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NONLINEAR HYDRODYNAMIC FORCES ON FLOATING BODIES*

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ABSTRACT

I. INTRODUCTION

In this paper we discuss numerically determined hydrodynamic forces on floating cylinders. Particular attention is given to nonlinear effects and to finite length effects. The numerical solution algorithms used for these studies are finite-difference techniques for the nonlinear Navier-Stokes equations. The two-dimensional algorithm is contained in the SOLA-SURF code.[1] This code has been used in extensive numerical studies of the hydrodynamic forces on rectangular and triangular cylinders in low amplitude forced heave, sway, and roll motions.[2-4] The good agreement obtained in these studies with linear theory and experimental data serves as a validation of the basic calculational procedures. The companion three-dimensional code, SOLA-3D, has been successfully applied to the calculation of wind loading on three-dimensional structures[5] and, in addition, has reproduced selected two-dimensional calculations for heave and sway motions for cross checking against the two-dimensional code.

In this paper we utilize the two- and three-dimensional SOLA codes to investigate nonlinear and three-dimensional effects influencing the hydrodynamic forces on floating cylinders. In particular, we discuss nonlinear effects arising during large amplitude swaying motions of a two-dimensional 60° triangular cylinder. The results of the numerical

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studies are compared with data and an interpretation of the observed nonlinear effects is discussed. A second study is presented that compares two- and three-dimensional calculations of the triangular cylinder in sway. Here the end effects associated with finite length cylinders are noted. Nonlinear finite amplitude effects for the three-dimensional triangular cylinder are also studied. Finally, some results are presented for other nonlinear forces experienced by cylinders in two- and three-dimensional situations.

II. SAMPLE RESULTS

The nonlinear effects associated with large amplitude motions of floating cylinders may be illustrated with a two-dimensional triangular cylinder in finite amplitude forced sway. This study was performed with the two-dimensional SOLA-SURF code. The amplitude of motion in the original low amplitude studies was 0.058 of the triangular cylinder beam width at the still water level. The cylinder draft was equal to 0.865 beam widths. The finite amplitude studies were performed with amplitudes increased up to a maximum value of 0.430 of the beam width. The main effect of this increase in amplitude is to produce a significant decrease in the phase shift of the dynamic pressure force relative to the cylinder displacement phase. Figure 1 shows this phase shift and the amplitude of the dynamic pressure force as functions of the amplitude of motion. The hydrodynamic coefficients (added mass and damping coefficients) reflect this shift in phase angle. For small phase shifts the damping coefficient is proportional to the phase shift and thus follows its trend. The added mass coefficient varies less than 10% from the linear theory values.

The SOLA-3D code was used to calculate the finite length effects associated with a 60° triangular cylinder in forced sway. It was determined, for example, that the end effects of the cylinder are not significant for low amplitudes of motion for cylinder length to draft aspect ratios greater than two. Length to draft ratios less than two have not been investigated, but the somewhat analogous studies of wind flows about flat plates indicate that the drag per unit length is not expected to vary significantly until aspect ratios less than one are reached.

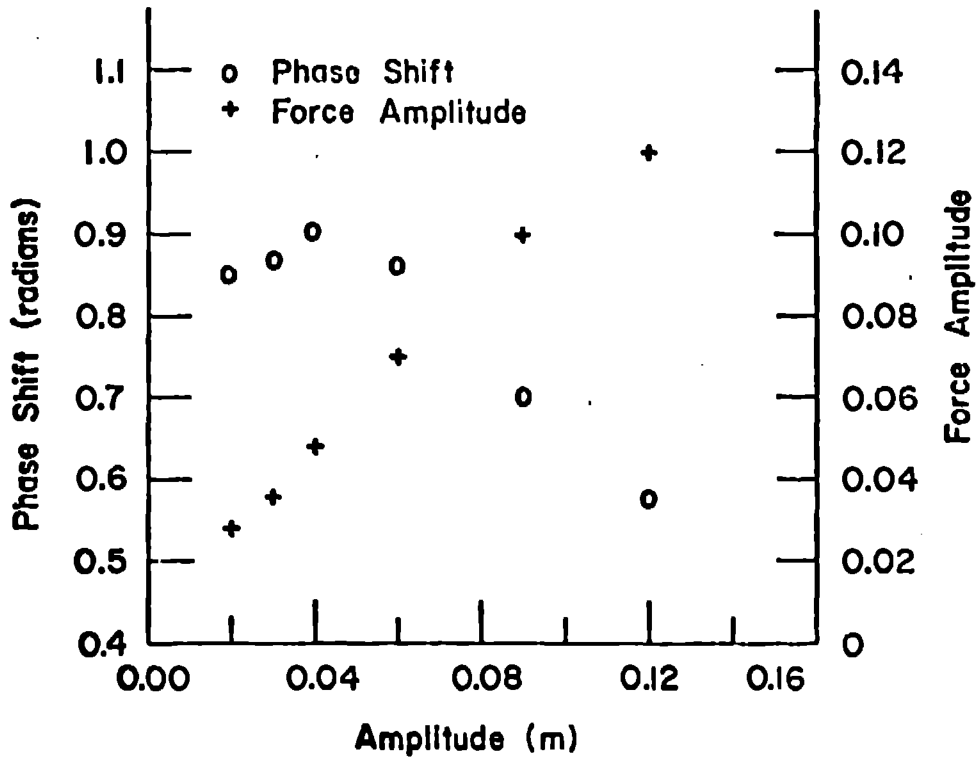

Fig. 1. Phase shift and amplitude of the dynamic pressure force as functions of the wedge displacement amplitude.

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