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Study of the motions of fishing vessels by a time domain panel method

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A B S T R A C T

In this paper, a wide variety of computed motion results is presented for three existing fishing vessels. In order to do that, time domain computations of 3D ship motions are performed with a time domain Green's function. The computational method adopted is based on a previously developed one, whose numerical scheme here is subjected to modifications that increase its robustness and overall efficiency, so that it can be applied to calculate the motions of fishing vessels. The results are then compared with simulations using WAMIT for the zero speed case, and a strip theory method is used to determine the effect of forward speed. Results are presented for head seas, quartering head waves and following waves with three distinct Froude numbers.

1. Introduction

Prediction of wave induced motions and sea loads with the best possible accuracy is very important in ship design. Large motions affect operability and safety while large loads can cause structural damages. Therefore development of wave induced motions and loads capability has been one of the interests in the marine hydrodynamics domain for many decades.

Initial developments for ship motion problems were based on two-dimensional strip theories. A variety of two-dimensional strip theories were developed during the 1960s and 1970s, but the Salvesen et al. (1970) (STF) version of strip theory is one of the most popular and widely used by the industry for the practical ship motion and wave load calculations. The theory is linear and in the frequency domain, but Fonseca and Guedes Soares (1998) adopted a similar kind of formulation in the time domain, having also introduced hydrostatic and Froude–Krylov non-linearities in their theory and made extensive validations with experimental results as for example in Fonseca and Guedes Soares (2002, 2004a,b).

Although strip theories are used in the industry for a wide range of applications, there are several restrictions for most versions of these two-dimensional methods. The assumption of slenderness of the hull, the low Froude number and the high frequency range are the basic limitations. The computation for following waves can also be troublesome when the frequency of encounter approaches zero. Therefore the application of these theories to fishing vessels can be problematic.

During the 1980s the increasing availability of efficient and powerful computers encouraged developments towards more sophisticated, 3D tools such as the panel methods incorporating an oscillatory free surface. Depending on the choice of the Green's function, 3D panel methods can be categorized in three basic types: (i) solution in the frequency domain using a zero and a forward speed Green's function (Guevel and Bougis, 1982), (ii) solution using a Rankine Green's function (Nakos and Sclavounos, 1990) and (iii) solution in time domain using a transient free surface Green's function (King et al., 1988).

Solutions using the Rankine Panel method require the discretization of the wetted hull surface and also some portion of the neighboring free surface, but for the other two procedures only the wetted hull surfaces need to be discretized. Free surface Green's functions are complex functions and are dependent on the class of each particular problem. Wehausen and Laitone (1960) provide expressions for the free-surface Green's functions for a wide variety of problems. Evaluation of Green's functions is mostly a nontrivial task. For example, evaluation of the finite depth Green's function for the zero speed 3D radiation diffraction problem, or evaluation of the forward speed frequency domain Green's function for the 3D ship motion problem, are extremely complicated.

The frequency and time domain approaches are related by a Fourier transformation for the zero speed problem. However, regarding the forward speed problem, no such transformations are available. In general, the frequency domain approach is widely used in the offshore industry. This development was accelerated by the fact that a strip theory type of method could not possibly be applied to typical offshore geometric configurations as they are not slender nor do they comply with most of the method's logical

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restrictions. The original codes for the solution of the linear 3D zero speed radiation-diffraction problem based on the frequency domain Green's function, used lower order panel methods for the numerical solution of the integral relations. The first commercial code using this approach is probably that by Garrison (1978) while the most widely used is probably WAMIT (Korsmeyer et al., 1988). These codes have been widely validated and subsequently enhanced to include second order mean drift and slowly varying forces.

However when ships are concerned, it is the forward speed that prevents the use of this approach. One of the reasons is that the forward speed Green's function is extremely difficult to compute compared to its zero speed case. The first attempt to compute ship motions using the forward speed oscillatory free-surface Green's function was reported by Chang (1977), with later contributions from other researchers such as Inglis and Price (1981), Guevel and Bougis (1982), Wu and Eatock Taylor (1987), Iwashita and Ohkusu (1992) and Chen et al. (2000). This approach however did not gain much popularity as an accurate evaluation of the Green's function continues to remain a difficult task.

Compared to the frequency domain consideration for the forward speed problem, a time domain approach is found suitable because the corresponding time domain Green's function is relatively easy to compute. The original formulation using the time domain Green's function is credited to Finkelstein (1957). Some of the important developments in this context are due to Liapis and Beck (1985), who introduced the time domain Green function based solution method for the 3D linear forward speed problem; while King et al. (1988), Lin and Yue (1990), Bingham et al. (1994) and Korsemeyer and Bingham (1998), among others, pursued variants of the same method for different classes of 3D forward speed problems.

Depending on the description of the wetted hull surface and distribution of the unknown field variable over the hull, panel methods can be divided into lower order and higher order panel methods. With the lower order approach, the body geometry is discretized by flat quadrilateral or triangular panels. Source potentials are assumed to be constant on each panel or as a linear function, whereas for the higher order panel method, both are represented by the higher order polynomials or higher order functions (such as B-spline basis functions). Some of the significant developments towards the higher order methods are due to Hsin et al. (1993), Maniar (1995) and Newman and Lee (2002), who solved a considerable amount of hydrodynamic problems using frequency domain Green's functions, whereas Danmeier (1998), Qiu et al. (2004) and Datta and Sen (2006) used time domain Green's functions for the solution scheme. Most of them implement B-splines or NURBS for the description of the hull geometry and the representation of the unknown potential over the hull surface. As for Newman and Lee (2002), bi-quadratic functions were chosen.

The panel method is known to represent better physics of the motions of a floater than the strip theory. The frequency domain panel method is extremely popular in the offshore industry, but it is not adequate for calculating rigid body motions of moving vessels. A time domain panel method is more convenient to handle such classes of problems. Non-linearities such as Froude–Krylov nonlinearity and non-linear hydrostatics, as well as geometric nonlinearity can be incorporated in the time domain formulation.

Lin and Yue (1990) argued that computational inefficiency for the linearized seakeeping problem is the only disadvantage of the time domain earth fixed formulation. The solution scheme proposed by Datta and Sen (2007) proved capable when intended for the Wigley and the Series-60 hull, but produced unsatisfactory results for the S175 hull and thus it is not expected to produce good results for the fishing vessels studied here. Although Singh and Sen (2007) had produced some linear and non-linear comparisons regarding the S175 hull, the presented results were not compared with other published results or methods, not even within the linear computation realm. Thus it constitutes a considerable motivation to further develop the computational scheme so as to increase its applicability to all kinds of vessels.

Fishing vessels hull forms diverge significantly from the ones of container ship or large cargo ship. They have different L/B ratios, block coefficient, and cross coupling also is very significant because of the asymmetry between bow and stern part. This cross coupling effect is important because the lengths of these vessels are very small compared to large ships, but the level of asymmetry is also the same. The computational scheme proposed by Datta and Sen (2007) shows good agreement with other published results for large ships. But it has been found to give inadequate results when applied to fishing vessels. Therefore, there is a need to introduce some modifications in the scheme, to go beyond such restrictions.

The objective of this paper is to compare the fishing vessels motion results between time domain method and strip theory. In order to do that, it is necessary to reformulate some of the conditions that are included in the earth fixed time domain formulation of Datta and Sen (2007). In this paper the lower order method approach is considered, leaving the extension to the higher order for future development.

Due to the unavailability of the experimental results for these fishing vessels, the validation of the present results is done initially with results obtained for zero speed by the well validated WAMIT code. WAMIT cannot be used for situations with speed of advance and thus to assess the importance of this effect the results are compared with the strip theory results obtained with the Salvesen et al. (1970) method, which is also a well validated method. The results presented show good agreement in most of the cases.

2. Brief mathematical formulation

Only a brief description of the problem formulation and the construction of the integral relations are presented here, since the details are available in several sources such as e.g. Lin and Yue (1990).

For the present linear ship motion problem, a three-dimensional floating body is considered advancing with steady forward speed within a linear incident wave field. As is well known, introduction of two co-ordinate systems, an inertial and a body-fixed system, is usual for defining such forward speed problem indicated in Fig. 1. Let *Oxyz* be an inertial (earth fixed), right

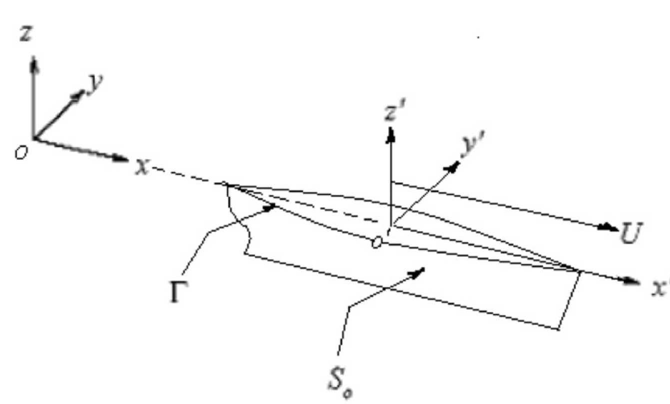

Fig. 1. Co-ordinate systems.