

Technical Comments

Comment on "Induced Side Forces at High Angles of Attack"

B. L. Hunt* and P. J. Lamont†
University of Bristol, Bristol, England

IN their recent paper, Wardlaw and Morrison¹ apply linear regression techniques to available experimental data for side forces on bodies of revolution at high angles of attack. In view of the inconsistencies and discrepancies in the data which have been published, their approach is fully justified and they are to be congratulated on their efforts to extract significant trends from the confusion of the published measurements.

In their paper, Wardlaw and Morrison correctly point out that the side forces are apparently very sensitive to small irregularities in model geometry and seemingly insignificant changes in test conditions, such as roll angle; this leads them to adopt their statistical approach. They conclude that a large number of further measurements, giving a more comprehensive data base, are required. Since a very large number of parameters are known or believed to be involved, the amount of testing implied by this approach is very great indeed. It may be helpful, therefore, to consider an alternative point of view.

In a recent paper (published after the acceptance of Wardlaw and Morrison's paper) Lamont and Hunt² have presented the results of an extensive experimental study of local side force distribution using a pressure-tapped model. They measured both time-averaged and fluctuating pressures. One of their conclusions is that serious unsteadiness of the flow pattern is a common occurrence and is a result of the flow switching from one of its bistable states towards and sometimes into the other state. They demonstrate that a major cause of such switching is freestream turbulence and that the resulting time-averaged force can be considerably less than the force corresponding to the unswitched state. From observations of models mounted on various balances, it seems likely that vibration of the model on its mounting can also be a cause of flow switching. Lamont and Hunt's time-averaged pressures (and hence forces) exhibited an irregular variation with roll angle, similar in nature to that observed in many overall force studies. However, their unsteady pressure measurements showed that this variation was due to variations in the unsteady flow behavior and that the inferred unswitched levels were independent of roll angle.

Confirmation of these findings is desirable but they do suggest that it is the switching behavior which is sensitive to model geometry and flow conditions and, further, that it may be possible to avoid the occurrence of flow switching by working with rigidly mounted models in low turbulence level environments. Some support for this view can be obtained by a careful examination of the published results.³

A conclusion from this discussion is that there is an alternative to the approach of conducting large numbers of overall force measurements and applying statistical methods to the accumulated data. The alternative is to work with rigidly clamped models in low turbulence level flows and to monitor the unsteady behavior so as to ensure that measurements only correspond to the unswitched state.

Values obtained in this way should always be larger in magnitude than the values obtained in less ideal conditions, where flow switching is occurring. Once the unswitched behavior is understood, the effect of flow switching can be studied as an unsteady phenomenon. Such an approach gives more detailed information than do statistical methods and seems to stand a better chance of providing the physical understanding which is rightly seen as essential by Wardlaw and Morrison.

References

¹Wardlaw, A.B. Jr., and Morrison, A.M., "Induced Side Forces at High Angles of Attack," *Journal of Spacecraft and Rockets*, Vol. 13, Oct. 1976, pp. 589-593.

²Lamont, P. J. and Hunt, B. L., "Pressure and Force Distributions on a Sharp-Nosed Circular Cylinder at Large Angles of Inclination to a Uniform, Subsonic Stream," *Journal of Fluid Mechanics*, Vol. 76, Oct. 1976, pp. 519-559.

³Lamont, P. J. and Hunt, B. L., "Prediction of Aerodynamic Out-of-Plane Forces on Ogive-Nosed Circular Cylinders," *Journal of Spacecraft and Rockets*, Vol. 14, Jan. 1977, pp. 38-44.

Reply by Authors to B. L. Hunt and P. J. Lamont

Andrew B. Wardlaw Jr.* and Alfred M. Morrison†
Naval Surface Weapons Center, White Oak
Laboratory, Silver Spring, Md.

IN their comment on our paper, Hunt and Lamont raise the question of unsteadiness in the high-angle-of-attack flowfield. In the past this type of consideration has been ignored and their concern is well justified. However, it is not clear that flowfield unsteadiness is the only factor leading to the extremely sensitive nature of side forces and moments. Another explanation is that there exist a number of possible steady vortex patterns behind a particular type of model, each producing a different level of side force. The precise pattern adopted depends on the particular idiosyncracies of the model and wind tunnel arrangement. There is evidence to support both points of view. Lamont and Hung have presented unsteady pressure measurements lending credence to the importance of unsteadiness and have found good agreement in a few instances between their discerned unswitched side force levels and measurements made at other facilities.^{1,2} Support for the existence of multiple stable vortex pattern comes from flow visualization studies.³⁻⁵ In particular, Clark and Nelson⁵ have filmed vortex patterns switching during a static test from a steady symmetric one to a steady asymmetric arrangement for no discernable reason.

In our view both unsteadiness and multiple stable vortex patterns contribute to the erratic nature of side forces and it remains to be determined what the relative importance of each of these two mechanism is. Also, the influence of these two mechanisms may vary with angle of attack and Mach number.

Received Jan. 17, 1977.

Index categories: LV/M Aerodynamics; Nonsteady Aerodynamics.

*Aerospace Engineer, Experimental Aerodynamics Branch; currently at Lincoln Laboratories, Lexington, Mass. Member AIAA.

†Aerospace Engineer, Experimental Aerodynamics Branch. Member AIAA.

Received Dec. 8, 1976.

Index categories: LV/M Aerodynamics; Nonsteady Aerodynamics.

*Reader in Aeronautical Engineering.

†Research Associate, Department of Aeronautical Engineering.

For example, most of the reports of multiple vortex patterns have occurred at angles of attack in the vicinity of 35 to 45 deg. It should be recalled that Lamont and Hunt's data was taken in compressible flow while the bulk of existing measurements are in the transonic regime. We agree with Lamont and Hunt that it is desirable to work with well-clamped models in a low-turbulence environment. However it seems premature to conclude that there is a unique unswitched vortex pattern associated with a specific model. In efforts to answer this and related questions, a combined unsteady pressure and Laser Doppler Velocimeter test is in progress at our facility. In view of the present uncertainty in the nature of the high-angle-of-attack flowfield, we recommend approaching the problem of defining side forces in the manner outlined in our paper.

References

- ¹Lamont, P. J. and Hunt, B. L., "Pressure and Force Distributions on a Sharp-Nosed Circular Cylinder at Large Angles of Inclination to a Uniform, Subsonic Stream," *Journal of Fluid Mechanics*, Vol. 76, Oct. 1976, pp. 519-559.
- ²Lamont, P. J. and Hunt, B. L., "Prediction of Aerodynamic Out-of-Plane Forces on Ogive-Nosed Circular Cylinders," *Journal of Spacecraft and Rockets*, Vol. 14, Jan. 1977, pp. 38-44.
- ³Wardlaw, A. B. Jr., and Morrison, A. M., "Induced Side Forces at High Angles of Attack," *Journal of Spacecraft and Rockets*, Vol. 13, Oct. 1976, pp. 589-593.
- ⁴Deffenbaugh, F. D. and Koerner, W. G., "Asymmetric Wake Development and Associated Side Force on Missiles at High Angle of Attack," AIAA Paper 76-364, San Diego, Calif., July 1976.
- ⁵Clark, C. W. and Nelson, R. C., "Body Vortex Formation on Missiles at High Angles of Attack," AIAA Paper 76-65, Washington, D. C., Jan. 1976.

From the AIAA Progress in Astronautics and Aeronautics Series . . .

HEAT TRANSFER WITH THERMAL CONTROL APPLICATIONS—v.39

Edited by M. Michael Yovanovich, University of Waterloo

This volume is concerned with the application of principles of heat transfer to one of the most complex engineering tasks in environmental control, the maintenance of thermal equilibrium in an isolated spacecraft thermal control system have necessitated a wide expansion of knowledge in fields such as surface emission and absorption characteristics, radiative exchange in complicated geometries, thermal contact resistance conduction in heterogeneous media, heat pipe phenomena, etc. The knowledge thus developed in the field of heat transfer, stimulated by the special requirements of spacecraft thermal balance and control, is directly applicable to many other engineering heat transfer projects. The book is recommended, therefore, to the broad community of heat transfer engineers as well as to the more specialized engineering community.

409 pp., 6 x 9, illus., \$19.00 Mem. \$35.00 List

TO ORDER WRITE: Publications Dept., AIAA, 1290 Avenue of the Americas, New York, N. Y. 10019