Nonlinear Wave Loads on Single Vertical Cylinders: 
Pressure and Wave Field Measurements and Theoretical Predictions

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ABSTRACT

The results of a large set of experimental tests on single vertical cylinders in regular waves are presented. The aim of the research project was to investigate the local behaviour of the pressure at the wall and the wave pattern around a cylinder in the case of inertia dominated and of diffraction dominated wave loads, with a specific interest in the nonlinear features of the phenomena. To this end, the tests have been accurately designed and the used instrumentation allowed to obtain highly reliable results. The parameter $ka$ has been varied between 0.2 and 1.4, the wave steepness $H/\lambda$ ranging between 1/15 and 1/50.

The results in terms of maxima, minima and phase lag to the undisturbed incident wave are here compared with the closed-form linear solution by Mac Camy and Fuchs (1954). This comparison proves to be extremely useful to highlight the involved deviations form linearity of peak values and phase lags as a function of the angular position around the cylinder.

LIST OF SYMBOLS

- $a$ cylinder radius ($D=2a$)
- $B$ breadth of the wave basin
- $B_\chi$ bias error
- $d$ distance between the cylinder axis and the incident wave gauge
- $h$ depth of water in the wave basin
- $H$ undisturbed incident wave height
- $H^{(1)}_m$ Hankel function of the first kind of order $m$
- $k$ wave number
- $L$ length of the wave basin
- $N$ number of maxima/minima within the time window
- $p$ dynamic pressure
- $\Pi_i$ label of the measurement point $i$ for $p$
- $r, \theta, z$ cylindrical coordinates
- $S_\chi \sqrt{N}$ standard deviation of the average of $N$ measurements
- $St_u$ Student parameter
- $S_w$ wave steepness ($H/\lambda$)
- $t$ time
- $t_p, \eta$ zero crossing instant of $\eta_w$
- $U$ 95% confidence interval
- $T$ wave period
- $\chi$ mean value
- $W_Gi$ label of the measurement point $i$ for $\chi$
- $J_m$ Bessel function of the first kind of order $m$
- $\eta$ wave elevation
- $\eta_w$ wave elevation at the incident wave gauge
- $\lambda$ wave length
- $\psi_i$ phase lag between $\eta_w$ and $p_i$ or $\eta_i$
- $\Delta \theta$ angular step of the azimuth $\theta$ angle
- $\sigma$ standard deviation

INTRODUCTION

Design and operation of offshore structures in meteomarine environments of ever increasing severity, constitutes one of the present days challenge. At the same time, the requalification of used plants poses problems of some complexity.

To the continuous demand of increased knowledge and confidence in the computation of sea loads and short/long term behaviour of the structure, the present response is still unsatisfactory. This is partly due to the fluctuations in the international market of oil that make, as a consequence, abandon some general systematic studies to put the efforts on ad hoc "global" computations/tests on a specific structure. For instance, particular attention is presently devoted in the international literature to the hydroelastic behaviour of very large and very flexible floating structures.

From the scientific point of view, it is generally recognized that, while the amount of experimental data on the integral responses (motions, shear and bending moment, ...) of simple or complex structures is rather large and includes both scale and full scale data, there is a dramatic lacking of data on primitive local quantities. We are now referring to something like wave contours (runup) and fluid velocity in the near field and pressure on the structure surface. In particular, data in the crest/trough zone become extremely interesting and useful since the load excursion is expected to be severe in that region and the usual mathematical modelling is to a large extent unsatisfactory. At the same time, the knowledge of the ranges where linear approaches are reliable in the multiparameter space is not completely known.