WIND TUNNEL WALL INTERFERENCE CORRECTIONS
(A BRIEF OVERVIEW)

BY

N. Ulbrich
Jacobs Technology Inc., Moffett Field, California 94025

June 2009

INTRODUCTION

In general, an accurate description of wind tunnel test data (e.g., aerodynamic loads) and of important flow field phenomena (e.g., shock location, wing stall characteristics, etc.), is only possible if wall interference phenomena are understood and wall interference corrections are applied to the data. The present write-up tries to give a brief overview of the classes of wall interference corrections that are usually applied to wind tunnel test data. In addition, different methods are discussed that may be used to compute wall interference corrections. Finally, recommended references are listed.

FIRST ORDER CORRECTIONS

The presence of wind tunnel test section boundaries changes the physical conditions that the test article experiences during the test. Therefore, wall interference corrections need to be applied to test results whenever data is to be related to a free-air situation -or- whenever a tunnel-to-tunnel data comparison is to be made.

During a wind tunnel test the physical conditions seen by the test article are primarily described using (a) the dynamic pressure, (b) the Mach number, and (c) the angle of attack at the location of the test article. Wall interference corrections are applied to these quantities so that the test results are reported correctly!

Wall interference corrections of (a) dynamic pressure, (b) Mach number, and (c) angle of attack are called “first order corrections”. They correct for the most important changes of the test data due to the presence of the test section boundaries. Wall interference corrections are not constant inside of the test section volume. They are a function of the chosen reference point coordinates. Therefore, the first order corrections are computed either at a predetermined location on the model -or- as a weighted average of values that were computed at several reference point stations on the test article. This approach makes it possible to correct dynamic pressure, Mach number, and angle of attack using three single numerical values.

The dynamic pressure and the Mach number correction are also called “blockage corrections.” They describe the fact that the test section boundaries alter the distance between the streamlines in the vicinity of the test article if their position is compared with the free-air situation. Both “blockage corrections” are directly derived from the so-called “blockage factor.” This value is the ratio between the axial interference velocity due to the test section boundaries and the flow's reference velocity. In a closed wall test section both "blockage corrections" are positive values. In an open jet, slotted wall, or perforated wall test section, on the other hand, both "blockage corrections" are usually negative values.

The test section boundaries also alter the stream angle at the location of the test article. Therefore, an angle of attack correction needs to be applied to the test data in order to describe the flow angle seen by the test article correctly. The angle of attack correction is derived from the ratio between the wall interference induced upwash velocity and the tunnel's reference velocity at the test article's reference points. It is a positive value for positive lift in a closed wall test section and usually a negative value for positive lift in an open jet, slotted wall, or perforated wall test section.

HIGHER ORDER CORRECTIONS

Higher order wall interference corrections may also be applied to wind tunnel test data. Most higher order corrections correct test data for the fact that the assessed wall interference corrections are not constant at different points on the test article. For example, a pitching moment correction for a swept wing may be computed that is a function of the variation of the wall interference induced angle of attack correction along the span of the wing. Similarly, a correction of the pitching moment may be computed that takes the chordwise variation of the angle of attack correction into consideration. It is also possible to compute a buoyancy correction of the drag force that takes the wall interference induced variation of the blockage factor along the fuselage centerline into account. Ultimately, the customer's test goals determine whether or not higher order wall interference corrections should be applied to the data.

WALL INTERFERENCE CORRECTION COMPUTATION

How are wall interference corrections computed for a model that is tested in a wind tunnel? In principle, three different type of computational techniques are used:

Type (1) - Analytical techniques that use solutions of the subsonic potential equation of the wall interference flow field in order to assess wall interference corrections. These analytical solutions of the wall interference flow field take advantage of the fact that wall interference is a "far-field" effect. Consequently, it is not necessary to represent every minute detail of the test article geometry in order to assess wall interference. Therefore, singularities like sources, sinks, doublets, or horseshoe vortices may me used to represent the test article. Analytical techniques include the method of images for tunnels with rectangular cross-section and Bessel function solutions of the interference flow field for tunnels with circular cross-section.

Type (2) - Numerical techniques that use a panel code or a CFD solver in order to obtain the wall interference flow field. The wall interference flow field is simply obtained by taking the difference between the computed solution of the wind tunnel and free-air flow field of the test article. These types of techniques usually require a detailed description of the geometry of the test article and the test section walls.

Type (3) - Methods that combine wall boundary measurements with analytical solutions of the subsonic potential equation in order assess wall interference corrections. Some of these techniques require a singularity representation of the test article (e.g., Hackett's wall signature method). Other methods do not require a singularity representation (e.g., Ashill's two variable method).

All three types of computational techniques require knowledge of the exact location of the test article in the wind tunnel, as wall interference corrections have to be computed at specific locations on the wind tunnel model. In addition, an accurate analytical or empirical description of the wall boundary conditions has to be known.

Techniques of type (1) and type (2) can be applied whenever the test article's expected separation wake is small. In all other cases methods of type (3) must be used. Only these methods match the measured wall signature on the test section boundary with numerical solutions that permit the calculation of wall interference corrections for separated flows!

SUGGESTED REFERENCES

[1] Ewald, B.F.R., et al., "Wind Tunnel Wall Correction," AGARDograph 336, published by the North Atlantic Treaty Organization, October 1998.

[2] Garner, H.C., Rogers, E.W., Acum, W.E.A., and Maskell, E.C., "Subsonic Wind Tunnel Wall Correction," AGARDograph 109, published by the North Atlantic Treaty Organization, October 1966.