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A PRACTICAL $O(\Delta\omega)$ APPROXIMATION OF LOW FREQUENCY WAVE LOADS

Charles Monroy
Research Department
Bureau Veritas
67-71,Boulevard du Chateau
Neuilly-sur-Seine
France
charles.monroy@bureauveritas.com

Guillaume de Hauteclocque
Research Department
Bureau Veritas
67-71,Boulevard du Chateau
Neuilly-sur-Seine, France

Xiao-Bo Chen
Research Department
Bureau Veritas
67-71,Boulevard du Chateau
Neuilly-sur-Seine
France

ABSTRACT

The low-frequency quadratic transfer function (QTF) is defined as the second-order wave loads occurring at the frequency equal to the difference frequency $(\omega_1 - \omega_2)$ of two wave frequencies (ω_1, ω_2) in bi-chromatic waves of unit amplitude. The exact formulation of the QTF which is recalled here is difficult to implement due to numerical convergence problems mainly related to the evaluation of an arduous free surface integral. This is why several approximations have been used for practical engineering studies. They have been the subject of a detailed review in [5]. Following this work, two closely-related formulations are investigated in this paper.

In [2], the classical formulations of QTF are examined by an analysis based on the Taylor development with respect to $\Delta\omega$ for $\Delta\omega \ll 1$ and an expansion of QTF in power of $\Delta\omega$ is then obtained. It is shown that the zeroth-order term is a pure real function equal to the drift loads and that the term of order O($\Delta\omega$) is a pure imaginary function.

The second-order low-frequency wave loading of order $O(\Delta\omega)$ contains a free-surface integral representing the second-order corrective forcing on the free surface. Since the integrand is of order $O(1/R^4)$ with R as the radial coordinate, the free-surface integral converges rapidly with the radial distance. Unlike what has been assumed in previous studies of particular cases, this free-surface contribution is, in general, not negligible for high $\Delta\omega$ compared to other components and the complete QTF.

Depending whether we use the $O(\Delta\omega)$ approximation for the whole QTF or only for this free surface integral, it leads to two different approximations. The first one is called original $O(\Delta\omega)$ approximation, because it is on this form that the $O(\Delta\omega)$ approximation was first described in [2]. If we use the $O(\Delta\omega)$ approximation only for the free surface integral, we call this approximation the practical $O(\Delta\omega)$ approximation. It is shown in this paper that the original formulation fails to predict the behaviour of the QTF even for small $O(\Delta\omega)$. Comparison for the $O(\Delta\omega)$ approximation of the free surface integral is performed against the analytical solution and the exact numerical formulation. The results are improved compared to when we neglect this free surface integral for the range of $\Delta\omega$ of interest, but still the agreement with the exact solution is not ideal. A path for further improvement is finally proposed.

INTRODUCTION

Mooring engineers often tend to use a straightforward approximation of the QTF loads based on an extrapolation of the diagonal terms of the QTF such as Newman approximation. It has the merit to avoid the time-consuming computation of the full QTF. However, even for deepwater cases where the resonance of the moored structures is reasonably low, it can lead to an under-