

Force Coefficient Estimation from Random Wave Data

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ABSTRACT

A brief summary of alternative methods of estimating drag and inertia coefficients from random wave and wave force data is given. Eight such methods are summarized, with six of these providing a single pair of force coefficients for each force record, and the remaining two providing variable coefficients. The methods are compared by using them to provide force coefficients from numerically simulated wave and force records which derive from linear wave theory and the Morison equation with specified force coefficients. These force coefficients are initially taken as constants, but in order to provide a more realistic representation of measured forces, simulations have also been obtained with variable force coefficients. On the basis of the comparisons made, the method of least squares applied to the force time series is found to be the simplest and most accurate method by which constant force coefficients may be estimated.

INTRODUCTION

The estimation of wave forces on offshore structures comprised of slender structural members is commonly carried out using the Morison equation, which entails the use of empirical drag and inertia coefficients. The selection of these coefficients for use in wave force calculations is an important concern related to the design of such structures. Knowledge of these coefficients has evolved over the last 40 years on the basis of laboratory experiments relating to an idealized uniform oscillatory flow, laboratory experiments involving regular or random waves, and field tests.

For the idealized case of a uniform sinusoidal flow, these force coefficients have been determined from accurate laboratory experiments, and their dependence on the relevant governing parameters has been clearly indicated (Sarpkaya and Isaacson, 1981). However, the applicability of such results to the more general case of random waves remains uncertain. On the other hand, the direct use of random wave data yields estimated force coefficients which exhibit a high degree of scatter. This scatter is in part due to experimental errors and an inadequate accounting of a variety of effects such as vortex shedding, wave nonlinearities, unknown currents, wave directionality, and so on. Furthermore, it is in part also due to variabilities associated with the sampling process, and it is thereby strongly influenced by the choice of estimation method.

Simply stated, an estimation method provides an estimate of the drag and inertia coefficients from known time histories of the force on a section of a structure and the corresponding water particle velocity and acceleration. The latter may be obtained either from direct measurement, or from the application of wave theory to a measurement of the free surface elevation. A number of alternative estimation methods has been used, and these may be classified into those which provide a single pair of force coefficients for a given set of time histories; and those which provide force coefficients which are variable, either in the frequency domain or the time domain.

Because of the other uncertainties associated with measured data, the source of scatter associated with the sampling variability

has been difficult to isolate. However, the relative accuracy of alternative methods may conveniently be assessed using numerical simulation. Since uncertainties associated with the applicability of the Morison equation, the accuracy of the kinematics and force, and general experimental errors are then avoided, discrepancies between the estimated and specified coefficients can be attributed solely to sample variability associated with each method of analysis. The most direct approach to accomplish this is to simulate the wave and force records on the basis of linear wave theory and the Morison equation with constant coefficients. In addition, it is also possible to generate a force record with variable coefficients in order to utilize a more realistic force record and thereby apply perhaps a more meaningful test. In this way the effects of experimental errors and theoretical approximations that influence the conditioning of the measured data for determining the force coefficients can be more suitably examined.

Such an assessment of the suitability of different methods by using them to analyze numerically simulated force records has recently been carried out using simulations involving both constant coefficients (Isaacson et al., 1990; Subbiah and Isaacson, 1991) and variable coefficients (Isaacson and Baldwin, 1991). The present paper serves to summarize the alternative estimation methods used, and to provide an overall comparison between them based on numerical simulation. Eight methods of estimating the force coefficients are considered in this way, including some which utilize data relating to force maxima rather than to the entire force time series. In addition to an examination of sample variability, the comparisons also relate to the influence of Keulegan-Carpenter number, and of the width of the wave spectrum. Of the methods examined, the least squares method applied to the force time series is found to be the simplest and most accurate.

ESTIMATION METHODS

The Morison equation expresses the force per unit length on a section of a cylinder in the form:

$$F = K_d u |u| + K_m \dot{u} \quad (1)$$

where $K_d = (1/2) \rho D C_d$, $K_m = \rho(\pi D^2/4) C_m$, ρ is the mass density of fluid, D is the diameter of the cylinder, u and \dot{u} are the fluid

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