ABSTRACT

FPSO roll prediction has traditionally been performed assuming symmetric roll damping resulting in identical roll responses from portside and starboard waves. Recent interest in the industry to predict asymmetric roll response, either due to asymmetric mooring and riser configurations or damping devices, has led to the development of time domain models utilizing asymmetric Morison drag elements. Here, a frequency domain methodology has been developed to account for asymmetric bilge keels leading to differing port versus starboard wave roll response. A nonlinear bilge keel drag formulation, that includes the effects of radiation velocity, is used, coupled with linearization techniques, to predict the difference in roll RAO from port versus starboard waves. The drag formulation is initially calibrated against FPSO decay tests before the model is validated against measured model test motions. Thus we show that the methodology proposed is capable of predicting the motions from an asymmetric configuration efficiently, such that it can be utilized in design projects requiring FPSO motions analysis.

INTRODUCTION

Roll motion prediction is an old topic in naval architecture (eg. [1]) that is still very relevant today, and also still challenging. Compared with other ship motions, roll is a very resonant phenomenon with little wave making damping. Therefore it is very much influenced by other sources of damping, such as the one provided by bilge keels, which are the traditional solution for roll mitigation and still the most used one for FPSOs. On these production units the size of the bilge keels is often increased to dimensions unseen on ships, but on the other hand they are sometimes cut to give space to riser porches, thus leading to asymmetric configurations.

It is a standard practice to model ship motions, including roll, using linearized hydrodynamic models, although it is well known that roll motion is a nonlinear phenomenon. Indeed, the linearization allows for a much easier and time efficient motion simulation in frequency domain. Spectral analysis remains the most convenient solution for long term analyses.

When using such linear hydrodynamic models based on potential flow theory it is usual to add an additional term in the motion equation, in order to account for the damping induced by physical phenomena that are not included in the model, such as the friction on the hull, the vortex shedding at the appendices. As stated above, for ship shaped units a significant amount of damping is provided by the wave radiation itself for all motions but roll, so that only roll motion is strongly influenced by the additional damping. Therefore, it is generally sufficient to define a single roll damping coefficient. Because of the nonlinear nature of additional roll damping, this coefficient should not be taken as a constant but rather as a function of the roll motion magnitude. A linear function is usually considered, that is defined by two parameters, namely the linear and the quadratic roll damping. The two parameters can be obtained from roll decay tests on scaled models or estimated from empirical formula such as the very popular ITH formulation by Ikeda, Himeno and Tanaka [2]).

When a single roll damping coefficient is used to represent the additional damping the predicted roll motion amplitude for waves coming from portside and starboard will always be identical. For the asymmetric configuration of bilge keels to be taken into account it is necessary to have more terms in the