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Morison Equation in Practice and Hydrodynamic Validity

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This paper presents a practical interpretation of the hydrodynamic force equation developed based on the velocity potential. It expresses the equation in an original version of the Morison equation as well as in its subsequent numerous extended or modified versions in the industry design practice. It is demonstrated that the hydrodynamic force equation derived from a velocity potential for slender structures can be expressed term-by-term in a form of the original as well as modified versions of the Morison equation as used for floating and flexible structures in motion in waves. From this expression, the validity range of Morison equation is presented and discussed from the point of view of the hydrodynamic force equation. Also further discussed are: (a) the drag term empirically added to the hydrodynamic force equation, similar to the term in the Morison equation; (b) the use of the frequency-dependent, added mass and radiation (or wave) damping accounting for free-surface effect; (c) periodic time-dependency in practice; and (d) member diameter relative to incoming wave length.

INTRODUCTION

Since the late 1940s, oil and gas drilling and production activities have been moving from coastal to offshore areas. The industry faced a new challenge in the design of offshore bottom-fixed pile structures in accounting for current and water waves in shallow depth: wave and current-induced forces on the submerged part of the pile structures.

Since the 1950s, the Morison equation has been applied to the design of numerous jacket platforms, risers, and pipelines with only few failures reported. This indicates that the Morison equation has worked as a safe design tool for the offshore structures and equipment for more than half a century. Even these days, however, there have been occasional debates over the validity of the equation, from some theoretical hydrodynamics points of view, and on the accuracy or applicability of various extended or modified versions of the equation. Expressions of periodic forces in the Morison equation used in the industry have been disputed by some. This prompted the author to make the connection between the Morison equation (Morison et al., 1950) and theoretical hydrodynamic equations (Chung, 1975, 1976).

Morison et al. (1950) proposed an empirical equation for the evaluation of wave force, based on the model test of a vertical rigid pile in a flume with free surface effect in finite-depth water. Users have referred to it as the Morison equation (Morison et al., 1950). Since the 1950s, the Morison equation has been applied to the design of numerous jacket platforms, risers and pipelines with only few failures reported. This indicates that the Morison equation has worked as a safe design tool for the offshore structures and equipment for more than half a century. The petroleum industry in Texas, Louisiana, and California, and little elsewhere, have used the Morison equation in design and installed numerous bottom-fixed pile structures in the shallow coastal waters of the Gulf of Mexico and California.

As offshore drilling and production moved deeper into deeper coastal waters, it necessitated modification of the Morison equation in the design of taller bottom-fixed and floating structures and associated equipment such as risers and pipelines. Accordingly, the users have modified the equations and came up with hundreds of various versions of the Morison equation. This raised questions and debates among many hydrodynamics specialists on the validity or validity range of various versions of the Morison equation. Even in the 2000s, some theoretical hydrodynamics specialists disputed the accuracy or validity of various modified versions of the Morison equation. Such dispute has been common even among some industry engineers who have been using the equation. This prompted the author of this paper in 1970 to explore the connection between the Morison equation and the theoretical hydrodynamic equation (Chung, 1975, 1976).

The main aim of this paper is to show that the hydrodynamic force equation derived from the velocity potential for pile-like structures can be expressed term-by-term in the original Morison equation and its modified version for bottom-fixed and members of floating structures in motion in waves. Furthermore, the validity range of the Morison equation is discussed from the point of view of the hydrodynamic force equation.

Referring much of theoretical side of the hydrodynamic force equation of this paper to the previous version of the hydrodynamic force equation based on velocity potential (Chung, 1975, 1976), this paper attempts to present a practical interpretation of the previous hydrodynamic force equation (Chung, 1975) term-by-term in comparison with a form of the original Morison equation (Morison et al., 1950) as well as its subsequent numerous modified versions in design practice.

Further theoretical bases for the use of the frequency-dependent, added mass and radiation (or wave) damping with free-surface effect and periodic time-dependency, as applied in the Morison equation, are discussed. Also discussed is the drag term empirically added to the hydrodynamic force equation, similar to the drag term in the Morison equation. A few additional remarks are given in Appendix III for the influence of water properties and current vector (speed and direction) in water column varying along a very long riser pipe in deep ocean.

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