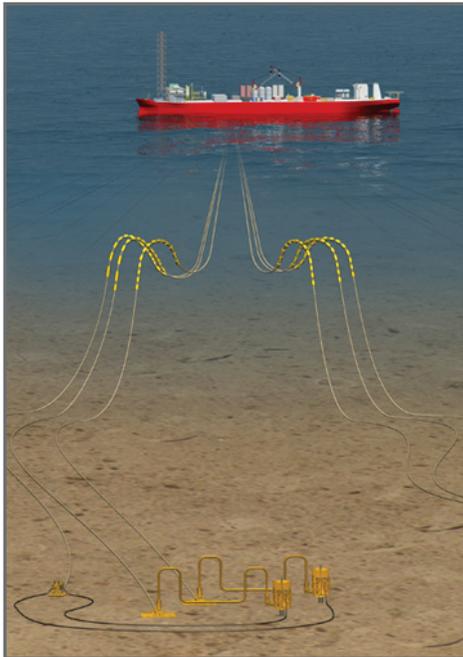


System Diagnostics

from Comprehensive Analysis of Measured Data



Million Dollar Question

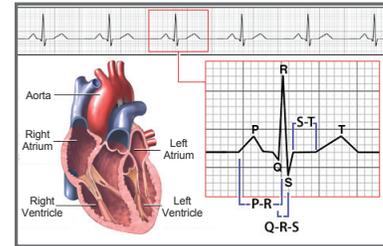
Expensive campaign for data collection. Is this for ...



Just measuring the pulse?

- RMS acceleration is ...
- PSD of acceleration is ...
- FPS response and fatigue estimation based on an **assumed** model

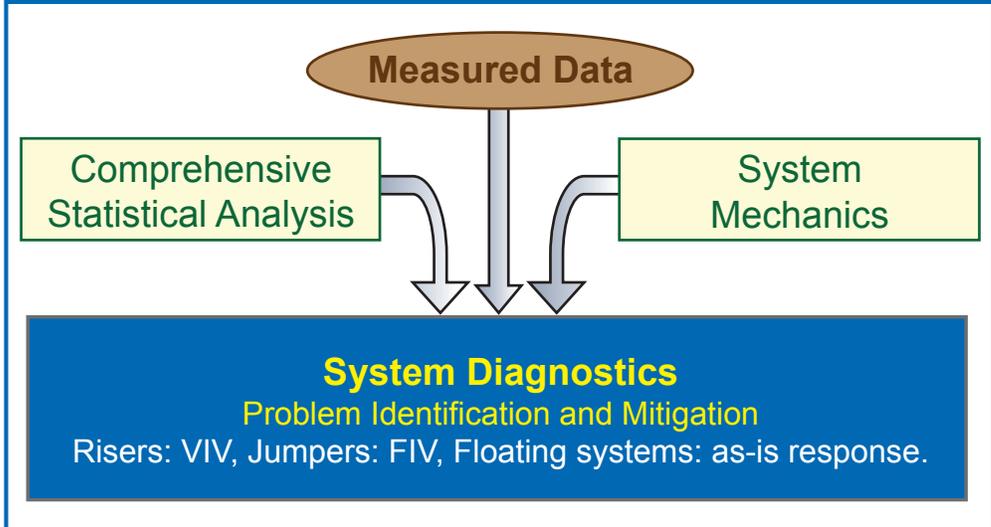
OR



Assessing system health from ECG?

- Characterization of excitation source
- Stress and fatigue estimation based on **the correctly identified** model
- Verified assessment of FPS response
- Gain system knowledge

A System Diagnostics Framework



Examples on the following pages are a small snapshot of what kinds of useful information can be extracted from measured data. We believe that measured data is telling us something about the system, similar to an ECG informing us about health of a heart. We listen to that information about your floating and subsea systems. Our goal is to diagnose the system before it is too late, so that your drilling and production activities run uninterrupted.

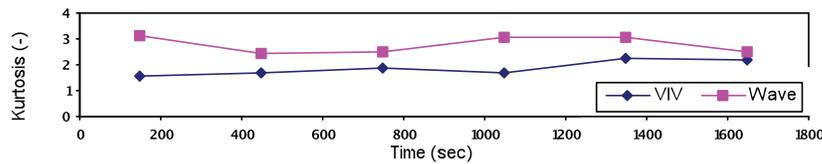
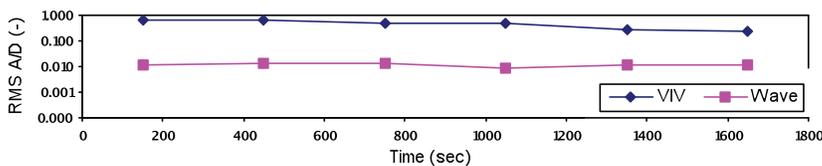
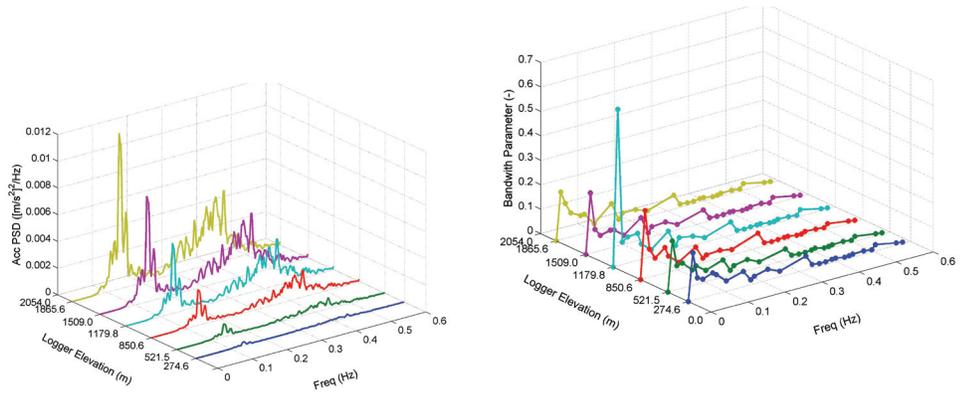
Measured data contains a lot of valuable information about an offshore system, be it a riser, a jumper or anything else. At Stress Engineering Services we go beyond providing a few tables and plots of statistics (RMS, PSD) estimated from the raw measured data, which may be corrupted. We combine decades of our experience about mechanics and behavior of floating and subsea systems with advanced data cleansing, signal processing, and statistical analyses to inform you about actual response and health of your system. We can identify damage hotspots and sources of damage, and suggest appropriate mitigation schemes. We can provide performance information you can rely on to maximize asset utilization and production rates.

You have spent a lot of effort and capital on collecting the data. We can help you realize the true value the data can provide.

Application to Risers

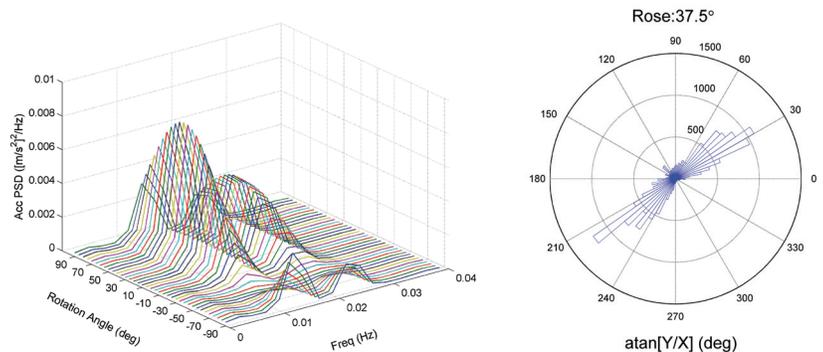
Deepwater risers are often exposed to strong currents whose magnitude and direction may not be precisely known. Vortex-induced-vibrations (VIV) of risers due to ocean currents often induce high fatigue damage rates. Suppression devices are used to reduce VIV but their efficiency is often unknown. Accelerometers are employed to monitor riser vibration. However, correct identification of VIV and its contribution to the riser fatigue from measured data is not a trivial problem.

By analyzing data from all loggers simultaneously, we get a better understanding of the global riser response. We identify major frequency bands, and we perform comprehensive analysis for each of these bands in order to confirm the source and the nature of vibrations. We also extract important parameters such as bandwidth from PSD, which can be used as inputs to various simulation tools.



Various characteristics of vibrations have specific signatures in different statistics. At Stress Engineering, we understand how to identify these vibration characteristics from various statistics. For example, for VIV, we can identify whether the response is single-mode or multi-mode, whether modes are switching, whether there are travelling waves, and so on. With this knowledge, we can use appropriate models in a calibration exercise. In other words, we can reduce the guesswork in simulations, and obtain more reliable estimates of fatigue.

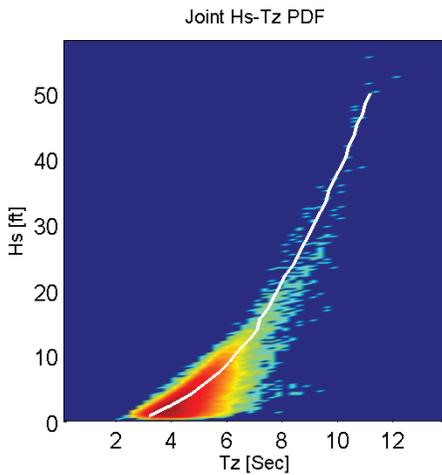
Vibration from any source, whether waves or VIV, typically has a specific principal direction, with which loggers may not be aligned. Many predictive tools assume a principal direction, and calibration exercises can only be accurate if principal directions are the same in simulations and measurements. We solve the complex problem of identifying principal directions from data.



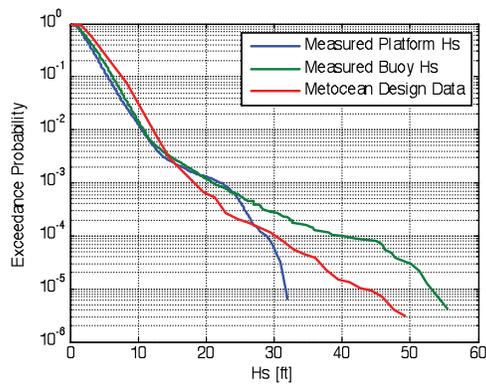
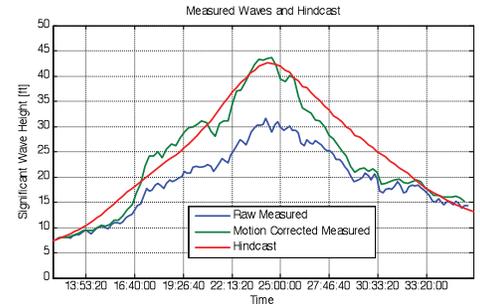
Various characteristics of riser vibrations have specific signatures in various statistics. By cross-confirming each vibration characteristic with multiple statistics, we obtain definitive conclusions on the riser behavior. Consequently, we can use the correct model to estimate extreme stresses and fatigue damage of the riser.

Application to Floating Systems

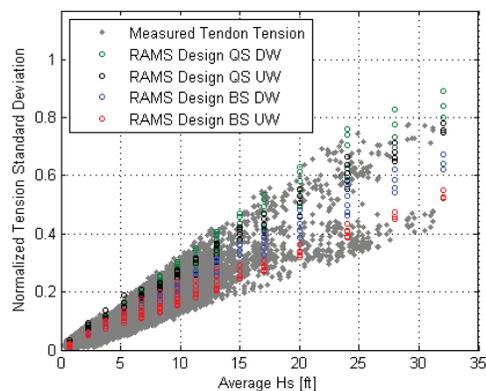
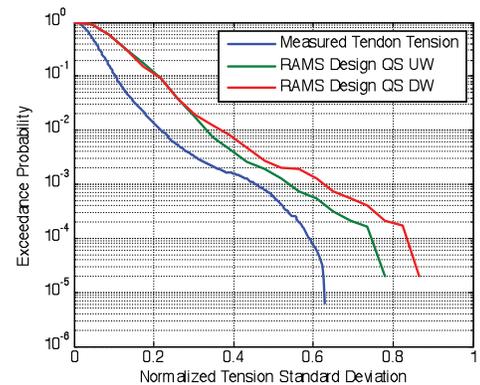
Floating Production Systems (FPS) represent a major financial investment. Structural integrity and performance in harsh environmental conditions is necessary to ensure optimized production. Many operators have realized the importance of continuously monitoring metocean conditions and the FPS response to support design verification efforts, evaluate future expansion capacity, and extend the service life of the asset. To maximize the impact of the data measurement program requires integrating knowledge of the environment and FPS response with proper data cleansing and analysis techniques.



Wave time series data is often collected using wave radars on semisubmersibles. Platform motions must be measured and removed from the data to obtain accurate wave information. The right figure shows comparisons of measured and hindcast significant wave height during hurricane conditions. The left figure compares the joint Hs-Tz distribution from measured data. For comparison, the Hs-Tz relationship from the design condensed scatter diagram is shown.

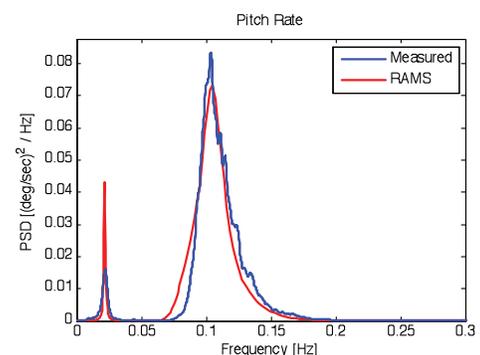


Continuous metocean and FPS response monitoring allows for assessment of the design environment and response. The left figure compares measured significant wave heights exceedance probability (from 5 years of FPS data, 14 years of buoy data) to metocean design data. The right figure shows (normalized) measured TLP tendon tension standard deviation exceedance probability, along with tensions resulting from the design scatter diagram.



Continuous monitoring also enables investigation of FPS performance. The left figure shows the relationship of normalized tendon tension standard deviation to significant wave height over a 5 year period along with RAMS¹ predictions from the design scatter diagram.

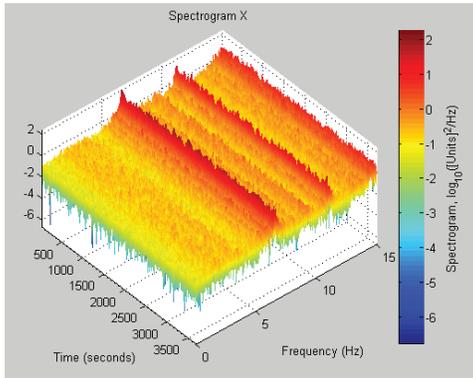
Measured data in various seastates can be compared to predicted responses. The right figure shows the pitch rate spectrum obtained from measured data and RAMS analysis for a spar in a winter storm.



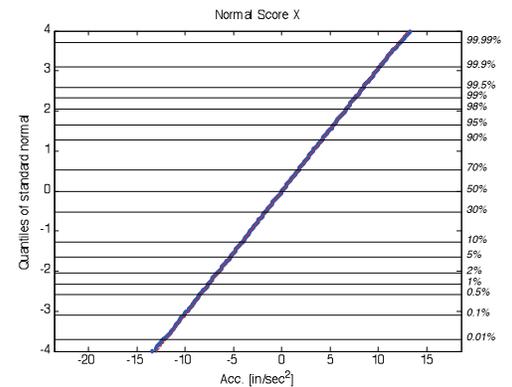
1. Rational Approach to Marine Systems (RAMS) is an in-house, fully-coupled analysis software for floating systems.

Application to Subsea Systems

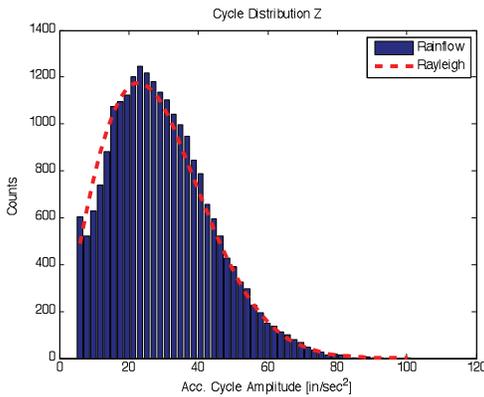
Flow Induced Vibration (FIV) of piping systems is generated by flow restrictions such as elbows, tees and partially closed valves. Vibrations can be severe enough to impose restrictions on production rates. Predictive analysis of subsea piping is limited due to lack of empirical data for common geometries and flow conditions. An alternative analysis approach, combining in-field measured data and Finite Element (FE) models can be taken to assess stress and fatigue damage. To obtain accurate results, understanding the nature of random response and applying appropriate data analysis methods are imperative.



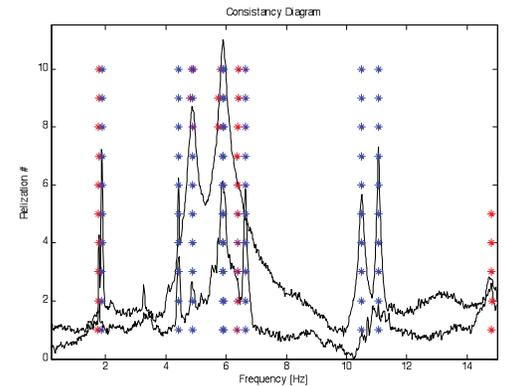
Measured jumper accelerations are examined first to determine the nature of random vibration. The left figure shows an acceleration spectrogram. The vibration is observed to be stationary over the measurement period. The right figure illustrates a normal score plot. Since the acceleration distribution falls on a straight line, the vibration is concluded to be Gaussian.



Peaks or rainflow cycles from stationary random vibration data follow a Rayleigh distribution if the vibration is also narrow-banded. The left figure compares the histogram from measured jumper vibration data to the theoretical Rayleigh curve.



Natural frequencies, damping and mode shapes can be extracted from measured vibration data and compared to FE model modal parameters. The right figure shows the results of modal identification from measured data.



The forcing function spectrum can be estimated from the measured acceleration data and FE model. The forcing function is then applied to the jumper FE model. Resulting FE acceleration spectra are compared to the measured acceleration spectra. The left figure shows the measured acceleration spectra from nine sensors. The right figure shows the FE accelerations. This calibrated analysis results in accurate stresses and fatigue damage estimates.

