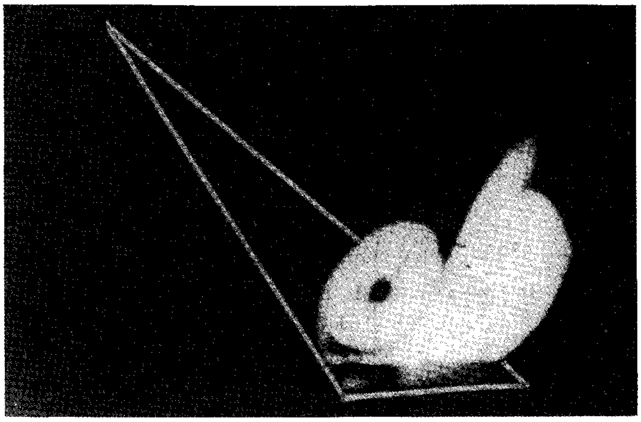

Fig. 3 Vortex flow behind delta wing: $A = 0.56$ and $Re_c = 1.32 \times 10^5$ (Ref. 6).

sider that use of the half-model test technique eliminates the phenomenon of asymmetric vortex breakdown, illustrated in Fig. 3 already at $\alpha = 35$ deg for an 82-deg sharp-edged delta wing.[6]

References

[1]Gu, W., Robinson, O., and Rockwell, D., "Control of Vortices on a Delta Wing by Leading-Edge Injection," *AIAA Journal*, Vol. 31, No. 7, 1993, pp. 1177–1186.

[2]Jenkins, J. E., Myatt, J. H., and Hanff, E. S., "Body-Axis Rolling Motion Critical States of a 65-Degree Delta Wing," AIAA Paper 93-0621, Jan. 1993.

[3]Ericsson, L. E., "Flow Physics of Critical States for Rolling Delta Wings," AIAA Paper 93-3683, Aug. 1993.

[4]Wendtz, W. H., and Kohlman, D. L., "Vortex Breakdown on Slender Sharp-Edged Delta Wings," *Journal of Aircraft*, Vol. 8, No. 3, 1971, pp. 156–161.

[5]Ericsson, L. E., and King, H. H. C., "Effect of Leading-Edge Cross-Sectional Geometry on Slender Wing Unsteady Aerodynamics," *Journal of Aircraft*, Vol. 30, No. 5, 1993, pp. 793–795.

[6]Stahl, W. H., Mahmod, M., and Asghar, A., "Experimental Investigation of the Vortex Flow on Delta Wings at High Incidence," *AIAA Journal*, Vol. 30, No. 4, 1992, pp. 1027–1032.

Reply by the Authors to L. E. Ericsson

W. Gu,* O. Robinson,* and D. Rockwell†

Lehigh University, Bethlehem, Pennsylvania 18015

REGARDING the remarks in the first paragraph, it would indeed be insightful to study further the high sensitivity associated with proximity to a critical state. This will require an investigation of a range of angle of attack and detailed characterization of the instantaneous flowfield in terms of effective swirl and axial velocity components.

The issues of effective angle of attack and sweep angle for a rounded vs a sharp leading edge are intriguing and deserve further study. It will be appropriate to provide a basis for interpreting these effective angles in terms of the detailed structure of the leading-edge vortex for a rounded vs sharp edge.

Regarding the difference in structure between the breakdown from a sharp edge and a rounded edge with blowing, again detailed characterization of the swirl and axial velocity fields would be required. As the magnitude of the tangential blowing velocity increases, it would tend to enhance the swirl velocity, and it is expected that a limiting value of the ratio of swirl to axial velocity would be reached, for which any further increases would actually tend to enhance the onset of vortex breakdown and move its location toward the apex.

Taken as a whole, the issues raised point to the need for further studies of the quantitative structure of the flowfield. In fact, studies of the flow past a delta wing at high angle of attack subjected to various types of local control are currently under investigation in our laboratories.

Received Jan. 19, 1994; accepted for publication Jan. 31, 1994.

*Research Associate, Department of Mechanical Engineering and Mechanics.

†Paul B. Reinhold Professor, Department of Mechanical Engineering and Mechanics.

Comment on "Nonlinear Response of Asymmetrically Laminated Plates in Cylindrical Bending"

C. T. Sun*

Purdue University, West Lafayette, Indiana 47907

A recent Technical Note by Carrera[1] suggested that the von Kármán large deflection plate theory[2,3] was not suitable for analysis of asymmetric composite plates. His conclusions were based on the discrepancy found in the comparison of the analytical solutions obtained by Sun and Chin[2,3] with his nonlinear finite element solutions. In his finite element analysis Carrera erroneously modeled the cylindrical bending problem as a thin laminate strip with free boundary conditions. This explains why his finite element solutions could not match the analytical solutions, thus leading him to incorrect conclusions.

References

[1]Carrera, E., "Nonlinear Response of Asymmetrically Laminated Plates in Cylindrical Bending," *AIAA Journal*, Vol. 31, No. 7, 1993, pp. 1353–1357.

[2]Sun, C. T., and Chin, H., "Analysis of Asymmetric Composite Laminates," *AIAA Journal*, Vol. 26, No. 6, 1988, pp. 714–718.

[3]Sun, C. T., and Chin, H., "On Large Deflection Effects in Unsymmetric Cross-Ply Composite Laminates," *Journal of Composite Materials*, Vol. 22, Nov. 1988, pp. 1045–1059.

Received Jan. 12, 1994; accepted for publication March 17, 1994.

*Professor, School of Aeronautics and Astronautics. Fellow AIAA.

Reply by the Author to C. T. Sun

Erasmo Carrera*

DIAS-Politecnico di Torino, Torino 10129, Italy

First of all I have to reply that in Ref. 1 I did not suggest that the von Kármán large deflection plate theory was not suitable for analysis of asymmetric composite plates. In fact I used this nonlinear theory in the FEM model empoyed in Ref. 1. Instead in my Note[1] concerning the cylindrical bending case, I mainly remarked what is in the following text:

1) The analysis in Ref. 2 is a linearized one in the sense that the load-deflection curve has the Euler buckling load as asymptote.

Received Feb. 25, 1994; accepted for publication March 17, 1994.

*Research Engineer, Corso Duca degli Abruzzi 24. Member AIAA.

2) I showed that Sun and Chin's results can be obtained starting from the linear expression of the stress resultants [Eqs. (8) of Ref. 1].

3) In Ref. 1 I have written that "the derivations . . . made in [Ref. 2] are mathematically unexceptionable, but in deriving them some nonlinear terms are tragically lost." That does not happen in the FEM model mainly because the boundary conditions are differently treated.

4) In Ref. 1 I introduced a simple elastic one-degree-of-freedom model which explains in a very simple manner the phenomenon.

I don't want to add other words to those in my Note[1], to which the interested readers are addressed for more details.

References

[1]Carrera, E., "Nonlinear Response of Asymmetrically Laminated Plates in Cylindrical Bending," *AIAA Journal*, Vol. 31, No. 7, 1993, pp. 1353–1357.

[2]Sun, C. T., and Chin, H., "Analysis of Asymmetric Composite Laminates," *AIAA Journal*, Vol. 26, No. 6, 1988, pp. 714–718.