Readers' Forum

Brief discussions of previous investigations in the aerospace sciences and technical comments on papers published in the AIAA Journal *are presented in this special department. Entries must be restricted to a maximum of 1000 words, or the equivalent of one* Journal *page including formulas and figures. A Discussion will be published as quickly as possible after receipt of the manuscript. Neither the AIAA nor its editors are responsible for the opinions expressed by the correspondents. Authors will be invited to reply promptly.*

Comment on "Wind Tunnel Wall Corrections Deduced by Iterating from Measured Wall Static Pressure"

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IN Ref. 1 a method for calculating tunnel-wall interference from measurements of wall boundary conditions is described. This method relies on solutions for the flow both within the working section (the "inner" region) and in the "outer" region outside the tunnel, together with an iterative scheme based on a comparison between calculated and measured boundary conditions. A representation of the model is required for the calculation of the "inner" region flow. However, it is not made clear[1] how sensitive the corrections derived by this method are to model representation, and the method is only used to calculate wall-induced upwash.

In fact,[2] within the limitations of linearized theory, tunnel wall interference is completely defined by measurements of the wall boundary conditions, rendering a model representation unnecessary. The tunnel-wall corrections to both incidence and stream speed may be derived from Green's theorem applied to a closed surface surrounding the model.[2] For a surface that is close to the tunnel walls, the surface integrals contain the wall boundary conditions and may be integrated directly. As Dr. Moses points out,[1] it is necessary only to measure static pressures at the walls for tunnels with solid walls, the effect of the wall boundary layers on the normal velocity of the equivalent inviscid flow at the walls[2] generally being negligible.

It is relevant to note that methods of determining wall corrections from boundary measurements in two-dimensional wind tunnels have recently been reviewed in Ref. 3.

I would be interested to have Dr. Moses' views on the sensitivity of the corrections of his method both to model representation (e.g., number and disposition of singularities) and to the number and spacing of static-pressure measurements on the walls. I was particularly intrigued to note that Dr. Moses needed only four static-pressure taps in the sidewalls in his experiment, especially since he studied a lifting model with a relatively large span-to-tunnel-width ratio. Finally, Dr. Moses' views would be appreciated on whether he considers that his method offers any advantages over the method of Ref. 2.

References

[1]Moses, D.F., "Wind Tunnel Wall Corrections Deduced by Iterating from Measured Wall Static Pressure," *AIAA Journal*, Vol. 21, Dec. 1983, pp. 1667-1673.

[2]Ashill, P.R. and Weeks, D.J., "A Method for Determining Wall-Interference Corrections in Solid-Wall Tunnels from Measurements of Static Pressures at the Walls," *Wall Interference in Wind Tunnels*, AGARD-CP-335, Sept. 1982.

[3]Mokry, M., Chan, Y.Y., Jones, D.J., and Ohman, L.H. (eds.), *Two-Dimensional Wind Tunnel Wall-Interference*, AGARD-AG-281, Nov. 1983.

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Reply by Author to P.R. Ashill

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IN his Comment, Dr. Ashill notes that in linear theory representation of the model is unnecessary. In the method reported on by the writer, the pressure distribution on the model is held constant during iteration to unconfined flow. This is equivalent to saying that there is no increment in model circulation from iteration to iteration and therefore the boundary condition for the inner flow description at the model is produced by having no model representation at all. However, in the equivalent case where model geometry is fixed, model representation would be required to obtain the impermeable surface boundary condition. The first case is preferable, to be sure. In this case, then, there would be no sensitivity of the method to model representation in calculating a lift correction. However, in extending the method to blockage correction this may be a concern.

The number and distribution of both singularity elements and flow parameter measurements (wall static pressure) are important concerns that will depend upon the detail and accuracy of the correction desired. Unfortunately these concerns could not be fully explored by the time of publication. These topics are being investigated; however, the writer is not ready to report results at this time. It was found, however, that increasing the number of singularity elements used to calculate the flowfields (beyond 140) produced a negligible effect on the wall correction results. It is felt that fewer singularities could be used, but the minimum number and the exact distribution have not yet been determined. More importantly, since the wall static-pressure distributions are rather smooth, an accurate lift correction would probably be obtained with significantly fewer measurements judiciously placed and concentrated near the model. Based on experiments so far, we may be able to limit measurements to half a model span upstream and downstream. Far upstream and downstream behavior could probably be represented analytically and matched to the particular extremity measurements of a given test. Of more importance, the writer feels, is the accuracy of flow parameter measurement. This forms the actual limit to correction accuracy. The relation between measurement error and resulting correction accuracy needs to be established when adapting the method to routine use.

The writer used only four side-wall measurements in his original experiment because that was the limit that could be installed in that particular wind tunnel and still maintain measurement accuracy. It is suspected that side measurements are unnecessary for symmetric tests, but this is still under investigation.

In comparing the Sears method of the writer with the method described in Ref. 2 of Dr. Ashill's Comment, it may

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be pointed out that the former is inherently exact since it satisfies directly the boundary conditions of unconfined flow. The method was demonstrated using an incompressible wind tunnel flow and therefore is not limited to small perturbations in this Mach number regime. At high subsonic Mach numbers the method still applies as long as the inner region contains at worst weak shocks. Performing flowfield calculations in inner and outer regions at these Mach numbers would be significantly more complicated and require much more computer time. It is not clear to the writer just how drastically it would change the description of the model. If the flow in the inner region were nearly linear the iterations could still be performed using increments to boundary conditions. The extension of the writer's methods to these higher Mach numbers is being studied. The extension of the computer programs to make more detailed wall correction calculations at the model also has not yet been done. At this point, then, it appears that the two methods would be comparable at high subsonic Mach numbers but the Sears method would be more accurate for low speed wind tunnels.

Comment on "Improved Solutions to the Falkner-Skan Boundary-Layer Equation"

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THE author of Ref. 1 is to be commended for his efforts to improve the solution to the Falkner-Skan boundary-layer equation. The results shown in the paper are, however, a little bit misleading. It seems that the author did not thoroughly take into consideration the effects of η_∞ used in the calculation on the value of $f''(0)$, whose accuracy he was trying to improve. The method stated in the paper: "For $-0.1988377 \leq \beta \leq -0.03$ the computed results are given to $\eta = 10.00$" will not yield the value of $\beta = -0.1988377$ for $f''(0) = 0$ and $\eta_\infty = 10$. Instead, the value of $\beta = -0.1988448$ under the above-mentioned conditions. When η_∞ is increased to 12 and 14, both calculations will yield $\beta = -0.1988378$ for $f''(0) = 0$. For $\beta = -0.1987686895$ ($m = -0.0904$), the values of $f''(0)$ are found to be 0.0072985, 0.0049750, and 0.0047700 for $\eta_\infty = 9.0$, 10.0, and 12.0, respectively. When η_∞ is increased to 14.0, the value of $f''(0)$ remains the same and is equal to 0.0047700. Therefore, the value of $f''(0)$ has an error of 0.000205 for $\eta_\infty = 10$. However, the value of $f'(\infty)$ will converge to 1 within the accuracy of 10^{-7} for the case of $\eta_\infty = 10.0$ and $m = -0.0904$ provided that $0.0049750 \leq f''(0) \leq 0.0049790$. All of these calculations are based on the double-precision algorithms. It will never converge to the above-mentioned accuracy if $f''(0)$ is set equal to 0.0047700 and $\eta_\infty = 10.0$.

It is found to be adequate to have $\eta_\infty = 10.0$ for $\beta = -0.06185567$ ($m = -0.03$). But it is found to be unsatisfactory to have $\eta_\infty = 7.5$ for $\beta = -0.02$. In this instance, the values of $f''(0) = 0.3112713$, 0.3112578, and 0.3112577 for $\eta_\infty = 7.5$, 9.0, and 10.0, respectively. The value of $f''(0)$ remains the same for $\eta_\infty = 10$ and 11.

The boundary-layer thickness where $u/U_\infty = 0.999$ will remain accurate to the second digit when the outer edge, where $u/U_\infty = 1.0$, is sufficiently large. Figure 1 shows the effects of the flow shape factor $m = \beta/(2-\beta)$ on the above-defined thickness and the least outer edge which must be used in the profile integration. There are, however, some exceptions. When $m = 6$, the least outer edge is 2.7, which yields $f''(0) = 2.9383650$. The outer edge from Fig. 1 is 2.4, which yields $f''(0) = 2.9383651$. The difference here is due to the roundoff effect. The thickness where $u/U_\infty = 0.999$ remains the same at 1.5 for both calculations. Figure 2 shows the effects of the outer edge location on the accuracy of $f''(0)$ for the cases where the value of $f'(\infty)$ converges to 1 within the accuracy of 10^{-7}. The error defined as the difference between the value of $f''(0)$ at the given η_∞ and the convergent value as the outer edge approaches infinity. As mentioned before, the last two digits are not very accurate for $m = -0.0904$ and the values of $0.0047700 \leq f''(0) \leq 0.0047730$ will yield a solution with $\eta_\infty \geq 11.75$. If $f''(0) = 0.0047700$ is used, a satisfactory solution can be obtained with the outer edge as low as 11.1. However, it is accurate to seven digits for all others where $m > 0$. The percent error increases with decreasing m as the value of $f''(0)$ also decreases. Blottner[2] used the fourth-order finite difference scheme with various η_∞ and obtained a very accurate result for $m = 0$ with only 81 grid points for $\eta_\infty = 7$ and a convergence accuracy of 10^{-10}. In comparison with the above results, the fourth-order Runge-Kutta method needs to integrate at least up to $\eta_\infty = 9.5$ for $m = 0$ and a convergence accuracy of 10^{-7}. The former method seems to yield more accurate results for the skin friction with fewer grid points than the latter.

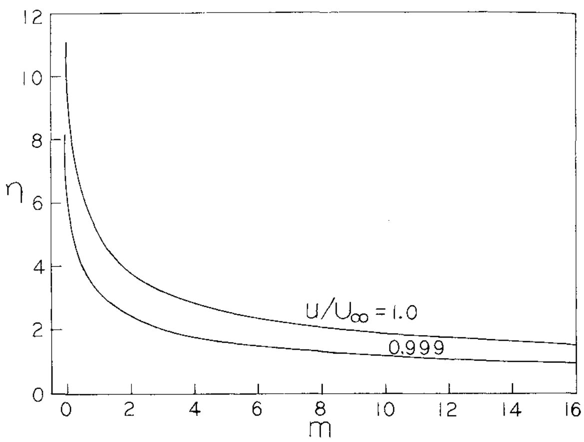

Fig. 1 Boundary-layer thickness vs flow shape factor.

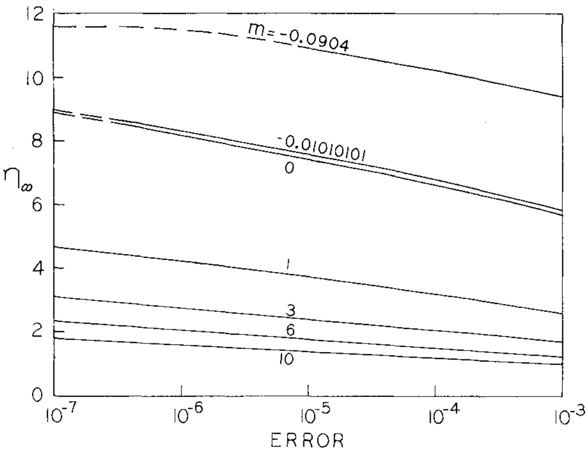

Fig. 2 Error in the dimensionless shear due to the outer edge location.

Equation (5) is inaccurate in the neighborhood of the point of flow separation, $f''(0) = 0$. At the flow separation point, the value of β should be equal to -0.1988378 ($m = -0.0904286$). Again, accuracies of Eqs. (5) and (6) are very poor. For example, Eq. (5) yields $\beta = -0.103823$ while

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