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Numerical analysis for hydrodynamic interaction effects between vessel and semi-circle bank wall

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ABSTRACT: *The hydrodynamic interaction forces and moments induced by the vicinity of bank on a passing vessel are known as wall effects. In this paper, the characteristics of interaction acting on a passing vessel in the proximity of a semi-circle bank wall are described and illustrated, and the effects of ship velocity, water depth and the lateral distance between vessel and semi-circle bank wall are discussed. For spacing between ship and semi-circle bank wall (SP) less than about 0.2 L and depth to ship's draft ratio (h/d) less than around 2.0, the ship-bank interaction effects increase steeply as h/d decreases. However, for spacing between ship and semi-circle bank wall (SP) more than about 0.3 L, the ship-bank interaction effects increase slowly as h/d decreases, regardless of the water depth. Also, for spacing between ship and semi-circle bank wall (SP) less than about 0.2 L, the hydrodynamic interaction effects acting on large vessel increase largely as ship velocity increases. In the meantime, for spacing between ship and semi-circle bank wall (S_P) more than 0.3 L, the interaction effects increase slowly as ship velocity increases.*

KEY WORDS: Interaction effect; Wall effect; Spacing between vessel and semi-circle bank wall; Ship velocity; Water depth.

NOMENCLATURE

B	Breadth of ship
C_F , C_M	Dimensionless hydrodynamic force and yaw moment of ship
d	Draught of ship
ε	Slenderness parameter
Φ	Velocity potential
h	Water depth
$H^{(\sigma)}, H^{(\gamma)}$	Functions on the bank wall
L	Ship length
ΔP	Difference of linearized pressure about x_1 -axis
$\sigma,\ \gamma$	Source and vortex strength
$\xi,\ \eta$	Source and vortex point
$S_P,\ S_T$	Lateral and longitudinal distance between ship and wedge-shaped bank
U	Ship velocity

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INTRODUCTION

During the last decades a continuous increase in speed and size of modern vessels makes their consideration in the design of channels, canals and ports. However, the dimensions of access canals, channels and ports frequented by these vessels often do not increase at the same rate. So, the problem of ship controllability in confined waters due to the effect of shallow water or inherently restricted nature of waterways is the main concern not only of naval architects and ship operators but also of engineers who will design future waterways. In general, the asymmetric flow around a vessel induced by the vicinity of banks causes pressure differences between starboard and port sides when a vessel is approached toward the bank in confined waters, such as near some fixed obstacles, or in a narrow channel. This phenomenon is known as bank effect and depends on many parameters, including the bank shape, depth, the spacing between vessel and bank, and ship velocity. Also, the bank effect has a significant impact on the maneuvering characteristics of the vessel, and the hydrodynamic force and moment between large vessel and bank can't be neglected from the viewpoint of marine disasters. For this to be possible, the hydrodynamic interaction effects between large vessel and restricted waters should be well understood, and the research on this field has been reported for the past years. Newman (1965; 1969; 1972) reported the force and moment between vessel and bank based on the slender body and some theory for ship maneuvering. Also, similar work was reported by Davis (1986), Norrbin (1974), Yeung and Tan (1980), Kijima et al. (1991) and Yasukawa (2002a) studied the hydrodynamic interaction forces and moments between vessels in the proximity of a bank wall. Kijima and Qing (1987), Kijima and Furukawa (1994), Yasukawa (1991), Yasukawa (2002b) investigated the bank effect on ship maneuvering motions in the proximity of bank or in a channel with varying width. Also, Lee and Lee (2008) analyzed the characteristic features of the hydrodynamic interaction effects between vessel and wedge-shaped bank of angle. Despite former studies, a detailed knowledge of the maneuvering characteristic safe ship operation between large vessel and bank or sidewall of the narrow channel is still being needed to prevent further marine accidents.

FORMULATION

Consider a slender vessel of length L moving parallel to one side of a semi-circle bank wall at a constant velocity U in an inviscid fluid of water depth h. The coordinate system fixed on ship is shown by $o_1 - x_1 y_1$ in Fig.1. In Fig. 1, S_P and S_T are lateral and longitudinal distance between ship and semi-circle bank wall. Assuming small Froude number, the free surface is assumed to be rigid wall, which implies that the effects of waves are neglected. Then, double body model of the ship can be considered. The velocity potential $\phi(x, y, z; t)$, which expresses the disturbance generated by the motion of the ship should satisfy the following conditions:

$$\nabla^2 \phi(x, y, z; t) = 0 \tag{1}$$

$$\left. \frac{\partial \phi}{\partial n} \right|_c = 0 \tag{2}$$

$$\left. \frac{\partial \phi}{\partial z} \right|_{z=\pm h} = 0 \tag{3}$$

$$\left. \frac{\partial \phi}{\partial n} \right|_B = U(t)(n_x) \tag{4}$$

$$\phi \to 0 \quad at \quad \sqrt{x_1^2 + y_1^2 + z_1^2} \to \infty \tag{5}$$

where B is the body surface of ship. (n_x) is the x_1 component of the unit normal $\vec{n}$ interior to B. The following assumptions of slenderness parameter ε are made to simplify the problem.