International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 15, No. 3, September 2005, pp. 189–197

Some Considerations on Forward-speed Seakeeping Calculations in Frequency Domain

Booki Kim*
Research and Product Development, American Bureau of Shipping, Houston, Texas, USA

Some aspects of the 3-dimensional forward-speed seakeeping calculation in frequency domain are considered. The steady wave flow is chosen for a basis flow approximation and applied to the implementation of the so-called m_j-terms. An efficient numerical method is applied for the accurate evaluation of the m_j-terms without deriving the second derivatives of the Green function. In addition, an expression for the classical restoring forces is enhanced, including the steady flow contributions. The steady trim and sinkage are also incorporated to determine the mean wetted part of the hull surface. For an approximate solution method, the use of the zero-speed pulsating Green function is exploited, and its validity is numerically investigated. The numerical results are compared with the results of the exact formulation that uses the translating and pulsating Green function. It is found that the use of the zero-speed pulsating Green function in conjunction with the steady wave flow approximation gives favorably good results in comparison with experimental results.

INTRODUCTION

In the design of ship structures, the ship motions and wave loads in the frequency domain are solutions to be preferred for use in the structural loadings of finite element analysis. We can outline 2 approaches in the frequency-domain forward-speed seakeeping prediction method, i.e., the Green function method and the Rankine panel method. The Green function method has advantages in that it requires distribution of singularities only on the wetted part of the hull surface, and it satisfies a radiation condition analytically. However, it can be cumbersome to evaluate the translating and pulsating Green function and its derivatives accurately, especially when the source and field points are close to the undisturbed free surface. In this case, special care should be paid to achieve the desirable accuracy. This difficulty may be avoided in the Rankine panel method because it uses the simple Rankine singularities. However, the Rankine panel method needs special attention in satisfying the radiation condition when the speed-frequency parameter is less than 0.25 (practically 0.5). The number of unknowns is much higher in the Rankine panel method than in the Green function method, as the free surface should also be discretized. The size of the free-surface domain should be carefully chosen, especially when the solutions in the low-frequency range are of interest. Among the state-of-the-art seakeeping tools linked to the finite element structural analysis packages, in practice, the computer codes developed based on the Green function method are dominant in the shipbuilding industries.

The 3-dimensional translating and pulsating Green function methods for the forward-speed ship motion problem have been developed by many investigators, e.g., Chang (1977), Inglis and Price (1981a), Guevel and Bougis (1982), Wu and Eatock Taylor (1989), Iwashita and Ohkusu (1989), Chan (1990), Kim and Ju (1993), Boin et al. (2000), Chen et al. (2000) and Maury et al. (2003). The mathematical formulations of the Green function method have been well established, but the numerical solutions have been presented in limited circumstances. For example, the interaction terms between the steady flow and unsteady wave fields, the so-called m_j-terms, have been overlooked. This is because the second derivatives of the steady potential in the m_j-terms are complicated and difficult to implement in an accurate manner. In many cases, the steady potential has been taken from free stream for simplicity. For other steady flow approximations, some studies have been reported to implement the m_j-terms based on the double body and steady wave flows rather than the free stream.

The importance of the m_j-terms in the forward-speed seakeeping calculation has been studied in Inglis and Price (1981b), Iwashita and Ohkusu (1989), Iwashita and Bertram (1997), Iwashita and Ito (1998), Fang (2000), Chen et al. (2000), Duan and Price (2002), and Ahmed et al. (2004). Inglis and Price (1981b) and Iwashita and Ohkusu (1989) showed significant change in the added mass and damping coefficients of a submerged prolate spheroid, depending on the inclusion of the steady wave flow. Iwashita and Bertram (1997) found that the effect of the steady wave flow could be remarkable on the local wave pressure near the bow region. Later, Iwashita and Ito (1998) claimed that the influence of the steady flow through the free-surface condition could be more important in the local wave pressure distributions at the bow region of a blunt ship. Fang (2000) included the steady wave potential in calculating the hydrodynamic forces and moments, while the m_j-terms were approximated with the free steam. The evaluation of the second derivatives of the steady potential was not involved, and the zero-speed pulsating Green function was used rather than the translating and pulsating Green function. Ahmed et al. (2004) improved this approach with the implementation of the m_j-terms based on the steady wave flow, but they still used the pulsating zero-speed Green function for the unsteady problem. Chen et al. (2000) adopted the double body model solution for the steady flow and calculated the second derivatives of the potential based on a biquadratic boundary element method. It was mentioned that the m_j-terms could play a great role in the results of the added mass and damping coefficients, especially for a large Froude number. Duan and Price (2002) found that the contribution of the m_j-terms could be significant near the bow and stern regions, even for a submerged slender body. Based on the results of these previous studies, the

*ISOPE Member.

Received March 17, 2005; revised manuscript received by the editors July 15, 2005. The original version was submitted directly to the Journal.
KEY WORDS: Forward-speed seakeeping, ship motion in frequency domain, Green function, m_j-terms, panel method.