Technical Comments

Comment on "Simplification of the Wing-Body Problem"

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THE formula for the total lift, including interference effects, for a wing mounted on a circular cylindrical body, in terms of the lift which would be experienced by the exposed wing alone, presented as Eq. (4) by Graham and McDowell[1] was apparently first given by Ward in 1949.[2] Ward also surmised that the formula might have much broader application than its origin in slenderbody theory would suggest. The same formula may be inferred from the results obtained by Spreiter,[3] and it has earlier antecedents in the classical work on wing-body combinations of minimum induced drag. Since Spreiter's and Ward's work, a vast literature on the subject of wing-body interference has come into being, including many heuristic and empirical methods built on extensions of slender-body theory results. Ward's formula was presented or utilized in many subsequent papers. For example, it appears in the survey paper by Lawrence and the writer[4] and, explicitly in the interference factor notation used in Ref. 1, in the book by Nielsen.[5]

The main purpose of this Comment, however, is not to set forth the historical development of the particular formula presented in Ref. 1. Rather it is, in view of the approach taken in Ref. 1, to point out again that the total forces and moments of aerodynamically interfering wing-body combinations can almost always be more readily obtained in simple closed form than the forces and moments of components. This can be done by a variety of methods, closely related in principle, but differing in convenience for particular applications. These methods include far-field contour integration as used by Ward,[2] direct application of conformal and mapping to the integral expressions for total force as used by Lawrence and the writer,[4] and Bryson's[6] apparent mass methods, which he applied extensively in the determination of stability derivatives. Utilizing these methods, relatively simple closed-form expressions for the total forces and moments on the various wing-body combinations of considerably more general configurations than the one considered in Ref. 1 have been obtained in the cited references and many other papers.

The formulas for slender-body theory interference ratios are usually applied to configurations which are not slender enough for the theory to apply with high precision, the aspect-ratio effects being taken into account through the expressions used for lift of the exposed wing alone. Therefore, in many applications, it is often convenient and also consistent from the standpoint of over-all accuracy to replace the complex expressions for lift on the wing and body separately by simpler approximations. The total lift on a wing-body combination, both at angle of attack α, L_{WB}, is given approximately[4] as

$$L_{WB} = L_W{}^*(1 + \sigma)^2 \tag{1}$$

where $L_W{}^*$ is the lift on the exposed wing at angle of attack α and σ is an interference factor. ($\sigma = R/b$ for a plane wing of total span $2b$ centrally mounted on a circular body of radius R, as in Ref. 1). For the case considered in Ref. 1, Eq. (1) is exact and equivalent to Eq. (4) of that paper and to Ward's formula.

The lift on the wing alone including interference effects, L_B, is approximated by[4,5]

$$L_W = L_W{}^*(1 + \sigma) \tag{2}$$

The lift on the body alone including interference effects, L_B, is then given approximately by[4]

$$L_B = L_W{}^*\sigma(1 + \sigma) \tag{3}$$

For the plane wing centrally mounted on a circular cylindrical body, Eq. (2) gives L_W within 4% of the exact result from slender-body theory over the entire range of R/b. Eq. (3) for L_B is within 10% of the exact results for $R/b >$ 0.3. (At $R/b = 0.1$, the error in L_B is 17.3%, but the body lift itself is only 11% of the total wing-body lift.) The errors relative to the slender-body theory results are such that the wing lift given by these formulas is too high and the body lift too low.

The analytical basis for these approximate formulas and methods for estimating σ for more general configurations have been given in Ref. 4.

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References

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[3]Spreiter, J. R., "Aerodynamic Properties of Slender Wing-Body Combinations at Subsonic, Transonic, and Supersonic Speeds, TN1662, July 1948, NACA.

[4] Lawrence, H. R. and Flax, A. H., "Wing-Body Interference at Subsonic and Supersonic Speeds—Survey and New Developments," *Journal of the Aeronautical Sciences*, Vol. 21, No. 5, May 1954, pp. 289–328.

[5]Nielsen, J. N., *Missile Aerodynamics*, McGraw-Hill, New York, 1960, p. 120.

[6]Bryson, A. E., "Evaluation of the Inertia Coefficients of the Cross-Section of a Slender Body," *Journal of the Aeronautical Sciences*, Vol. 21, No. 6, June 1954, pp. 424–427.