Estimating Quadratic Transfer Functions for Floating Structures using Model Test Data from Irregular Sea States

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ABSTRACT

This paper describes and validates a method for estimating quadratic transfer functions (QTF) for floating structures based on model experiments with irregular wave loading. With the QTF for a specific floating moored structure the slow drift forces acting on the structure can be estimated. This serves as input in the design phase of e.g. the mooring system. One method for experimental determination of the QTF involves a large number of bi-chromatic wave conditions in order to cover the two-dimensional frequency space that defines the QTF. This is a time consuming and tedious approach. In the present study, a method based on a time-domain analysis of measurements of forces or motion responses of a floating structure was implemented. The aim is to develop a practical engineering tool that, based on a limited number of irregular sea states, can estimate the QTF for a floating structure. The method was validated by three test cases: 1) a synthetic response signal generated based on a known QTF, 2) a measured force signal on a fixed structure, and 3) a measured surge displacement signal on a floating moored structure. The synthetic test signal showed that the method is capable of reproducing the test QTF. For the real case example where wave force measurements from the fixed structure was applied a good agreement was found between measured forces and those reconstructed based on the estimated QTF. For the floating structure some discrepancies were seen between measured and reconstructed motions. The method was found in general to be applicable for estimating the QTF. It is recommended to apply the method based on a measured wave force signal on a fixed structure. The method can be applied based on different types of input. If measurements of motions, velocities, and accelerations are available these can be applied directly for estimating the QTF. The latter method is

KEY WORDS: Floating structures; Slow drift forces; Quadratic Transfer Functions; Model experiments.

INTRODUCTION

When dealing with moored floating structures exposed to waves, the structure will in general experience two loadings which are governing for the response of the structure. 1) a direct wave forcing from the individual waves and, 2) a slow drift wave force which gives rise to a long period oscillation. The slow drift wave force is of interest for the design of the mooring system as the associated horizontal surge motions can attain large amplitudes. One way of evaluating the slow drift wave forces is by means of the quadratic transfer function (QTF) which describes the relationship between a wave forcing expressed by the surface elevation and the resulting slow drift force.

In Pinkster (1980) it was described how the QTF corresponds to the low frequency component of the second order force when a structure is floating in a regular wave group consisting of two regular waves (bi-chromatic wave). With this in mind the QTF can be estimated based on model experiments in bi-chromatic waves. Each experiment provides a value to the QTF for the specific combination of frequencies for the two regular waves in the bi-chromatic wave. In order to cover the two-dimensional frequency space of interest for the QTF a large number of individual experiments are required.

An alternative to bi-chromatic wave experiments is irregular wave experiments which can be applied with a cross-bi-spectral estimation procedure. In Dalzell (1972) this method was developed and was later also applied in Pinkster (1980). The method was further developed in Stansberg (1997, 2001), still applying a frequency domain analysis. For irregular wave experiments a time domain analysis may also be applied where the measured low frequency forces can be used directly to estimate the QTF. This was shown in e.g. Bunnik (2006).

With the goal of implementing and validating a method to be practical applicable for engineering purposes the method presented in Bunnik (2006) was applied. The present work extends the previous implementations and validations of the applied method to incorporate test cases of floating structures in real sea keeping tests. Here, the measured time series data of low frequency forces are used directly in the analysis. The method can be applied based on different types of input. If measurements of motions, velocities, and accelerations are available theses can be used for estimating the wave drift force by solving an equation of motion. The estimated wave drift force is hereafter applied for computing the quadratic transfer function. If measurements of the forces acting on the structure are available these can be applied directly for estimating the QTF. The latter method is