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Autor(en): **Arcilla, A.S.**

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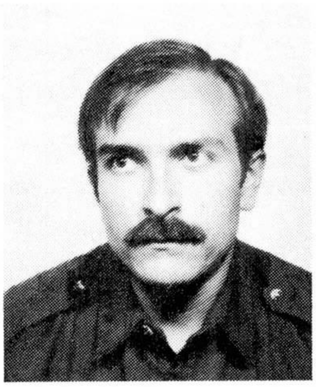
Modeling Ship Manoeuvres in Arbitrary Fluid Domains

Modèle de manoeuvre dans un domaine fluide arbitraire

Simulation von Schiffsmanövern in willkürlichen Strömungsbereichen

A. S. ARCILLA
Prof. Dr.-Ing.
University of Barcelona
Barcelona, Spain



A. S. Arcilla got his civil engineering degree at the University of Madrid. He followed post-graduate courses at several European Universities and defended his Ph. D. Thesis at the University of Barcelona. For five years he was involved in environmental conditions for the design of maritime structures. Now he is professor of Ocean Engineering.

SUMMARY
The motion of a ship as it advances towards a bridge or structure is performed in a fluid domain of varying geometry. The numerical simulation of this problem requires a different spatial discretization at each time step. To simplify the calculations a modified set of governing equations is presented here. The paper explains how to obtain these equations and their advantages.

RÉSUMÉ
Le mouvement d'un bateau à l'approche d'un pont ou d'une structure, est réalisé dans un domaine fluide à géométrie variable. La simulation numérique de ce problème nécessite une discrétisation spatiale différente pour chaque intervalle de temps. Pour simplifier les calculs, une version modifiée des équations de base est présentée. L'article montre le calcul de des équations et leurs avantages.

ZUSAMMENFASSUNG
Die Bewegung eines Schiffes in der Nähe einer Brücke oder Struktur wird in einem willkürlichen Strömungsbereich mit wechselnder Geometrie untersucht. Die numerische Simulation dieser Aufgabe erfordert eine räumliche und zeitliche Diskretisierung der Hauptgleichungen. Eine vereinfachte Berechnung wird mit deren Vorteilen vorgeschlagen.

1. INTRODUCTION

The motion of a ship in the vicinity of a structure, even to the point of collision, is a problem of great practical significance but difficult to simulate numerically. To illustrate this we shall consider both ship and structure as rigid bodies which means that the model is valid up to the instant of collision. The fluid domain in which the ship moves varies with time. Therefore, the boundary of this domain is different at each time step and a new spatial discretization is required at each time level. Furthermore, the motion of the ship, resulting from waves, current and wind action and the corresponding rudder and propeller forces, will be far from sinusoidal. This fact, together with the non-linearity of the system, precludes an analysis in the frequency domain as is usual for sea-keeping studies. On the other hand, most of the models dealing with the motion of a ship in the time domain are suitable for just two cases:

- The fluid domain geometry is constant at each time step. This happens when the ship performs small oscillatory motions from a stationary average position. A typical example could be a moored ship.([1], [2]).

- The ship performs small oscillations superposed to a rectilinear, uniform motion, as e.g. when she is under way. The corresponding equations are shown in [2] but they are not intended for arbitrary fluid domains. The reason is that the main aim of the model were the motions of a ship under way, subject to wave action, and this usually happens in relatively deep water.

In other words, most of time-domain analyses, reviewed in [3] and [4] are not prepared to tackle with ships moving very near a structure and performing a highly irregular motion due to waves, currents, winds and the corresponding actions of propellers and rudders. The model introduced in this paper develops the governing equations for this problem. It will be organised as follows:

- Brief review of currently used mathematical models.
- The proposed formulation.
- References.

2. REVIEW OF CURRENTLY USED MODELS

Models used to predict the motion of a rigid body are based on Newton's second law. The main difficulty arises from the hydrodynamic forces on the body. These forces depend on the geometry of the domain and on the environmental disturbances acting (e.g. waves and current). There are two approaches to solve this problem:

- The well-known method of hydrodynamic coefficients in which forces are expressed as a combination of variables significant to the problem affected by the appropriate coefficients.

- The development of a mathematical model starting from a set of basic hypothesis.

The first method is not recommended for restricted fluid domains with arbitrary geometry as many of the coefficients do not have a clear physical meaning and must be evaluated through model tests ([5]). This situation worsens if the geometry varies at each time step. The second approach starts considering that the hydrodynamic forces on the body are associated to inertial, gravitational and viscous effects. The latter will be modelled here with a standard velocity squared law [6], to focus the attention on the first two. The corresponding forces will be called "potential" for, since viscosity is left out of this part of the analysis, the resulting fluid motion will be described in terms of a potential function ϕ. The standard models to evaluate potential forces in restricted waters are not able to deal with a ship moving in the vicinity of a structure, from a certain distance apart right up to the point of collision. There are two reasons:

- The variation, with time, of the domain geometry in which the ship moves.

- The boundary condition on the immersed surface of the ship. This condition must be imposed on the exact position of the surface ([7]). Only if the motion consists of small oscillations from a stationary average position, can the condition be imposed on this average surface.

3. PROPOSED FORMULATION

The proposed model will obviate some of these difficulties by solving an alternative problem in which the ship remains fixed in space and it is the fluid and the rest of the boundaries that perform a motion equal and opposite to that of the ship. This situation (S2) is obtained from the real one (S1) by applying to every element of the system the additional accelerations $(-\ddot{x}_j)$, j=1-6, in which the $(\ddot{x}_j)$ define the motion of the ship. In order to include an average trajectory plus the wave-induced motions the six degrees of freedom must be retained throughout the development. The first three (j=1, 2, 3) denote translations and the remaining ones (j=4, 5, 6) rotations with respect to the same axes. The problem, as it has been said, will be solved in the time domain by means of the impulse-response-function technique ([4]). In each time step the potential equation, $\nabla^2 \emptyset=0$, will be solved with a 3D sink-source technique, described, e.g. in [8]. Now it is necessary to calculate the "differential forces", if any, between the real (S1) and fictitious (S2) situations. These forces will be due to the additional accelerations, $(-\ddot{x}_j)$, j=1-6. Consider now the translatory motion defined by $(\ddot{x}_j)$, j=1-3. These accelerations (in the fluid domain) must be generated by a force field per unit volume:

$-p\ddot{x}_j$, j=1, 2, 3; p being the mass density of the fluid. This force field must be generated by a pressure gradient in the j-direction (j=1, 2, 3): $p\ddot{x}_j$.

The resulting pressure field is: $p\ddot{x}_j x_j$, for a fixed j (j=1, 2, 3). Therefore, the generalised "differential force" in mode k(k=1-6) due to an acceleration in mode j (j=1-3) is $DF_{kj}=-\iint_s p\ddot{x}_j x_j n_k ds=-p\ddot{x}_j\iint_s x_j n_k \, ds$ $= -p\ddot{x}_j a_{kj}$ in which s is the immersed surface of the ship and n_k is the unit nomal vector, positive towards the fluid. The coefficient a_{kj} is a function only of the immersed surface geometry because $(\ddot{x}_j)$ is constant in the fluid domain.

The evaluation of these DF_{kj} has been quite simple in this "purely translational" case because, in this case, the fluid motion is irrotational and, thus, the resulting hydrodynamic pressures, normal to S. The differencial forces (DF's) associated to the rotational case are somewhat more difficult to calculate unless the tangential component of the pressure is neglected. This has been done in [9] based on the fact that the DF coming from the accelerations of rotation affects the viscous force, while the emphasis of the model was in the potential force.

The resulting expressions are:

$$DF_{kj} = -p\ddot{x}_j \; b_{kj} \; -p(\dot{x}_j)^2 \; c_{kj} \quad k=1-6 \;, \; j=4-6$$

It should be noted that, if the impulse function technique is applied potential forces on the ship can be calculated either in S1 or S2. This is because in each time step only impulsive motions are performed in which no linear accelerations exist. Observe that, with this model structure, the only "correction" for the potential force comes from the DF_{kj}, j=1, 2, 3. Summarizing, in each time step the potential problem is solved as it would be done for a ship with a stationary average position ([1]). Next, the resulting hydrodynamic forces on the ship in each time step are composed linearly. Let us assume that, in time step i, the instantaneous potential force is PI^i_k (t), k=1-6, and the "differed" one, due to the memory effect introduced by the free-surface, is PD^i_k $(t-Z_i)$. Z_i is the instant in which time step i ended ([9]). The total potential force, P, can then be evaluated as:

$$P^i_k \;(t) = PI^i_k \;(t) + \sum_{l=1}^{i-1} PD^l_k \;(t-Z_l) \qquad k=1-6$$

Substituting these expressions, together with the "differential forces", in the equations of motion the following structure is obtained:

$$E^i_k \;(t) = A^i_{kj} \;\ddot{x}_j + D^i_{kjl} \;\dot{x}_j\dot{x}_l + P^i_{kj}\dot{x}_j + C^i_{kj}x_j + f^i_k(t); k, \; j,l=1-6$$

in which:

$E^i_k(t)$ is the external exciting force, in time step i, and may include the action of waves, currents, tug-boats, etc.

f^i_k (t) is the memory function due to the free-surface effect.

The precise formulation of the function f^i_k (t), together with that of the coefficients A^i_{kj}, D^i_{kjl}, P^i_{kj}, and C^i_{kj} may be found in [9].

4. SUMMARY AND CONCLUSIONS

A formulation to predict the motion, with 6 degrees of freedom, of a rigid body in a restricted fluid domain has been proposed. The problem has been solved in the time domain, the emphasis being placed on the potential reaction.

It is recognised the need to develop a similar model for the viscous reaction. Due attention should also be paid to the "external exciting force" and to the numerical propagation of errors, which is now being studied for the proposed model.

REFERENCES

1. VAN OORTMERSSEN, G., The motions of a moored ship in waves, Ph. D. Thesis, Wageningen, 1976.
2. CUMMINS, W.E., The impulse response function and ship motions, DTMB Rep. 1661, Washington D.C., 1962.
3. OGILVIE, T.F., Recent progress towards the understanding and prediction of ship motions, 5th. Symp. Nav. Hydrodyn, Bergen, 1964.
4. PRICE, W.G. and BISHOP, R.E.D., Probabilistic theory of ship dynamics, Chapman and Hall, 1974.
5. TUCK, E.O., Hydrodynamic problems of ships in restricted waters, Ann. Rev. Fluid Mech. 10, 1978.
6. REMERY, G.F.M. and VAN OORTMERSSEN, G., The mean wave, wind and current forces on offshore structures, OTC 1741, 1973.
7. TIMMAN, R. and NEWMAN, J.N., The coupled damping coefficients of symmetric ship, J.S.R. March, 1962.
8. NEWMAN, J.N., Marine hydrodynamics, M.I.T. Press, 1977.
9. ARCILLA, A.S., A new hydrodynamic model for restricted fluid domains, 4th. Int. Conf. on Fin. Elem. in Water Res., Springer-Verlag, 1982.