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Technical Comments

Brief discussion 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 "Determination of Slender-Body Aerodynamics Using Discrete Vortex Methods"

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IN Ref. 1, Gebert makes the interesting suggestion of using semi-infinite vortex lines rather than the usual infinite lines in the discrete-vortex method (DVM) for simulation of flows about slender airframes. He suggests that doing so eliminates the need to use the so-called vortex reduction factor, which is usually set to 0.6 for subsonic flows.[2] Unfortunately, Gebert did not prove his case by showing results with and without his new model. It would be helpful to the rest of the modeling community if he would present such results.

It should also be pointed out that Gebert is incorrect in his statement that there is no mathematical rationale for the impulsively-started-cylinder analogy, which is basic to his method and to all other versions of the DVM. The analogy has been rigorously derived independently by Klopfer and Nixon[3] and by Dagan and Almosnino.[4] Gebert also seems to be unaware that a uniformly valid composite solution for any angle of attack can easily be constructed that eliminates the logarithmic singularity at infinity.[2,4–6]

References

[1]Gebert, G. A., "Determination of Slender Body Aerodynamics Using Discrete Vortex Methods," *Journal of Spacecraft and Rockets*, Vol. 31, No. 2, 1994, pp. 200–206.

[2]Mendenhall, M. R., and Lesieutre, D. J., "Prediction of Vortex Shedding from Circular and Noncircular Bodies in Subsonic Flow," NASA CR 4037, Jan. 1987.

[3]Klopfer, G. H., and Nixon, D., "Transonic Flows with Vorticity Transport around Slender Bodies," *AIAA Journal*, Vol. 27, No. 10, 1989, pp. 1461–1464.

[4]Dagan, A., and Almosnino, D., "Vorticity Equation Solutions for Slender Wings at High Incidence," *AIAA Journal*, Vol. 29, No. 4, 1991, pp. 497–504.

[5]Ashley, H., and Landahl, M., *Aerodynamics of Wings and Bodies*, Addison-Wesley, Reading, MA, 1965.

[6]Hemsch, M. J., "Comparison of High-Angle-of-Attack Slender-Body Theory and Exact Solutions for Potential Flow over an Ellipsoid," *Journal of Aircraft*, Vol. 27, No. 6, 1990, pp. 569–571.

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Reply by the Author to M. J. Hemsch

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HEMSCH is correct to point out[1] that Ref. 2 did not make comparisons between the results of the old and the new models. The paper was written stating the details of the body geometries and the flow perturbation necessary to generate the asymmetries. The geometries and flow perturbations can be entered into other discrete vortex method (DVM) codes, and the results can then be compared with those presented in Ref. 2. The thrust of the paper[2] was to give a physical explanation to the "vortex reduction factor" and show the self-consistency of the method.

By replacing the infinite vortex line with a semi-infinite line, the vortex reduction factor is replaced with Eq. (8) of Ref. 2. The part of the equation corresponding to the factor in question takes on values from 0 to 1, but will usually fall in the range of 0.5 to 0.9. The factor changes from point to point in the flow, which causes a different mixing of the vortices than is achieved with a set vortex reduction factor.

A comparison of the old and new models is made now. Figures 1 and 2 are the side loadings computed on a $3.5D$ ogive nose in a flow of Mach number 0.086. The angle of attack is varied from 0 to 55 deg. The computed values are compared with the experimental results of Roos and Kegelman,[3] who actually introduced a small geometric disturbance at the nose tip to generate the out-of-plane loading. Figure 1 shows the results of the DVM with infinite vortex lines and a vortex reduction factor set to 0.6. The results shown in Fig. 2 are generated with the same code except that the semi-infinite vortex line assumption is made. The flow in each case is disturbed by multiplying the strength of the shed vorticity on one side of the body by $1 + f$ for a length 4% down from the nose tip. The different values of f generate the different curves.

An examination of the two figures yields two immediate observations. First, for the present DVM, a smaller flow perturbation is required to generate the out-of-plane loading using the semi-infinite filament assumption. Even when the flow is disturbed by increasing the strength of the vorticies on one side of the body by 30%, Fig. 1 never shows the code predicting the higher-angle-of-attack side loading corresponding to the experimental results. Second, there is apparently a greater cause–effect relationship between the size of the perturbation and the size of the side loading for the infinite vortex line than for the semi-infinite filament. Note that in Fig. 1, up until 45 deg, the larger perturbations generate consistently larger side loadings. Even after 45 deg, the larger perturbations generate more rapid and extreme changes in the loading. This effect is also true for the results shown in Fig. 2. However, it is somewhat less pronounced. Up to 45 deg, in the semi-infinite filament case, disturbances of $f = 0.1$, 0.2, and 0.3 generate nearly the same values, and

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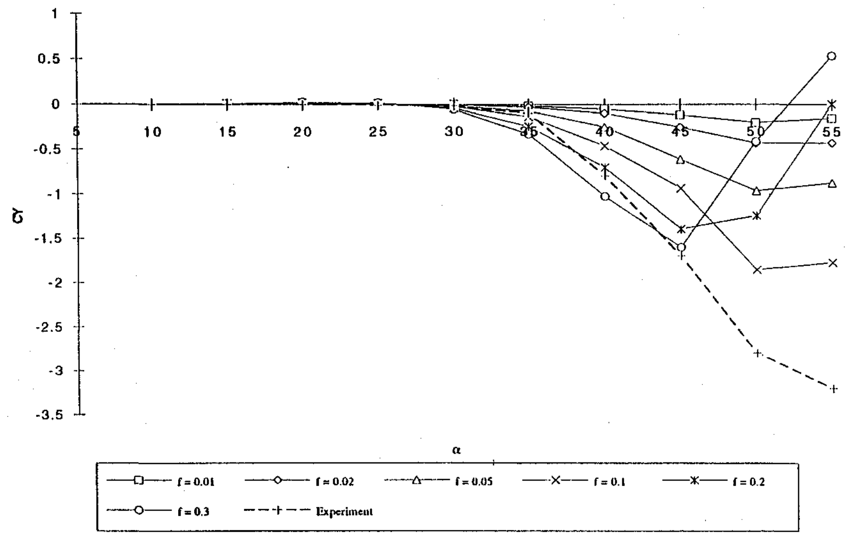

Fig. 1 Comparison of the computed side-force coefficient at different perturbation values for a DVM employing infinite vortex filaments and a vortex reduction factor.

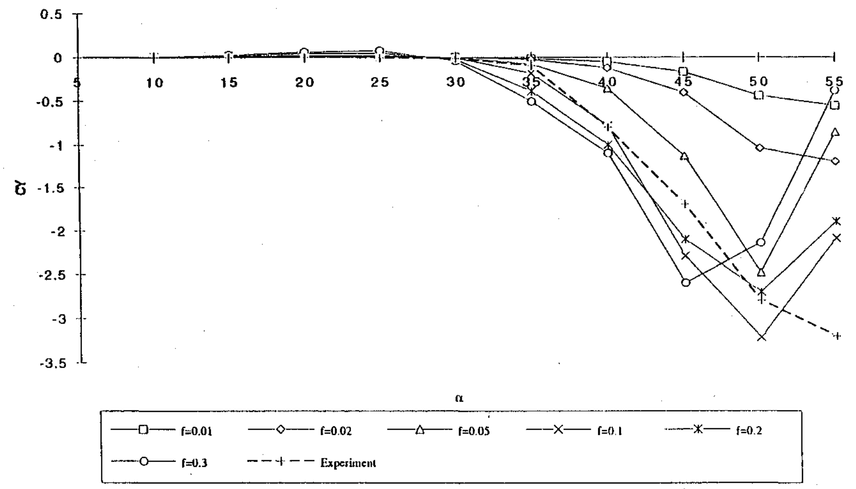

Fig. 2 Comparison of the computed side-force coefficient at different perturbation values for a DVM employing semi-infinite vortex filaments.

the values are reasonably close to the experimental results. Beyond $\alpha = 45$ deg, Fig. 2 shows only slightly better results than Fig. 1.

Finally, it may be noted that the results shown in Fig. 2 do not exactly match those of the corresponding figure (Fig. 14) in Ref. 1. Since the writing of Ref. 1, the program has been modified in its computation of the flow separations. The original code has been discarded and replaced with this new code. The results are qualitatively the same, but some differences do exist.

Hemsch is correct in pointing out that Klopfer and Nixon[4] and Dagan and Almosnino[5] give rigorous derivations of the analogy with the impulsively started cylinder. There was unfortunate phrasing in Ref. 1. These derivations should have been referenced.

In response to Hemsch's comment about the logarithmic singularity at infinity, it is known that the singularity can be eliminated.[5–8] Reference 1, however, was concerned with calculating the forces on the body and not the pressure values. Since the singularity is independent of the body angle, its integration around the body for the computation of the forces causes its effect to vanish. In the interest of computational speed, the uniformly valid composite that Hemsch addressed was not employed.

The assumption of semi-infinite vortex filaments has the appeal of giving physical justification to a semiempirical factor. The vortex reduction factor can be easily removed through only a small additional amount of bookkeeping and computation time. In our tests, the semi-infinite filaments have made our code less sensitive to the flow perturbations and applicable to a wider geometry for flows.

References

[1]Hemsch, M. J., "Comment on 'Determination of Slender-Body Aerodynamics Using Discrete Vortex Methods,'" *Journal of Spacecraft and Rockets,* Vol. 32, No. 2, 1995, p. 383.

[2]Gebert, G. A., "Determination of Slender Body Aerodynamics Using Discrete Vortex Methods," *Journal of Spacecraft and Rockets*, Vol. 31, No. 2, 1994, pp. 200–206.

[3]Roos, F. W., and Kegelman, J. T., "Aerodynamic Characteristics of Three Generic Forebodies at High Angles of Attack," AIAA Paper 91-0275, Jan. 1991.

[4]Klopfer, G. H., and Nixon, D., "Transonic Flows with Vorticity Transport Around Slender Bodies," *AIAA Journal*, Vol. 27, No. 10, 1989, pp. 1461–1464.

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[8]Mendenhall, M. R., and Lesieutre, D. J., "Prediction of Vortex Shedding from Circular and Noncircular Bodies in Subsonic Flow," NASA CR 4037, Jan. 1987.