by equilibration in a Rayleigh process. The loss of performance of frozen vibration flow with respect to equilibrium vibration flow was determined. Calculations were made for a pure nitrogen gas flow and kerosine/air combustion products for fuel/air ratios of 0.03 and 0.06. Both frozen and equilibrium chemistry models were investigated. The results for pure nitrogen are shown in Fig. 2 and for kerosine/air mixtures in Fig. 3. The isentropic expansions and Rayleigh process were evaluated using the gas tables of Ref. 3 for several cases. Excellent agreement was obtained. In accord with Ref. 1, the effect of assuming the flow to be frozen or in chemical equilibrium was negligible. The calculated losses would not be realized in practice since finite relaxation processes would significantly reduce them. The results of Phinney,[4] indicate that the nitrogen flow would be relaxed within a fraction of an inch, as shown in Fig. 4. An average temperature for the expansion process is assumed to be representative (bearing in mind that as the total temperature is decreased, the velocity of the flow is decreased), thus tending to compensate for the increase in relaxation time. The presence of carbon dioxide and water vapor would reduce this relaxation time significantly because of the near resonant collisional energy transfer processes[5,6]

Conclusion

The performance losses attributable to freezing vibrational energy in nitrogen should not be significant.

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Technical Comments

Comment on "Correlation of Wing-Body Combination Lift Data"

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NICOLAI and Sanchez[1] have presented some new experimental wing-body data in support of the well-known formula for wing-body lift

$$(C_{L\alpha})_{WB} = F(C_{L\alpha})_W \qquad (1)$$

Here $(C_{L\alpha})_{WB}$ includes the lift of the wing in the presence of the body and the lift induced on the body by the presence of the wing, but not lift which is attributed to the body alone. $(C_{L\alpha})_W$ refers to the exposed portions of the wing (not a hypothetical wing extending through the body). Both coefficients are based on the area of the exposed wing. Since traditional wind-tunnel practice in testing wing-body combinations is to test, as the "wing alone," the hypothetical planform extended through the body, it is usually necessary to use theoretical values of $(C_{L\alpha})_W$ in Eq. (1).

Although formulas and methods closely related to Eq. (1) may be found in many early studies of wing-body interference, Ward[2] was apparently the first to make the explicit suggestion that, in such a formula, F could be closely approximated by a function of body diameter to the over-all span only, and that effects of Mach number and wing planform (aspect ratio, taper ratio, sweepback, etc.) would be small. Ward based his concept on the form which the wing-body lift takes in low aspect-ratio wing theory for wings centrally mounted on a circular cylindrical body, which is

$$(C_{L\alpha})_{WB} = (C_{L\alpha})_W(1 + d/b)^2 \qquad (2)$$

or

$$F = (1 + d/b)^2$$

where d is the body diameter and b is total span of the wing-body combination.

The experimental data on delta wing-body combinations presented by Nicolai and Sanchez is of considerable interest since it covers a wide range of Mach numbers for the same configurations. However, the values of F they obtained appear to be considerably larger than those determined by other investigators at both subsonic and supersonic speeds. In addition, the variation of F with Mach number is larger than previous experimental data have shown.

Correlation in Ref. 3 (Fig. 8) of subsonic experimental data for six wings varying in d/b from 0.1 to 0.5, in aspect ratio from 0.5 to 6.1, and including rectangular, tapered and swept planforms, indicated that predictions according to Eq. (2) were generally good but tended to be between 5 and 10% low. Additional low speed experimental data (force tests) from Ref. 4 for a family of eight 45° sweptback untapered wing-body combinations, correlated herein, show similar small deviations from Eq. (2). These tests were run at Mach 0.14 and 0.29. Lift of the exposed sweptback wings was computed for these configurations from a formula due to Polhamus, quoted in Ref. 4.

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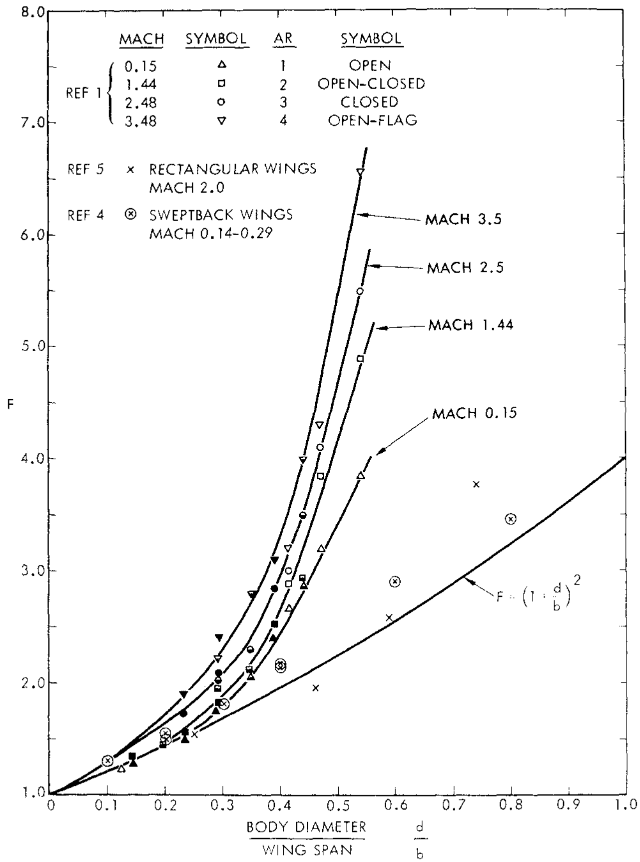

Fig. 1 Comparison of experimental and theoretical values of the wing-body lift factor, F.

$$(C_{L\alpha})_W = \frac{\pi A}{1 + \left[1 + \left(\frac{\pi A}{a_0 \cos \Lambda}\right)^2 - \left(\frac{\pi A M}{a_0}\right)^2\right]^{1/2}} \quad (3)$$

where a_o is the two-dimensional section slope of lift curve, Λ is the sweep of the 50% chord line, A is the aspect ratio of the exposed wings, and M is the Mach number.

Experimental supersonic pressure distribution data from Ref. 5 on a family of five rectangular wing-body combinations at $M = 2.0$, varying in aspect ratio from 0.5 to 4.29 and in d/b from 0.25 to 0.74, which were analyzed in Ref. 3 are further correlated herein and show close agreement with Eq. (2), except for the case of aspect ratio 0.5, $d/b = 0.74$. The lift on the exposed rectangular wings at supersonic speed was computed from the linearized theory as

$$(C_{L\alpha})_W = \frac{4}{\beta}\left(1 - \frac{0.5}{A\beta}\right) \quad (4)$$

where $\beta = (M^2 - 1)^{1/2}$ and A is the aspect ratio of the exposed wings. (This applies to all the wings tested except for the aspect ratio 0.5 wing on which the tip Mach cones intersect on the wing requiring an additional correction, which was small in this case.)

All these data points, however, exhibit F values well below Nicolai and Sanchez's data as can be seen in Fig. 1. It is also clear that in comparing the data from Refs. 4 and 5, the Mach number dependence is small as surmised by Ward.

Obviously such variables as body length, which are not always included in defining the factor F in Eq. (1), will have an effect on F. However, examination of the experimental wing-body pressure distribution data presented in Refs. 3 and 5 indicates that since positive body lift carryover continued well beyond the point at which the wing root Mach lines crossed the body, the effect of reduction of body lengths in the integration of the pressure data of Refs. 3 and 5, to be more comparable to the body length in the tests reported in Ref. 1, would be to decrease rather than to increase the experimental values of F, and thereby to make the disparity between these two sets of data greater.

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