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On the Irregular Frequencies Appearing in Wave Diffraction-Radiation Solutions

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ABSTRACT

The paper presents the method for removing the effects of irregular frequencies in the numerical solution of water wave diffraction-radiation problems. After a brief introduction and explanation of the phenomenon, the method is detailed. Inspired from some previous works, it consists of changing the ficticious interior boundary value problem in such a way that it becomes uniquely defined for all frequencies. Some practical advice concerning the implementation is also given. Numerical results demonstrating the efficiency of the method are finally presented.

INTRODUCTION

The detrimental effects of irregular frequencies are well known in naval hydrodynamics when using the boundary integral equation (BIE) method to solve the diffraction-radiation problem. These frequencies do not represent any kind of physical resonance but are due to a peculiarity of the BIE method involving the fictitious interior problem, which has no unique solution at some eigen-frequencies. The finite element method, for example, and, as we will see, even some type of BIE methods are free of this effect.

There are today several methods in use to remove the effects of irregular frequencies for a three-dimensional body of arbitrary shape. The first one, which can be called the modified BIE method (Lee et al., 1989), consists of combining the original BIE for the potential with a BIE for normal derivative. Theoretically the new BIE is free of irregular frequencies. However, two numerical disadvantages are introduced by this unnatural coupling. The first one is the necessity to evaluate the second order derivatives of the Green function which need a special treatment, and the second one is the choice of the coupling constant on which greatly depends the efficiency of the method.

The second method commonly used is the so-called extended BIE method, which consists of adding a kind of artificial lid on the fictitious free surface inside the body. This method also eliminates the effects of all irregular frequencies at the cost of modeling the interior free surface, which increases the number of unknowns, and the necessity for special treatment of the logarithmic singularity which appears in the expression for the Green function when two points are close to each other and close to the free surface. However, this method seems to be more efficient than the previous one because of its generality and absence of any arbitrary constant in the formulation. A brief summary of these methods can be found in Lee et al. (1989) and Zhu et al. (1994). It is also important to note the interesting method presented by Ohmatsu (1983). The paper deals with a 2-D case, and the so-called combined integral equation method is developed. In this method two additional conditions for one point inside the body are introduced in order to insure the uniqueness of the solution. The resulting linear system becomes overdetermined and is solved by special methods.

In this paper we are concerned with the different variations of the extended BIE method, and we try to give some new theoretical clarifications; also we give some practical advice concerning numerical implementation of the method. The classical linear diffraction-radiation problem of the freely floating body is considered in the context of two types of BIE methods: The first one is the so-called wave Green function method where the effects of irregular frequencies are present, and the second one is the so-called Rankine panel method, which is free of irregular-frequencies effects.

IRREGULAR FREQUENCIES

In the BIE method, we make use of the Green function, which satisfies the governing equations in all fluid domain $z \le 0$. Thus, the real physical problem (exterior) and fictitious (interior) problem are connected and solved at the same time. If the Green function is chosen in such a way that the interior problem has no unique solution at some frequencies (irregular frequencies), the exterior solution will be also affected and important numerical errors will arise around these frequencies.

To put these statements into a clear perspective, let us consider the exterior/interior boundary value problems presented in Fig. 1. In the context of BIE methods, this problem is usually solved either by the source method or by the mixed singularity method (direct application of the Green theorem). Because the source method seems to be more adapted to show evidence of irregular frequencies and discuss their removal, only this method will be considered.

The application of the Green theorem to the exterior/interior problem leads to the integral representation of the potential in two

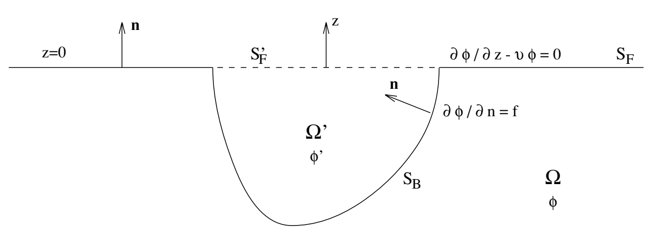

Fig. 1 Different domains of interest

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