

Bilge Keel Damping

from in-field Motion Measurements

Chevron and MARIN worked together on a novel approach to characterize the actual damping for an FPSO in real world conditions. Results show that using damping from model tests means that roll decay in calm water is conservative and that natural roll periods are less sensitive to the FPSO draft than often considered in the design phase.

Due to the resonance behavior of roll motions, roll damping is an important consideration for vessel motions and the associated extreme and fatigue loading on the hull, topsides and risers of an FPSO. In many cases radiation damping is limited and passive damping devices, such as bilge keels, are installed to spur viscous eddies and hence limit the roll motions.

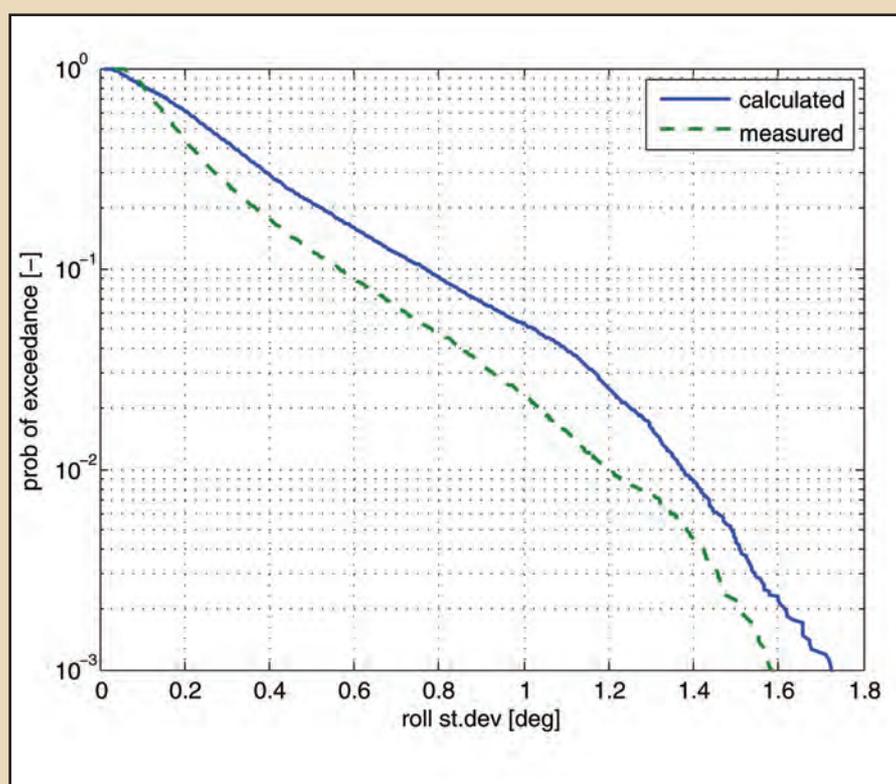
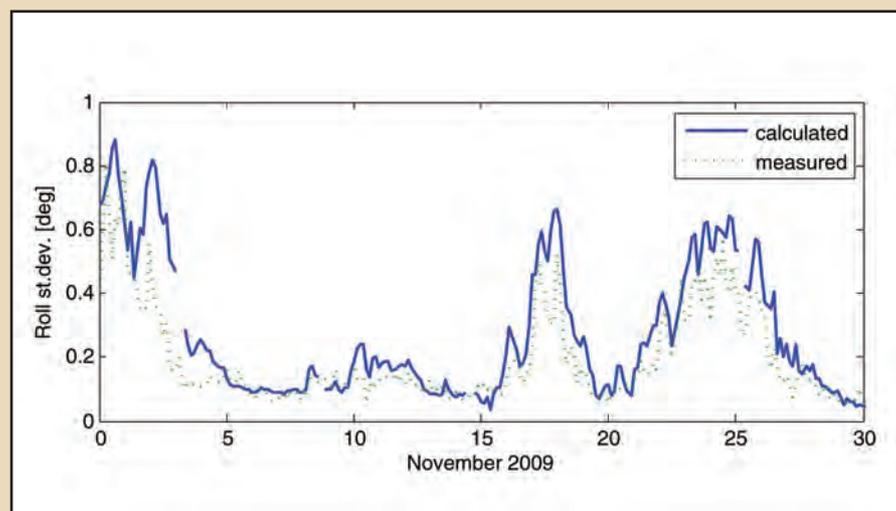
This contributes nonlinear damping to an already complex problem.

Designers often rely on model tests to assess this damping. Based on test results, empirical and semi-empirical estimation models have been developed, but examples of benchmark validation with real world data are limited. These benchmarks are often hindered by uncertainty in the observed weather conditions, vessel loading conditions and vessel heading with respect to the waves.

Bilge Keel Reduction

In this study, MARIN examined five years of hindcast weather data, along with FPSO heading and roll motion measurements. The studied FPSO is a VLCC sized converted tanker with an internal turret located in an approximate 1,000 meter water depth. The configuration of the bilge keel was modified resulting in an effective reduction of the projected bilge keel area of about 60% since its initial construction. The reduction was completed in a phased effort over a period of several years. Therefore, the bilge keel reduction process was ongoing for the duration of this study; so the results could capture the impact of a progressive reduction in roll damping as it was reduced.

The measured roll response is correlated to the hindcast weather conditions and contrary to the conclusions from the established norms, the FPSO heading



appears to be primarily dominated by current, with wind playing a secondary role. Local sea and swell appear to have relatively little influence on vessel heading. Additionally, due to the lack of coherence between the current, wind, swell and local sea directions, the FPSO might be at higher risk of extreme beam swell conditions than was assumed during the design phase. To compare the damping in the field with the damping estimated from model tests, a numerical model based on a roll Response Amplitude Operator (RAO) was set up. The natu-

ral period of roll was tuned to match the roll periods in the field. While the draft increases from 10m to 16m, the prevalent zero-up crossing period in the roll motions increases from 12.3s to 13.5s. This 1.2 second change in roll period due to draft change is small, hence the roll RAO, used to calculate the roll response in historic weather, is considered independent of the draft.

Realistic Estimate

With a stochastic linearization of the quadratic roll damping from the model



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tests, the standard deviation of the roll motions can be evaluated in the hindcast weather. The figure compares these calculated roll motions with the measurements for the month of November 2009. The method gives a qualitative idea about the roll damping available in the field but makes it difficult to quantify since the ratio between measurement and calculation varies over time.

Instead of comparing calculated and estimated roll of the same time periods, a novel method was proposed to study the distribution of roll against probability of exceedance. This distribution is also driving the fatigue life consumption. The measured and calculated distributions are compared in the second figure, which also shows the results with the model scale damping in calm water are conservative.

Both comparison methods indicate that the predicted roll motion is conservative due to the conservatism built into the roll damping estimate. By comparing occurrence probability and exceedance probability of the calculated and measured roll motions, the probabilistic method can be used to quantify the infield roll damping as well. This probabilistic method provides a realistic estimate of the roll damping for full-scale results and demonstrates the effect of the bilge keel modifications.