Weisshaar's Comment, did not come as a total surprise to the author.

Before proceeding to discuss Prof. Weisshaar's arguments and conclusions, it might be worthwhile to explain to readers what has been referred to in his Comment as "a number of developments that previously appeared in Refs. 2 and 3." The aeroelastic model used in Ref. 3, which is similar to that used by Housner and Stein,[4] is basically a product of the generalized Hooke's law and the bending-torsion displacement assumptions, both of which are well documented in the literature. Therefore, the claim that "the aeroelastic model chosen by Dr. Oyibo in his development was originally developed and used by the present writer" is inaccurate.

Prof. Weisshaar's argument that the term "generic" used in the title of Ref. 1 is "inappropriate" just because the generalized Poisson's ratio has minimal effects on the divergence boundaries (due to the chordwise displacement assumptions) is inapplicable because 1) the approach used in Ref. 1 is independent of displacement assumptions, and 2) the results of Ref. 1 are generic in the sense that they are true for *all* composite materials, not just for a sample composite material.

So that readers may readily verify that the author's published comments, in which he stated that some calculations of Ref. 3 are modified by those of Ref. 1, may have been an understatement, Fig. 1 is reproduced here from Ref. 1. First of all, Ref. 3 shows clearly that, according to Prof. Weisshaar's theory, divergence can only be precluded for $\theta > 90$ deg, i.e., only for fibers oriented forward of the spanwise reference axis. Figure 1a clearly disproves this conclusion by showing that at $\theta = 5$ deg (<90 deg) divergence is capable of being precluded. Prof. Weisshaar's argument about interchanging Q_{11} and Q_{22} is also inapplicable since the range of r is constant ($0 < r \leq 1$) throughout Ref. 1. For instance, Figs. 1a and 1b show the divergence free-sweep angles for forward and backward swept fibers of 5 and 95 deg, respectively, which are 90 deg apart. It seems clear that the range of r for $\theta = 5$ deg is not inverted for $\theta = 95$ deg. Therefore, it is hard to see how the r-inversion argument could be used to compare the trends at $\theta = 5$ and 95 deg. Notice also that if $D^* = 0.319$, and $r = 0.314$, the results of Ref. 3 are recovered from the figures in Ref. 1 (including those reproduced here). Therefore, if his argument were correct this trend would have been visible in his analysis.[3] The claim in Ref. 3 that the maximum divergence-free forward-sweep angle is about 49 deg (at $\theta = 102$ deg) is inaccurate since it is clearly seen in Fig. 2 and Fig. 14 of Ref. 1 that divergence-free forward-sweep angles of 62 deg and over 80 deg are possible at $\theta = 102$ deg and $91 \leq \theta \leq 95$, respectively. Therefore, the conclusion that "an optimal orientation for wing divergence performance appears to occur when the lamina fibers are aligned at angles of 10-15 deg forward of the swept wing box beam reference axis" in Ref. 3 appears to be correct only for the class of parameters examined.

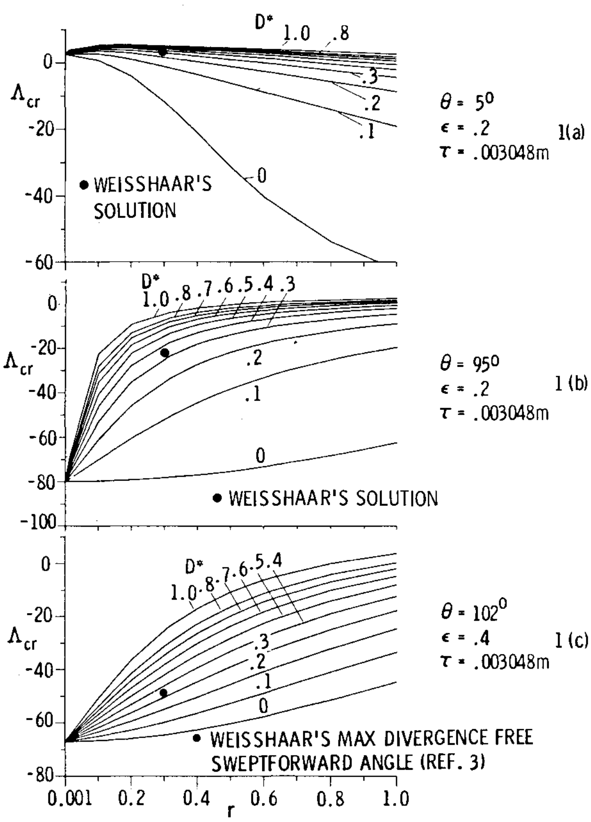

Fig. 1 Divergence free sweep angle vs *r*.

The author wishes to point out that Prof. Weisshaar should be complimented for his very valuable earlier work.[3] However, it should also be noted that, in the spirit of recognition that the state of the art does not stand still, the author did not criticize the results of any earlier investigators, but simply pointed out that his own contribution provided a generic approach which adds to the general understanding of the diveregence phenomenon. Instead of obtaining particular solutions based on a single-parameter representation, as was done by all previous investigators, the author demonstrates that there are generic parameters which have physical meaning and hence give the aeroelastician a wider range of possibilities in which acceptable practical solutions are to be found while avoiding divergence. For example, in Fig. 1 the author has plotted Prof. Weisshaar's particular solutions which appear as isolated points on his own field of solutions.

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[1]Oyibo, G. A., "Generic Approach to Determine Optimum Aeroelastic Characterisitics for Composite Forward-Swept-Wing Aircraft," *AIAA Journal*, Vol. 21, Jan. 1984, pp. 117-123.

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Comment on "Doublet-Point Method for Supersonic Unsteady Lifting Surfaces"

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TWO comments on Ref. 1 are made to emphasize the simplicity and generality of area-averaged downwash or doublets in lifting surface modeling.

First, steady-state area integration of an x/y^2R function can be approximated in a particularly general way. This is illustrated with Eq. (1a), which is based on Fig. 1 and the definitions of Eqs. (1b-1f). First the x integration was completed. The y integration was then replaced by a summation-integration. This computationally efficient form can replace Eqs. (6-10) of Ref. 1. It applies to either unswept or swept parallelogram patches, may be used at any Mach number through the use of Eq. (1f), and may be used for the influence between any two patches. N must be an odd integer.

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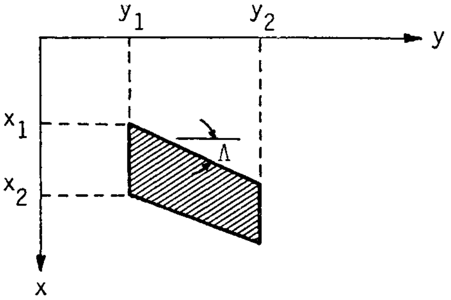

Fig. 1 Parallelogram patch.

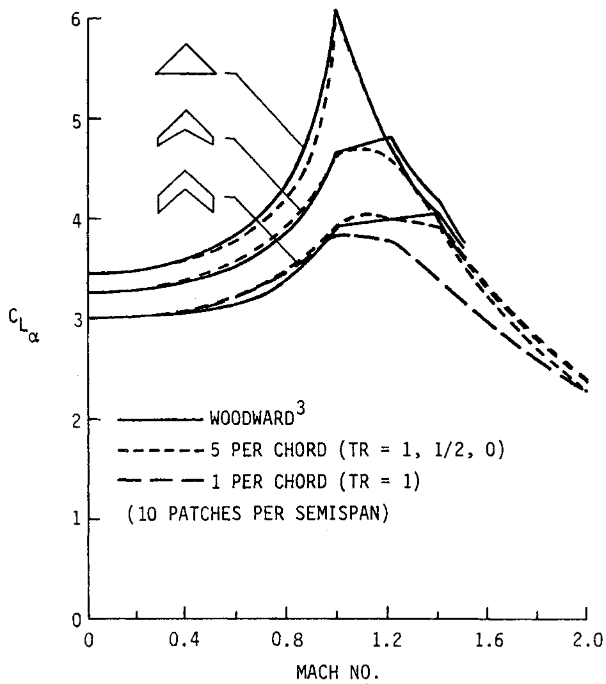

Fig. 2 Lift-curve slopes, aspect ratio 4 wings.

$$I=\int_{y_1}^{y_2} \mathrm{d}y \int_{x_1}^{x_2} \frac{(x-\lambda y_1+\lambda y)\mathrm{d}x}{y^2 R(x-\lambda y_1+\lambda y, y)}$$

$$\approx 2\epsilon \sum_{k=1}^{N} \frac{R(x_2+\Delta x_k, y_k)-R(x_1+\Delta x_k, y_k)}{y_k^2-\epsilon^2} \tag{1a}$$

$$\lambda = \tan\Lambda \tag{1b}$$

$$\epsilon = (y_2-y_1)/2N \tag{1c}$$

$$y_k = y_1 + (2k-1)\epsilon \tag{1d}$$

$$\Delta x_k = (2k-1)\lambda\epsilon \tag{1e}$$

$$R(x,y) = [x^2 + (1-M^2)y^2]^{1/2}, \qquad M<1$$

$$= \{\mathrm{Max}[0, \mathrm{Max}^2(0,x) + (1-M^2)y^2]\}^{1/2}, M>1 \tag{1f}$$

Second, the most desirable relative location of the doublet/averaging area is that which yields lifting line results when used subsonically with one patch per chord. When averaging over a parallelogram patch, the preferred doublet location is $1/(e^2+1) = 11.92\%$ of patch chord at the spanwise patch center, whereas Ref. 1 used the leading edge. This is discussed in Ref. 2 for the analogous downwash-point method. [Reference 2 also used unsteady/steady kernal ratios for supersonic solutions, as in Eqs. (19a) and (19b) of Ref. 1, but did not recognize the extra term in Eq. (19c), Ref. 1.] Figure 2 illustrates the use of this doublet location and of Eq. (1) with $N=5$, using the planforms of Ref. 3. Patch centers of pressure are not dictated by the doublet location used in forming the influence matrix, but may be assumed to be at 25% chord for $M<1$, at 50% chord for supersonic patch leading edges, and interpolated for in-between Mach numbers.

References

[1]Ueda, T. and Dowell, E. H., "Doublet-Point Method for Supersonic Unsteady Lifting Surfaces," *AIAA Journal*, Vol. 22, Feb. 1984, pp. 179-186.

[2]Roger, K. L., "Airplane Math Modeling Methods for Active Control Design," *AGARD CP-228*, April 1977, pp. 4.1-4.11.

[3]Woodward, F. A., "Analysis and Design of Wing-Body Combinations at Subsonic and Supersonic Speeds," *Journal of Aircraft*, Vol. 5, Nov.-Dec. 1968, pp. 528-534.

Reply by Authors to K. L. Roger

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WE wish to thank K. L. Roger for his interest and remarks concerning our paper.[1] His first Comment suggests replacement of our analytical results for the integration of an $x/(y^2R)$ function by a numerical quadrature. Let us consider the unswept case for simplicity; then we can find that Eq. (1a) of the Comment corresponds to neglecting the second term $\sin^{-1}(\beta y/x)$ of Eq. (6c) in Ref. 1. The approximation may be allowable provided that contributions of the inverse sine term are small in comparison with those from the first term, $R/(\beta y)$, which is the case for a small $|\beta y|$ or ϵ. Since it is easy to compute the inverse sine function by using modern computers, we do not think that the replacement of our analytical integration by Eq. (1a) is always efficient. Although analytical integration is also possible for swept and/or tapered regions, we use rectangular geometry for the upwash averaging area, believing that the effects of the shape deformation are of the same order as of the descretization error.

The second Comment by K. L. Roger is on the location of the area. He referred to the method described in Ref. 2, which seems to be based on the constant pressure panel method[3] using the velocity potential. Unfortunately, we could not discuss the method in detail since in Ref. 2 there is no detailed formulation but only a brief description. The location recommended in the Comment could be worthy of a trial. The optimal locations for the doublet points and upwash averaging area are uncertain. As stated in Ref. 1, they are determined by trial-and-error considering the trading-off of the undulation of the solution and the smearing of pressures at Mach lines from break-off points in the leading edge. Our results, however, show satisfactory pressure distributions and good convergence as the number of elements increases.

References

[1]Ueda, T. and Dowell, E. H., "Doublet-Point Method for Supersonic Unsteady Lifting Surfaces," *AIAA Journal*, Vol. 22, Feb. 1984, pp. 179-186.

[2]Roger, K. L., "Airplane Math Modeling Methods for Active Control Design," AGARD CP-228, April 1977, p. 4.1-4.11.

[3]Woodward, F. A., "Analysis and Design of Wing-Body Combinations at Subsonic and Supersonic Speeds," *Journal of Aircraft*, Vol. 4, Nov.-Dec. 1968, pp. 528-534.

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