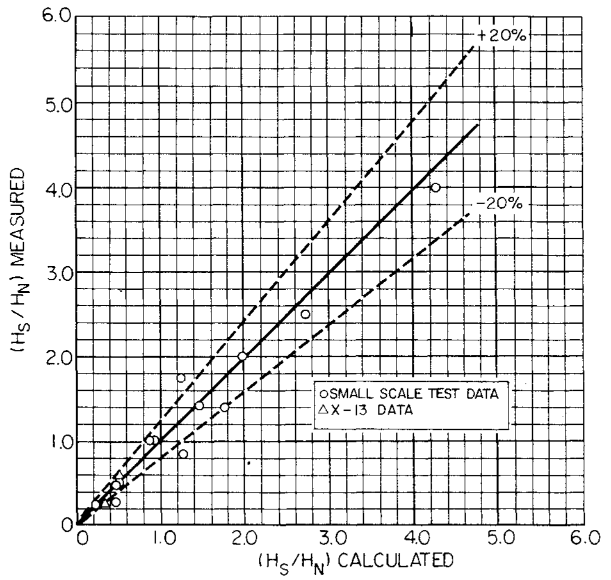

Fig. 3 Comparison of predicted and observed spray heights.

pressures (1000-3000 psf) are needed before an accurate prediction of spray height can be made. The effects of temperature, in so far as steam may be produced, have been ignored and should be investigated in future tests. In spite of this, a rough estimate of spray height can be made using the empirical equation derived here. This spray will clearly affect the operating environment of VATOL aircraft during takeoff and landing over water. This problem must be considered carefully in the design.

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Interference Effect of Catamaran Planing Hulls

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Introduction

By assuming that the effective width of a catamaran planing surface is the total width of the two surfaces or the width of the individual surface, Wang et al.[1] obtained two sets of equations for lift and center of pressure of such a surface. Comparing the experimental data with the calculated results, it was found that the drag-lift ratio of the experimental data was larger than those calculated by assuming that the effective width is the total width of the two surfaces. The deviation may be due mainly to the neglect of the interaction effect of the two surfaces. Savitsky and Dingee[2] studied the interference effects between two flat surfaces planing parallel to each other. They found that the lift generated by an individual surface when the two surfaces were placed close together was always larger than when the surfaces were widely separated. The difference may be attributed, essentially, to the interference phenomena. The merits of Savitsky's equation[3] also could be applied to the catamaran planing surface, provided that an interference factor is introduced. This Note gives a preliminary analysis of this factor. The exact value of this factor depends, essentially, on the speed coefficient and the hull configuration. Its range lies between 1.0 and $\sqrt{2}$.

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Analysis

The equations developed by Savitsky[3] have been used widely to predict the resistance and running trim of a V-shaped planing surface. For a catamaran planing surface as shown in Fig. 1, the hull is composed of one flat surface in the middle and two half V-shaped surfaces at the two sides. The width of the hull is b, and the total width of the two half V-shaped surfaces is b_l; the separation ratio is defined as

$$r = b_l / b \tag{1}$$

The limiting case is that when $r=1$, the hull becomes a single V-shaped surface. By assuming that b_l is the effective width of the planing surface, Savitsky's[3] equations for the lift C_{L0} and center of pressure C_p for flat planing surface can be written as

$$C_{L0} = \Delta / \tfrac{1}{2}\rho V^2 b^2 = (0.0012\lambda^{1/2} + 0.0055\lambda^{5/2}/C_v^2 r) r^{3/2}\tau^{1.1} \tag{2}$$

$$C_p = 0.75 - \frac{1}{2.39 + 5.21(c_v^2/\lambda^2) r} \tag{3}$$

where

λ = mean wetted length-beam ratio Lm/b
C_v = speed coefficient $V/\sqrt{gb}$
τ = trim angle

The total wetted surface S includes the wetted parts of the two inner surfaces and the bottom surfaces. It can be expressed as

$$S = b^2 [(r/\cos B) + 2\lambda \tan\tau]$$

Thus the drag-lift ratio can be written simply as

$$\frac{D}{\Delta} = \tan\tau + \frac{(V_m/V)^2 C_f}{C_L \cos\tau}\left(\frac{r}{\cos B} + 2\lambda\tan\tau\right)\lambda \tag{4}$$

where

V = speed of the surface
V_m = average bottom relative velocity
B = deadrise angle
C_f = skin-friction coefficient

The preceding analysis corresponds to the full interference condition, because it is imagined that there is no space between the two surfaces. On the other hand, if there is no interference effect, $b_l/2$ should be used as the effective width. By applying a similar analysis, the lift and center-of-pressure equations for this case are modified as

$$C_{L0} = [0.012\lambda^{1/2}/\sqrt{2} + (0.0055\sqrt{2}\lambda^{5/2}/C_v^2 r)] r^{3/2}\tau^{1.1} \tag{5}$$

$$C_p = 0.75 - \{2.39 + [5.21/(\sqrt{2})^2](C_v^2 r/\lambda^2)\}^{-1} \qquad (6)$$

The form of drag-lift ratio is not changed.

Comparing Eqs. (2) and (5) and Eqs. (3) and (6), it can be found that there is a factor of $\sqrt{2}$ involved. Equations (2) and (3) correspond to the full interference case, whereas Eqs. (5) and (6) correspond to no interference. For a specified catamaran planing surface, the actual values of lift and center of pressure should be located between the two extreme cases. If C_v is very large, the dynamic component of the lift is predominant. The ratio of the dynamic lift of the two cases is $\Delta_l/\Delta_2 = \sqrt{2}$, where Δ_l is the lift attributed to the surface with effective width b_l, and Δ_2 is the lift attributed to the two surfaces with effective width $b_l/2$ each. When the two surfaces were placed closely together, which corresponds to the full interference condition, the effective width was the summation of two surfaces b_l; Savitsky and Dingee's[2] result of an increase in lift due to the interference effect was found by a factor of 1.45, which is very close to $\sqrt{2}$. When the two surfaces are widely separated, Eqs. (5) and (6) should be used. At a moderate separation distance, the equations for the lift and center of pressure may be modified to

$$C_{L0} = [0.012\lambda^{1/2}/A + (0.0055\lambda^{5/2}A/C_v^2 r)]r^{3/2}\tau^{1.1} \qquad (7)$$

$$C_p = 0.75 - [2.39 + 5.21(C_v^2 r/A^2\lambda^2)]^{-1} \qquad (8)$$

where A is defined as the interference factor, its range being between 1 to $\sqrt{2}$. Figure 1 shows the variation of $C_{L0}/\tau^{1.1}$ with λ of the two extremes cases for $C_v = 2$ and various values of r.

Equations (7) and (8) may be used to calculate C_{L0} and C_p for catamaran planing surfaces at moderate separation distance unless the numerical value of A for a particular surface is given. Its value may depend on many factors and can be obtained only by correlating experimental data. As a preliminary test of the preceding analysis, Fig. 2 shows the comparison between the experimental data of Wang et al.[1] and the results of the foregoing analysis. It can be observed that, when the distance between the two surfaces is large (r small), the experimental data fit the upper curve better, but when the separation distance is zero, they fit the lower curve ($A = 1.0$). At the two intermediate separation distances, most of the experimental points fall in between the two curves.

As more calculations were performed, the best-fit value of the inteference factor for the case of $r = 0.702$ was found to be roughly 1.33, whereas for $r = 0.851$, $A = 1.25$. For $r = 0.553$, A is assumed to be 1.414. Figure 3 shows the relation between interference factor and the distance of separation. It can be

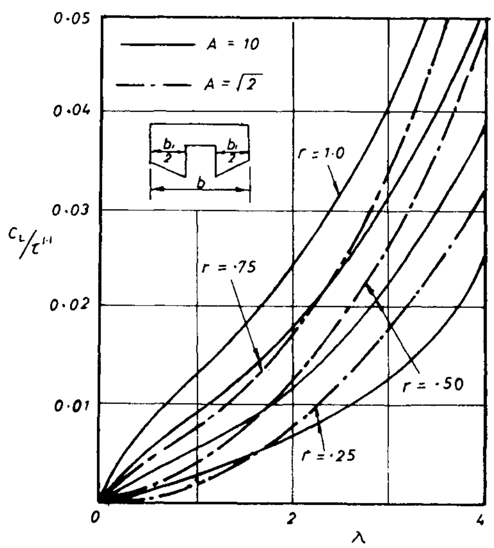

Fig. 1 Relation between $C_L/\tau^{1.1}$ and λ.

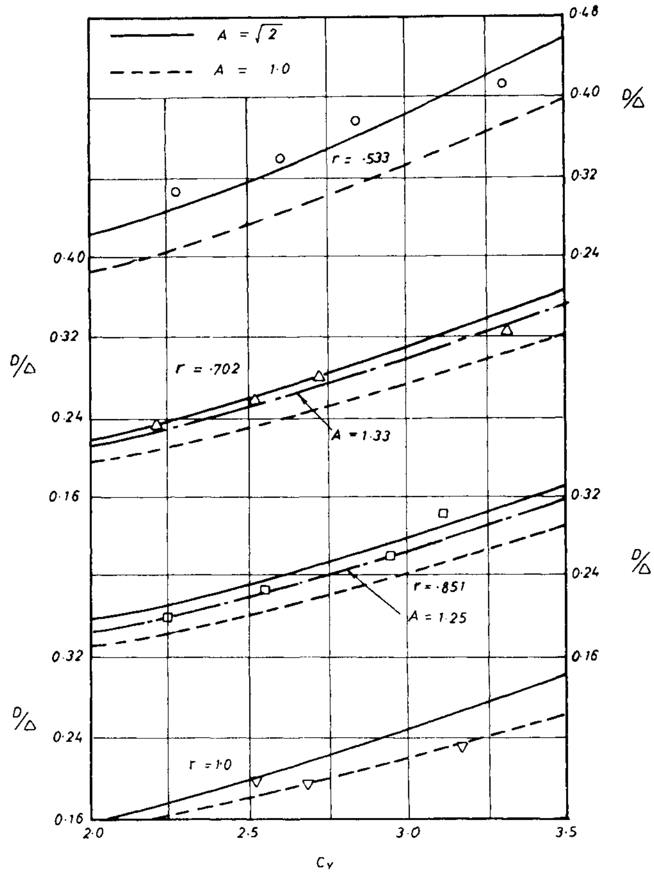

Fig. 2 Comparison with experimental results.

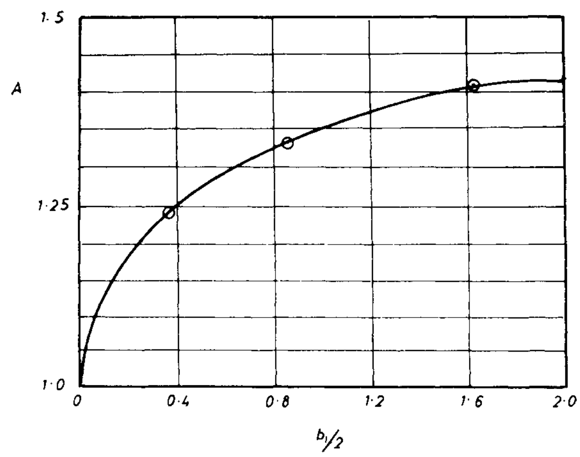

Fig. 3 Interference factor between the two surfaces.

observed that A approaches 1.414 when d is equal to 1.6, which is different from Savitsky and Dingee's result (3.0). This is because A depends on C_v. The two sets of data were tested at different C_v.

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