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HYDRODYNAMIC FORCES ON VERTICAL CYLINDERS AND THE LIGHTHILL CORRECTION

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Abstract—In the keynote address to the 1979 Behaviour of Offshore Structures (BOSS) Conference, Sir James Lighthill pointed out the absence of a second-order term of potential origin from the Morison description of the hydrodynamic force on a vertical cylinder. This term, referred to as the Lighthill correction, is due to the nonlinear interaction between the flow velocity and its horizontal gradient. As noted by Lighthill, if this term is omitted, the estimated drag force in the Morison equation is equal in effect to the actual drag force *plus* the Lighthill correction.

Thus, it would appear that in cases where hydrodynamic damping plays an important role and should therefore be estimated as accurately as possible, corrections of the Lighthill type might have to be added to the Morison expression for the hydrodynamic force. (One such case is the dynamic amplification of wind-induced fluctuating motions of tension leg platforms.) In particular, it might be expected that the estimation of the damping force would be more strongly affected in situations involving low Keulegan–Carpenter numbers, and therefore relatively low damping forces.

It is thus of interest to examine the effect of the Lighthill correction quantitatively. In this work, the expression for the Lighthill correction was derived for finite water depths. Measurements obtained in periodic wave flow at the Naval Civil Engineering Laboratory and in random wave flow at the Delft Hydraulics Laboratory were subjected to an extensive analysis. The results of the analysis showed that for both the periodic and random wave conditions and addition of the Lighthill correction (1) did not improve the Morison equation significantly, and (2) had no significant effect on the estimation of the drag force, including the drag force corresponding to very low Keulegan–Carpenter numbers.

INTRODUCTION

WAVE FORCES on cylindrical elements are of considerable interest in the design of offshore facilities. Morison *et al.* (1950) proposed a simple equation expressing the total wave force as the sum of two components: an inertia force, due to the effects of irrotational (potential) flow, and a drag force, due to viscosity (skin friction and flow separation) effects. The equation is calibrated with two empirical coefficients which are referred to as the inertia and drag coefficient and are functions of the flow conditions.

The Morison equation has been criticized as oversimplifying the fluid mechanics of the loading but an alternative rigorous approach has not been developed to date. There appears to be a consensus that, to represent the fluid mechanics more closely, it is better to add correction terms to the Morison equation rather than devise a completely new relationship (Keulegan and Carpenter, 1958; Lighthill, 1979; Sarpkaya, 1981; Cook, 1987). The corrections of Keulegan, Carpenter and Sarpkaya are aimed essentially at accounting for vorticity effects. The topic of this paper, the Lighthill correction, is a correction associated with irrotational (potential) flow effects.

In his keynote address to the 1979 Conference on the Behaviour of Offshore Structures (BOSS) Sir James Lighthill showed that the force associated with the irrotational flow includes, in addition to the linear inertia term of the Morison equation,