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Comparison of Higher-Order Boundary Element and Constant Panel Methods for Hydrodynamic Loadings

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ABSTRACT

This paper presents the description of a higher-order boundary element method (HOBEM) for calculating linear hydrodynamic loadings on large floating bodies, and a comparison with constant panel methods and HOBEMs that are employed in conjunction with the hybrid boundary integral equation procedure, for a variety of structural configurations. It was concluded from the study that HOBEM has several important features: It uses many fewer boundary elements and much less computer time, with higher accuracy than conventional methods. In addition, the computer code for hydrodynamic loadings can easily be used for finite element structural analysis.

NOMENCLATURE

$C(p)$	:	normalized solid angle at field point p on boundary Γ_s
F_r	:	rth mode wave exciting force
$G(p,q)$	:	Green's function
g	:	gravitational acceleration
i	:	imaginary number, $\sqrt{-1}$
$J(\xi,\eta)$	:	Jacobian matrix
L	:	length of floating box or ISSC TLP
M	:	total number of elements on Γ_s
M_2	:	pitch wave exciting moment
$NENN(j,e)$	:	connective matrix (correspondence between local and global nodes)
$N_j(u,h)$	:	shape function
NOD	:	total number of nodes on Γ_s
$n(p), n(q)$	:	outward normal vector at field point p or source point q
p	:	field point (x_p, y_p, z_p)
q	:	source point (x_q, y_q, z_q)
S	:	number of nodes of each element
V	:	volume of body
α_i	:	solid angle at field point $i(p)$ on boundary Γ_s
β	:	wave heading angle
Γ_e	:	e_{th} element
Γ_j	:	j_{th} panel
Γ_s	:	body surface boundary
δ_{ij}	:	Kronecker delta
η_a	:	incident wave amplitude
ξ,η	:	intrinsic coordinates
ν	:	ω^2/g, wavenumber
ρ	:	fluid density
σ_j	:	source strength on jth panel
Φ_D, Φ_I	:	diffraction and incident wave potential
ω	:	wave frequency

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KEY WORDS: Higher-order boundary elements, boundary element method, constant panel method, hydrodynamic loadings.

INTRODUCTION

Reliable estimates of the hydrodynamic loadings on large offshore structures are critical in the assessment of structural response, stability and fatigue life. The constant panel method (CPM) introduced by Hess-Smith (1964) has been widely used for calculating hydrodynamic loadings, for example by Faltinsen-Michelsen (1974); Garrison (1979); Inglis-Price (1980); Ostergaard-Schellin (1987); and Korsmeyer et al. (1988). In the constant panel approach, the surface of a three-dimensional body is replaced by quadrilateral or triangular facets. Each facet (or panel) represents a source distribution of constant strength with satisfaction of a Neumann boundary condition required at the center (control point) of each panel. The panels are chosen so that the control points may contact or nearly contact the actual body surface from outside or inside the body. Consequently, the constant panel approach has several limitations: (1) the source distribution is discontinuous, i.e., the source strength is constant over each panel and jumps stepwise at the boundary of neighboring panels; (2) for curved body surfaces, the quadrilaterally faceted surface becomes discontinuous as all the four corner points generally do not coincide with those of the neighboring panels. Thus, the faceted surface introduces so-called leaks.

To overcome the foregoing limitations, Webster (1975) proposed the use of triangular panels with linear source distributions located just beneath the actual body surface. As there is no clear criterion for specification of the distance between these two surfaces, the approach yields considerable effect on the numerical errors.

CPMs have been employed either in the indirect (source-sink) or direct boundary integral equation formulations.

The higher-order boundary elements have been applied in the so-called hybrid boundary integral equation formulation by Eatock Taylor and Zietsman (1982); Tong (1989); and Matsui and Kato (1990). In these procedures the fluid domain is generally divided into inner and outer regions by a fictitious surface enclosing the floating body, on which the continuity requirements of the velocity potential and the normal velocity of the fluid are to be satis-