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Interference Factor for Catamaran Planing Hulls

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Introduction

IN 1954, Savitsky and Dingee[1] studied the effects of separation ratios on the lift force of two flat surfaces planing parallel to each other. Their results showed that the interference factor a_I, defined by the ratio of the measured lift for one flat plate planing parallel to another and the measured lift for one flat plate planing alone, at identical conditions of trim, speed, and depth of immersion, is always greater than unity. Liu and Wang[2] obtained a similar interference factor for the asymmetric catamaran planing hulls shown in Fig. 1. Their interference factor had upper and lower bound values of $\sqrt{2}$ and 1, respectively. However, neither Savitsky and Dingee[1] nor Liu and Wang[2] took into account changes in the interference factor due to changes in the speed coefficient C_v and in the actual mean wetted length-beam ratio λ_a. The speed coefficient is defined as $C_v = V/(gb_I)^{1/2}$, and the actual mean wetted length-beam ratio is $\lambda_a = 1/2(L_k + L_c)/b_I$, where V is the speed of the surface vessel, g the gravitational acceleration, b_I the effective beam of the vessel (as shown in Fig. 1), and L_k and L_c are the wetted lengths at the keel and chine of the vessel at the corresponding speed coefficient.

This Note presents an analysis of the hydrodynamics of the catamaran planing hulls as shown in Fig. 1 with the introduction of an improved interference factor a_I. This factor a_I is a function not only of the separation ratio, as analyzed by Savitsky and Dingee[1] and Liu and Wang,[2] but also of the speed coefficient C_v and the actual mean wetted length-beam ratio at the corresponding C_v.

Analysis: Catamaran Planing Hulls with Interference Effects

Consider the asymmetric catamaran planing hull shown in Fig. 1 as a vee-shaped hull bisected at the middle-line plane and connected by a flat plate across the bisected hulls. Interference between the two half-vee-shaped hulls is expected to occur while the vessel is in motion. Savitsky's's[3] equations for the lift coefficient C_{L0} and the coefficient of center of pressure C_p for zero deadrise surface are modified for asymmetric catamaran double half-vee-shaped hulls as

$$C_{L0} = \left(0.012\lambda_a^{1/2}\, a_I + \frac{0.005\lambda_a^{5/2}}{C_v^2 r}\right) r^{3/2} \tau^{1.1} \tag{1}$$

where a_I is the interference factor between the two half-vee-shaped hulls, τ the trim angle in degrees, and r the separation ratio (b/b_I). It is assumed here that the center flat surface is always above the water surface.

At the corresponding C_v and r, the resulting lift coefficient of Wang et al.[4] is modified as

$$C_{L\text{plate}} = \left[0.012\lambda_a^{1/2} \frac{a_2(r,C_v)}{\sqrt{2}} + \frac{0.005\lambda_a^{5/2}}{C_v 2r}\sqrt{2}\right] r^{3/2}\tau^{1.1} \tag{2}$$

where $a_2(r,C_v)$ is obtained from experiments.[4]

Comparing the preceding two expressions gives the interference factor for the double half-vee-shaped hull as

$$a_I = 0.173\frac{\lambda_a^2}{C_v^2 r} + \frac{a_2(r,C_v)}{\sqrt{2}} \tag{3}$$

With the effect of deadrise angle β, Savitsky[3] gave the lift coefficient as

$$C_{L\beta} = C_{L0} - 0.065\beta C_{L0}^{0.6} \tag{4}$$

The actual interference-affected mean wetted length-beam ratio is given by

$$\lambda_a = \lambda' + a_{\lambda'}(r,C_v)$$

where $a_{\lambda'}(r,C_v)$ is due to the interference effect on the mean wetted length-beam ratio λ' of a single flat plate planing alone. Savitsky[3] gave λ' as

$$\lambda' = 1.60\lambda_s - 0.30\lambda_s^2 \quad \text{for} \quad 0 \le \lambda_s \le 1$$

$$= \lambda_s + 0.30 \quad \text{for} \quad 1 \le \lambda_s \le 4$$

where λ_s is the still-water mean wetted length-beam ratio of a deadrise surface; that is,

$$\lambda_s = (1/b_I)(d/\sin\tau - b_I\tan\beta/2\pi\tan\tau)$$

where d is the depth at transom.

With the preceding definition of interference factor and the interference-affected mean wetted length-beam ratio, the coefficient of the center of pressure for the planing surface is given by

$$C_p = 0.75 - [2.39 + 5.21(C_v/\lambda_a)^2 r a_I]^{-1} \tag{5}$$

and, noting that the total wetted surface of the catamaran includes the wetted parts of the two inner surfaces and the bottom surfaces, the drag-lift ratio can be written as

$$\frac{D_\beta}{\Delta} = \tan\tau + \frac{(V_m/V)^2 C_f}{C_{L\beta}\cos\tau}\left(\frac{r}{\cos\beta} + 2\lambda_a\tan\tau\right)\lambda_a \tag{6}$$

where V is the speed of the surface vessel, V_m the average bottom relative velocity, and C_f the skin-friction coefficient, and (V_m/V) is obtained by applying the Bernoulli equation between the freestream and the conditions on the bottom of the planing surface; i.e.,

$$\left(\frac{V_m}{V}\right)^2 = 1 - \frac{C_{Ld0} - 0.065\beta(C_{Ld0})^{0.6}}{\lambda_a r\cos\tau} \tag{7}$$

where $C_{Ld0} = 0.012\tau^{1.1}\lambda_a^{1/2} r^{3/2} a_I$.

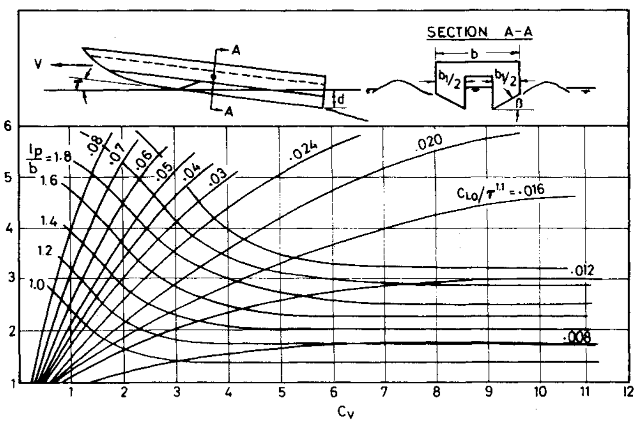

Fig. 1 Nomogram for equilibrium running conditions of an asymmetric catamaran planing hull.

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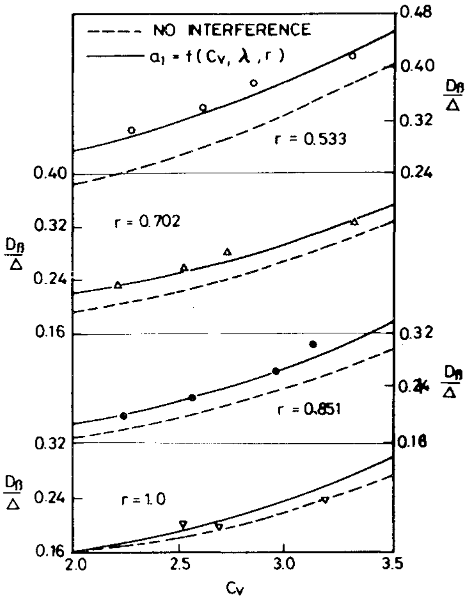

Fig. 2 Comparison with experimental results.[4]

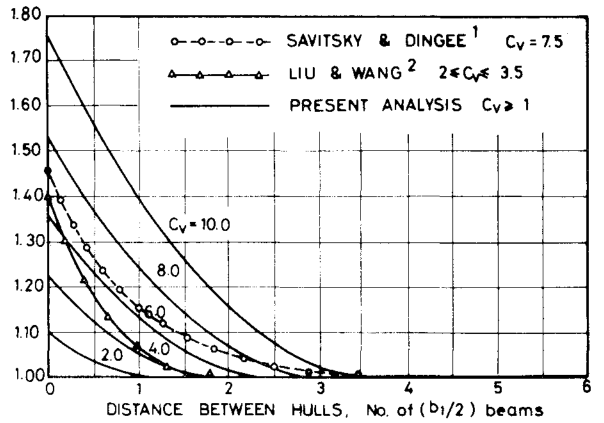

Fig. 3 Interference factor for asymmetric catamaran planing hulls.

The plots of $C_{L0}/\tau^{1.1}$ and $\ell_p/b = C_p\lambda_a$ as a function of C_v and λ_a, with $a_I = f(C_v, \lambda_a, r)$, are shown in Fig. 1. For a given r, the intersection of C_v vs ℓ_p/b curve gives the corresponding value of $C_{L0}/\tau^{1.1}$, say, m. Therefore at equilibrium running condition, C_{L0} can be expressed in terms of $\tau^{1.1}$ as

$$C_{L0} = m\tau^{1.1} \tag{8}$$

The lift coefficient of the catamaran with deadrise angle is given by Eq. (4) as

$$C_{L\beta} = m\tau^{1.1} - 0.0065\ (m\tau^{1.1})^{0.6} \tag{9}$$

The lift coefficient of the catamaran is also given by

$$C_{L\beta} = \frac{\Delta}{\frac{1}{2}\rho v^2 b_l^2} = \frac{\Delta}{\frac{1}{2}\rho C_v^2 b_l^3 g} \tag{10}$$

Equating (9) and (10), the values of $\tau^{1.1}$ and τ can be obtained by some numerical methods. From this the D_β/Δ ratio can be obtained.

Results and Conclusions

Results of an experimental study of catamaran planing hulls in the towing tanks of the National University of Singapore and National Taiwan University[4] were obtained. They are shown in Fig. 2. It is noted that expressions with interference factors included gave better agreement with the experimental results than expressions with zero interference ($a_I = 1.0$). Further comparison of the interference factor obtained in this work with that of Savitsky and Dingee[1] and Liu and Wang[2] is shown in Fig. 3. It is observed that the interference factor is a function not only of r, but also of C_v and λ_a. For a fixed r and $1 \leq \lambda_a \leq 4$, the interference effect decreases with increases in separation (i.e., decreases in r). The results also show the applicability of the derived expressions to the hydrodynamics of asymmetric catamaran planing hulls—obtained by considering only the results on single vee-shaped hulls and two flat plates planing parallel to each other.

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Computational Study of the Magnus Effect on Boattailed Shell

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Introduction

RECENT papers[1-3] have reported the development and application of the thin-layer parabolized Navier-Stokes computational technique to predict the flow about slender bodies of revolution at supersonic velocities. Reference 3 showed the technique to be a viable computational tool for

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