International Journal of Offshore and Polar Engineering
Vol. 4, No. 2, June 1994 (ISSN 1053-5381)

Wave Slamming on a Horizontal Circular Cylinder

Michael Isaacson* and Sundar Prasad
Department of Civil Engineering, University of British Columbia,
Vancouver, British Columbia, Canada

ABSTRACT

The present paper examines the impact loads due to waves interacting with a horizontal circular cylinder located near the still water level. Numerical models based on the use of a slamming coefficient are indicated for simulating the time history of the vertical force on both a fixed and dynamically responding cylinder. An approach based on an impulse coefficient is proposed for estimating the maximum response of a dynamically responding cylinder. Experiments have been conducted to measure the corresponding slamming and impulse coefficients, as well as the impulse rise-time and duration. Corrections to the measured coefficients to account for buoyancy, dynamic response and free surface slope are indicated. The coefficients exhibit a considerable degree of scatter, even when the various corrections are taken into account. However, the degree of scatter of the impulse coefficient is notably less than that of the slamming coefficient. The practical application of the various approaches described is illustrated.

INTRODUCTION

Impact loads due to wave slamming on horizontal members of an offshore structure are of considerable interest in the context of offshore design, particularly because fatigue stressing of joints due to such loads can give rise to structural failure. Predictions of the wave slamming force generally involve the use of a slamming coefficient C_s. Various analytical and experimental studies have been carried out in order to establish appropriate values of the maximum slamming coefficient for the common case of a circular cylinder. Some theoretical models have indicated a maximum slamming coefficient $C_{so} = \pi$ (Kaplan and Silbert, 1976; Faltinsen et al., 1977; Sarpkaya, 1978), whereas others conclude that $C_{so} = 2\pi$ (Fabula, 1957; Armand and Cointe, 1986). Experimental studies have yielded values of C_{so} which exhibit a considerable degree of scatter, ranging from about 1.0 to 6.4 (e.g. Dalton and Nash, 1976; Miller, 1977; Sarpkaya, 1978; Campbell and Weynberg, 1980; and Isaacson and Prasad, 1992).

Experiments of wave slamming usually involve the measurement of dynamic forces with a strain-gauge based system that depends on a displacement response (translation or bending) of a test cylinder. The measurement system's dynamic response can amplify or attenuate the observed force, and the member's response can itself affect the applied force. The rise time for the slamming force to reach its maximum value also affects the dynamic amplification of the measured force, and depends on various parameters such as air entrainment, compressibility, cylinder roughness, cylinder inclination and cylinder motion. In addition to the slamming force, a horizontal cylinder undergoing intermittent submergence in waves is also subjected to buoyancy, inertia and drag force components.

The present paper describes a numerical and experimental study of the vertical force acting on a section of a fixed, horizontal circular cylinder located near the free surface. The two-dimensional case of unidirectional waves propagating in a direction orthogonal to the cylinder axis is considered. Numerical models are developed for the time-varying vertical force on fixed and dynamically responding cylinders on the basis of specified empirical force coefficients. As an alternative to the conventional approach involving the slamming coefficient, the suitability of an impulse coefficient which combines the impact force and rise-time into a single dimensionless quantity is also examined. The experimental data have been analyzed to obtain both slamming and impulse coefficients, as well as the impulse rise-time and duration, and possible corrections to the measured coefficients to account for buoyancy, dynamic response and free surface slope are indicated. The practical application of the various approaches described is illustrated, and maximum responses predicted on the basis of the proposed impulse coefficient are compared with those based on the more traditional approach involving the slamming coefficient.

THEORETICAL FORMULATION

Governing Equations

A rigid, horizontal circular cylinder of radius a is located such that its lower surface is a distance h above the still water level as

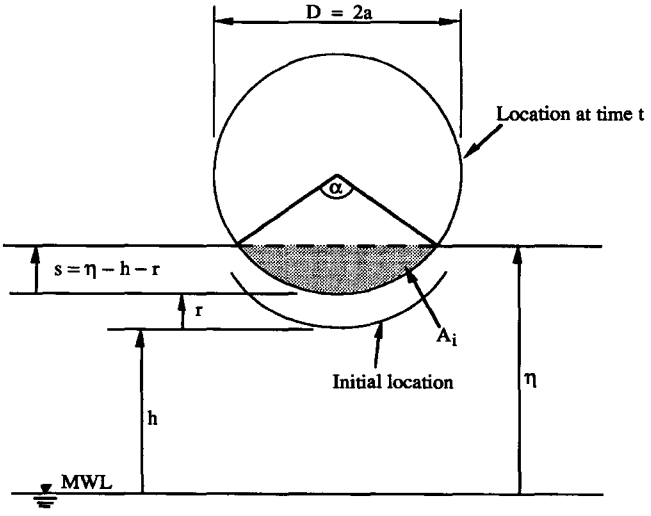

Fig. 1 Definition sketch

*ISOPE Member.

Received March 25, 1993: revised manuscript received by the editors January 31, 1994. The original version (prior to the final revised manuscript) was presented at the Third International Offshore and Polar Engineering Conference (ISOPE-93), Singapore, June 6-11, 1993.
KEY WORDS: Cylinders, hydrodynamics, impulse, ocean engineering, offshore structures, slamming force, waves.