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Validation Studies of Panel-Free Method for Wave-Body Interaction Analysis

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The Motion Analysis Program Suite (MAPS) has been developed based on the panel-free method for the accurate computation of wave-body interactions in the frequency domain. In the panel-free method, the desingularized integral equations in terms of source strength distribution are developed by removing the singularity due to the Rankine term in the Green function. NURBS (Non-Uniform Rational B-Splines) surfaces are adopted to describe the exact body geometry mathematically. The integral equations are discretized over the body surface by Gaussian quadratures. In this work, computations of 1st-order solutions by the panel-free method have been extended to floating bodies with complex geometry. Validation studies are presented for a liquefied natural gas (LNG) carrier in shallow water and a floating production storage and offloading (FPSO) vessel in deep water. Results are compared with experimental data and those by the panel method. Wave drift forces for a floating box were also computed based on the near-field formulation and compared with the far-field solution.

INTRODUCTION

The panel method has been widely used in the computation of ship and offshore structure responses in waves. Hess and Smith (1964) pioneered the panel method in which the body surface was subdivided into flat quadrilaterals. The integration of the singular $1/r$ term over a panel was obtained by assuming that the panel is planar quadrilateral or a triangle with the constant source strength distribution. It is often referred to as the constant-source-flat-panel method or a lower-order panel method. Normally, a large number of panels is required to achieve accurate results. For bodies with complex geometry, it is challenging to develop a panel generator for practical applications.

Higher-order panel methods have been developed in various degrees to overcome the deficiencies of the constant-source-flat-panel method. Most higher-order methods allow for linear or quadratic panels and 1st- or 2nd-degree polynomial distribution of source strength over a panel. For example, Lee et al. (1998) and Danmeier (1999) have presented a geometry-independent higher-order method which separates the geometric and hydrodynamic representations. The body surface was represented by a number of patches. The B-splines were employed to represent the geometry and the velocity potential on each patch. Lee and Newman (2001) used B-splines only to represent the velocity potential. The accuracy of the solution can be refined by controlling the degree of B-splines and/or subdividing patches. Chen et al. (2000) developed a bi-quadrature patch method where the geometry of a ship is described by biquadrature patches, and the Galerkin procedure is used to improve the accuracy of solutions. In the higher-order panel methods, the integration of the singular $1/r$ term can be evaluated numerically in a variety of ways. For example, in the work of Danmeier (1999), an adaptive subdivision and triangulation scheme was used.

In general, the computational error of the panel method is mainly due to 4 sources: (1) the geometrical approximation; (2) the assumption of a certain degree of velocity potential or source strength distribution on a panel; (3) the evaluation of the singular terms in the integral equation; and (4) the evaluation of the free-surface Green function. A panel-free method has been developed by Qiu and Hsiung (2002) and Qiu et al. (2006) to remove the error due to the first 3 sources. They have applied this method to wave interactions with bodies in the time domain and in the frequency domain. In their work, the desingularized integral equations were first developed by removing the singularity due to the Rankine term in the Green function. The Non-Uniform Rational B-Splines (NURBS) were adopted to describe the exact body surface mathematically. The regular integral equations were then discretized over the body surface by Gaussian quadratures. The accuracy and the reliability of the method have been demonstrated by its applications to bodies with simple geometry such as hemispheres, submerged spheres, vertically floating cylinders and Wigley hulls.

In this work, the panel-free method has been extended to compute the wave interaction with floating bodies with complex geometry in the frequency domain. Validation studies were carried out for a liquefied natural gas (LNG) carrier in shallow water waves and a floating production storage and offloading (FPSO) platform in deep water. Studies were mainly focused on head-sea conditions. The computed results were compared with the exper-

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KEY WORDS: Panel-free method; Green function; frequency domain; NURBS; Gaussian quadrature; wave drift force; validation.