Improvement of Flow Quality at the University of Washington Subsonic Wind Tunnel

Shojiro Shindo* and William H. Rae, Jr.†
University of Washington, Seattle, Wash.
and
Yoshio Aoki‡ and Eugene G. Hill§
The Boeing Commercial Airplane Co., Seattle, Wash.

Abstract

A METHOD for improving flow quality in the University of Washington Aeronautical Laboratory (UWAL) 8×12 ft closed, double return wind tunnel was developed by a joint effort of The Boeing Company and the University of Washington. The importance of flow quality has been rapidly increasing in wind-tunnel testing because modern aircraft performance improvements are attained by relatively small configuration changes. The capability to measure and interpret small changes in configuration is limited in part by the uniformity of flow in the test media. The improvements attained, which included a more uniform flow, reductions of power and turbulence levels, and their effect on aerodynamic test data are presented.

Contents

Early studies indicated that a problem with flow quality existed with the University of Washington Aeronautical Laboratory (UWAL) facility.[1,2] The tunnel's original flow characteristics showed what appeared to be flow patterns similar to four solid body rotations. In surveying other wind-tunnel facilities, large gradients in angularity in the test volume were found, indicating that this was not a problem unique to the UWAL facility. Single return wind tunnels exhibited similar flow rotations.[3] Early investigations suggested that these rotations were caused by combined viscous and inertial effects of fluids flowing in ducts and/or turning corners.[4-9] In spite of what appeared to be a possible explanation, the sense of rotation in all cases was reversed from that predicted by theory. Another potential source for the rotations was the contraction cone. For this investigation a three-dimensional vortex panel potential flow computer program was used to model the flow in the contraction cone and test section. No evidence of solid body rotations was produced. Interestingly, the accuracy with which the program predicted the effects of protuberances in the stream such as the model mounting strut suggested the possibility of future optimization of fairings and support systems to minimize flow disturbances.

The significant parameters that controlled angularity in the test section were found to be a) flow uniformity in the fan diffuser and b) the effect of horizontal and vertical vanes in the fourth corner prior to the test section. After improvements to the fan diffuser were made and the fourth corner vanes were fine tuned, angularities were reduced to ±0.25 deg. An additional benefit was a significant reduction in the turbulence level. The flow improvements attained are shown in Fig. 1. Immediately downstream of the UWAL fan are four streamlined struts supporting the gear housing. Attached to these struts are antiswirl vanes which were originally installed to straighten the twist in flow imparted by the fan.

Tests in a 0.125-scale model facility showed that the rectangular fan diffuser had very low velocities near the corners. Deflecting the antiswirl vanes to larger angles than required to remove the twist or to large angles to aid the twist increased the velocities in the corners. This more uniform velocity

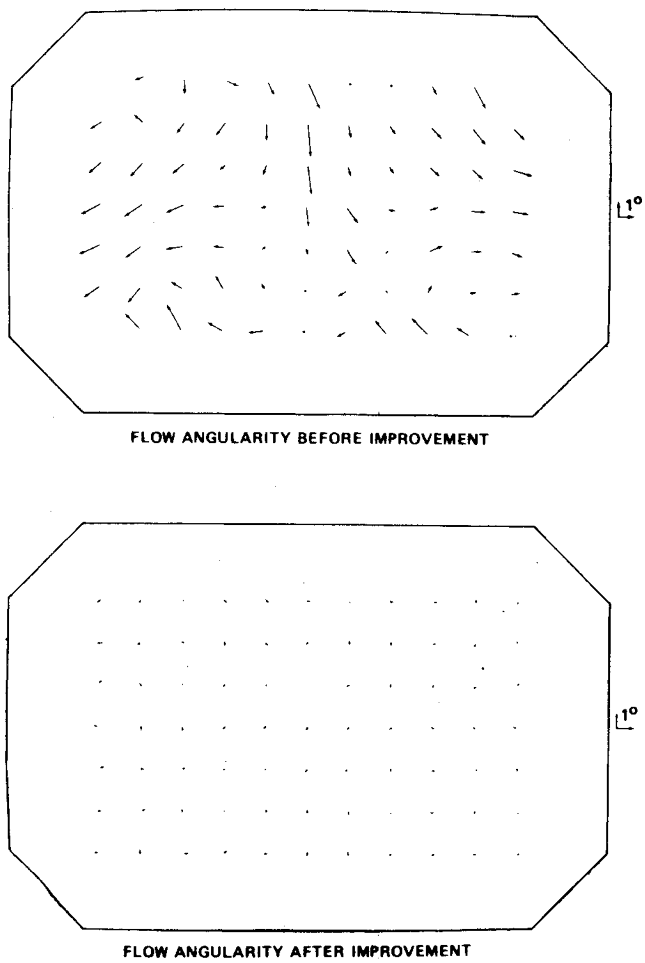

Fig. 1 Comparison of flow angularity before and after improvement.

Presented as Paper 78-815 at the AIAA 10th Aerodynamic Testing Conference, San Diego, Calif., April 19-21, 1978; submitted Aug. 17, 1978; synoptic received Feb. 15, 1979. Full paper available from AIAA Library, 555 West 57th Street, New York, N.Y. 10019. Price: microfiche, $2.00; hard copy, $5.00. **Order must be accompanied by remittance.**

Index categories: Testing, Flight and Ground; Subsonic Flow.

*Aeronautical Engineer, Dept. of Aeronautics and Astronautics.

†Associate Professor and Associate Director, Aeronautical Laboratory, Dept. of Aeronautics and Astronautics. Member AIAA.

‡Senior Specialist Engineer. Member AIAA.

§Senior Group Engineer, Testing Development.

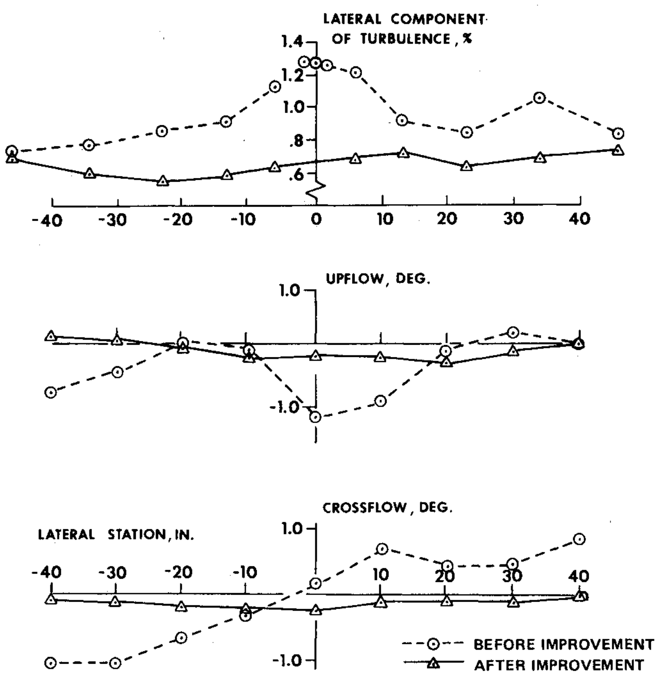

Fig. 2 Flow characteristics at test section centerline.

distribution produced large reductions in the test section flow angularities. To fine tune the test section flow in the full-scale tunnel, 24-in. chord extensions were used on the vertical fourth corner vanes in conjunction with horizontal splinter plates. The power of these devices was amply demonstrated by their ability to completely reverse the flow angularities. The tunnel flow was very sensitive to the vane extension angles, and adjustments as small as 0.125 in. on a 24-in. chord vane extension were required. The tailoring of the flow took over 100 configurations.

Figure 2 shows the improvements to turbulence, upflow, and crossflow on the balance moment center in the lateral direction. Turbulence level measured with a hot wire for the lateral component is shown on the upper portion of the figure. The upflow distribution presented in the middle portion shows a reduction to ± 0.25 deg. The crossflow shows a complete elimination of the gradient near the vertical centerline. The same reduction in flow angles is dramatically illustrated in Fig. 1.

To check the effects of the tunnel flow modifications a typical jet transport type model was used with no change in the model when tested before and after the tunnel modification. Significant changes to model data were noted. For example, the large improvement in tunnel crossflow resulted in a 12% change in vertical tail effectiveness. The changes would of course be of significance only as they relate to the flow changes incurred in this facility. Changes in airplane performance due to small changes in model configuration such as wing twist could easily be masked by the original upflow distribution shown on Fig. 2. Power consumption of the tunnel drive system was reduced by 2% at all speed ranges.

The flow improvement program described herein resulted in the identification of the portions of a subsonic wind tunnel circuit which may have predominant influence on flow uniformity in the test section. With minor modifications to existing UWAL component hardware, significant improvements were made to flow quality at minimum cost. Rotational flow patterns which were not unique to this double return facility were eliminated.

References

[1] "Upflow and Cross Flow Calibration," University of Washington Aeronautical Laboratory, University of Washington, Seattle, Wash., UWAL Rept. 396-L, July 1962.

[2] "Dynamic Pressure Calibration," University of Washington, Aeronautical Laboratory, University of Washington, Seattle, Wash., UWAL Rept. 396-N, Feb. 1966.

[3] Reynolds, H.A., "Air Speed Calibration of the 8×12 Foot Test Section of the General Dynamics Low Speed Wind Tunnel to Establish an Air Speed Calibration with the Bellmouth Honeycomb Installed and Determine the Effects of this Installation on the Tunnel Air Flow," Convair Division, General Dynamics Corp., San Diego, Calif., Rept. C-7004, March 1970.

[4] Schlichting, H., *Boundary-Layer Theory*, McGraw Hill, New York, 1968, pp. 575-578, 589-592.

[5] Hawthorne, W.R., ed., "Aerodynamics of Turbines and Compressors," Princeton Univ. Press, Princeton, N.J., 1964, pp. 287-296.

[6] Falkner, V.M. and Nixon, H.L., "Experiments on Air Flow in the 7-Foot Open-Jet No. 1 Wind Tunnel and Application to Wind Tunnel Design," Ministry of Supply, London, R&M 2484, ARC Technical Rept. 1951.

[7] Krober, G., "Guide Vanes for Deflecting Fluid Currents with Small Loss of Energy," NACA Tech. Memo. 722, 1933.

[8] Klein, G.J., Tupper, K.F., and Green, S.S., "The Design of Corners in Fluid Channels," *Canadian Journal of Research*, Vol. 3, Sept. 1930, pp. 272-285.

[9] Page, R.J., "An Experimental Study of Developing Turbulent Flow in a Square Duct," M.S. Thesis, University of Washington, Seattle, Wash., 1971.