Readers' Forum

Comment on "Marching Control Volume Finite-Element Calculation for Developing Entrance Flow"

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THE authors of Ref. 1 incorrectly state that a numerical solution of the classic entrance flow or developing flow problem requires that the streamwise extent of the computational domain be constrained, without prior knowledge, to some finite entrance length. It has been shown that the simple transformation[2]

$$z = x/(1 + x)$$

where x = streamwise coordinate, and z = transformed coordinate, maps the space $0 \leq x \leq \infty$ to the computational space $0 \leq z \leq 1$ since $z \to 1$ as $x \to \infty$. The downstream Poiseuille flow boundary condition then can be applied at $x = \infty$ or $z = 1$.

References

[1]Fang, Z. and Saber, A. J., "Marching Control Volume Finite-Element Calculation for Developing Entrance Flow," *AIAA Journal,* Vol. 25, Feb. 1986, pp. 346–348.

[2]Barbee, D. G. and Mikkelsen, C. D., "Field Descriptions for a Steady, Developing Tube Flow of Vanishing Reynolds Number," *Zeitschrift für Angewandte Mathematik und Physik,* Vol. 24, No. 5, 1973, pp. 73–82.

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Reply by Authors to C. D. Mikkelsen

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IN our paper, we state "...use of [numerical analyses of the Navier-Stokes equations] presents a problem in that the streamwise extent of the computational domain must be selected without a priori knowledge of the fully developed entrance length L_f. The solution thus is constrained."[1] We did not mean to suggest that the "streamwise extent of the computational domain be constrained, without a prior knowledge, to some [necessarily] finite entrance length."

The transformation cited by C. D. Mikkelsen, namely $z = x(1 + x)$, is convenient for scaling flow problems. Indeed, it has been used by Barbee and Mikkelsen in "the case of a steady, laminar, Newtonian tube flow developing from an initial flow of zero Reynolds number."[2] In the cited paper, the authors selected an axial computational domain $0 < x < \infty$ and solved the derived partial differential equations subject to applied boundary conditions. In particular, a Poiseuille flow boundary condition is specified at $z = 0$ $(x \to \infty)$ to allow "space for an infinite tube of [fixed radius] to run from zero to infinity."

Extending the domain infinitely also can be employed to advantage in other situations, such as where the boundary conditions at finite distances are unknown or difficult to resolve.[3] We consider that cases with "the streamwise extent of the computational domain" presumed to be infinite have a "constraint imposed" and so "a priori knowledge of the fully developed flow length L_f" is not needed.[3]

In our problems of interest, neither the extent of the flow field nor the fully developed flow length are known or defined in advance. However, they are presumed to be finite. Therefore, in our opinion, the transformation $z = x/(1 + x)$ does not offer us the advantages presented when the domain is presumed infinite. Furthermore, for formulations based on the case of "infinite extent," our computer resource limitations (memory and speed) may encumber arriving at acceptable solutions to problems over reasonable periods of time. Therefore, an alternate route for numerical solution of the partial differential equations involved had to be found.

Our alternate route, as reported in our submission, involves applying a Green's formula transformation to the Galerkin-weighted residual formulation of the stream function and vorticity expression of the Navier-Stokes equations. This technique causes the downstream boundary integrals to vanish and thereby precludes either a requirement for a priori definition of spacial extent or extension to infinity. Consequently, our formulation does not require the advantages that the transformation $z = x/(1 + x)$ has to offer when the domain is presumed infinite.

References

[1]Fang, Z. and Saber, A. J., "Marching Control Volume Finite Element Calculation for Developing Entrance Flow," *AIAA Journal,* Vol. 25, Feb. 1987, pp. 346–348.

[2]Barbee, D. G. and Mikkelsen, C. D., "Field Descriptions for a Steady, Developing Tube Flow of Vanishing Reynolds Number," *Zeitschrift für Angewandte Mathematik und Physik,* Vol. 24, No. 5, 1973, pp. 73–82.

[3]Thibault, P. A., "Numerical Modeling of Transmission Phenomena in Gaseous Detonations," *Proceedings of the 11th IMACS World Congress on System Simulation and Scientific Computation,* Oslo, Norway, 1985.

Submitted June 1, 1987; received May 12, 1989.

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