Numerical Evaluation of the Strut Interference and the 3-Run Image method for Wind Tunnel Tests

Byeong-Hee Chang*
Aerodynamics Department
Korea Aerospace Research Institute, Taejon, Republic of Korea, 305-333

Abstract

In order to correct the strut interference in wind tunnel tests, image methods are conventionally used. Because of their excessive extra runs, some alternatives have been tried to reduce the extra runs. In this study, these alternatives were reviewed and checked by the strut interference evaluation with the panel code, CMARC. The present work shows that the strut interference is free from neither model configuration nor model attitude. This dependency makes the alternatives to the image method unfeasible. The 3-run image method was also evaluated. It worked well even for the exaggerated windshield. At this point, reducing the image runs by neglecting parameters affecting minor influence would be best.

Key Word : strut interference, wind tunnel test, 3-run image method

Introduction

Strut interference is one of the main obstacles in wind tunnel tests using an external balance. In order to correct the strut interference, image strut methods are conventionally used. But the image methods are based on the assumption that the influence of lower struts is independent from that of their image struts and vice versa. But, theoretically, the singularity strength representing a specific body is affected by its surroundings such as flow speed and other bodies. This interference between the strut and its image deteriorates the accuracy of the image methods. Moreover, the image methods require extra runs to evaluate the strut interference. Depending on the strut tare isolation, there are two kinds of image methods, the 3-run method and the 4-run method. Even for the 3-run method, two times extra runs are required to obtain the strut tare and interference.

Hence there have been many tries to develop simpler methods to replace the image methods. One of them is the NLR method[1] which is independent on the model attitude including control surface deflection. The more simplified method would be the global correction method like wall correction that is not model-dependent but strut-dependent only.

In this study, the strut interference was calculated and the 3-run image method was evaluated by the panel code, CMARC.[2] The possibility of the alternatives to the 3-run method was reviewed. A possible option to reduce the extra runs in the image method was considered also.

3-Run method

The 3-run method requires three types of run as follow;

1) N : Normal run with lower strut
2) I : Inverted run with lower strut

---

* Principal Researcher

3) II : Inverted run with lower strut and image strut.

The bayonet of image strut should be attached to the model and isolated from the image strut windshield

The strut tare and interference can be derived as mixed by the following equation. In this study, the aerodynamic force to be considered is lift only, but the remains are obtained by the same formula.

$$\Delta L = L_{II} - L_I$$

With this result, the measured data with the lower strut can be corrected to the strut-free data as follow;

$$L_C = L_N - \Delta L$$

where the subscript C means "corrected".

Testing configuration

Testing configuration is based on the NLR SWIM test.[3] The lift contribution of fuselage is so negligible that the body was neglected from the SWIM. Because no detail information of the flap position is available in Ref[3], the location(x,y,z) of the flap leading edge from the wing trailing edge was assumed as;

(x,y,z) = (-0.01C, 0.0, -0.0225C), where C is the wing chord

The test section shape and size was taken as same as NLR's.

The bayonet in the strut system was neglected, because lift is the only one coefficient to be considered and tare effect is neglected in this study. As a result, the strut interference was investigated with the single windshield and its image.

The windshield configuration is based on UWAL[4] but its section shape was a little thickened to amplify the strut interference. The chord length of the windshield is 15% of the test section height. In order to compare the strut effects, two sizes of windshield were taken. The details of two windshields are as follow;

Table 1. Two kinds of windshields

Windshield	Small	Large
Section	NACA0024	NACA0044
Chord	15% of H	15% of H
Height	1/3 of H	1.15/3 of H

Where H is the test section height

Computing method

The CMARC is one of the most updated panel codes and has a capability of internal flow analysis.[2] The panel distribution on the test wing surface was modeled by 14 chordwise panels and 20 spanwise panels on the upper side and the lower side. Flap has 8 chordwise panels and 20 spanwise panels on each side. Horizontal tail has 8 chordwise panels and 10 spanwise panels on each side.

Figure 1 shows the surface panel distribution of the test model installed on the lower strut in the test section.

In computing a lifting body with a panel code, wake modeling is necessary for the accurate lift prediction. In this case, wing, flap, and tail have their own wakes generated from the trailing edge of each one. The time step for wake development is based on the half chord length propagation. In order to achieve an enough convergence, wake length should be more than 10 or 20 times of the chord length.[2] Figure 2 shows the shape of the developed wake of the wing.

After the wake propagated downstream more than 15 times chord length, the surface pressure distribution was obtained as Figure 3.

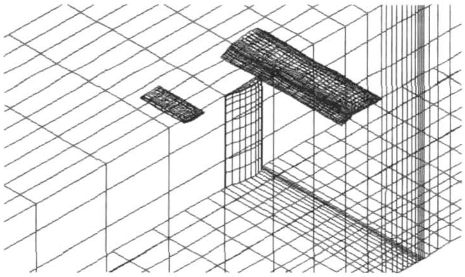

Fig. 1. Test model supported on the strut in the test section.

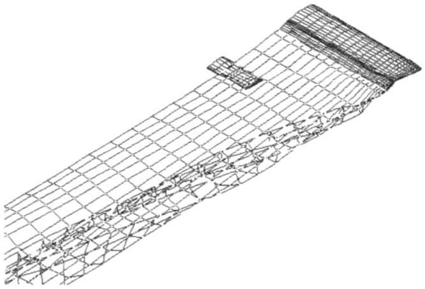

Fig. 2. Wake formation behind the wing.

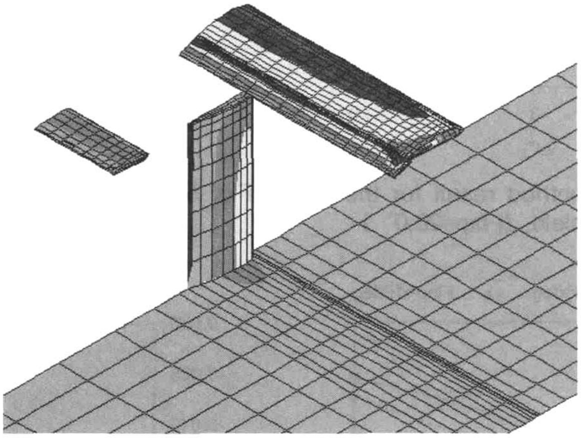

Fig. 3. Pressure coefficient distribution on the model surface.

Results and Discussion

Figure 4 shows the comparison of the no-strut(strut-free) results and the corrected results by the 3-run method in case of the small windshield. The maximum interference occurs at Alpha = -6.0° at which the model is closest to the windshield. As well converged results, the 3-runs method corrects the strut interference within the error of 0.45% at Alpha = -6.0° . But the interference of the windshield is too small to notice the correction effect of the 3-run method in this Figure.

In order to amplify the strut interference, the large windshield was tested. As expected, the difference between the no-strut state and the with-strut state can be seen clearly in Figure 5. The interference of the large windshield is 4.9 times amplified at Alpha = -6.0° than that of the small one. But it can be corrected within 0.55% error as only 20% increased from that of the small one.

This means that even for the large windshield case, the 3-run method works well for the lift correction. In other words, even though there is interaction between the strut and its image, the 3-run method works well. But the top of windshield should be, of course, designed carefully not to provoke flow separation or severe wake that was not calculated by the panel code.

The characteristic of the strut interference dependency on the testing model was also investigated. Figure 6 shows the strut interference comparison between the flap angle 10.0° case and the 20.0° case for the small windshield. The smaller flap angle shifts down the strut interference.

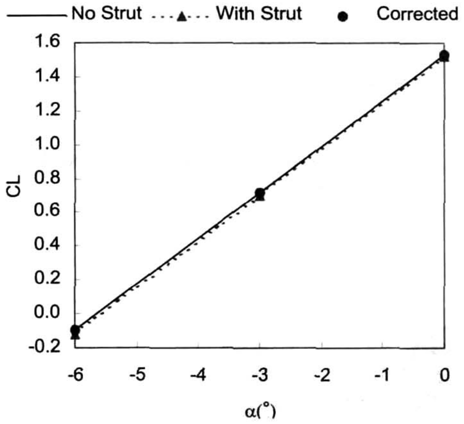

Fig. 4. The 3-run method result for the small windshield. (Flap=20.0°)

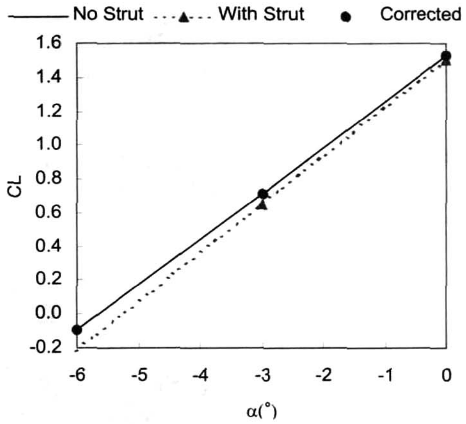

Fig. 5. The 3-run method result for the large windshield. (Flap=20.0°)

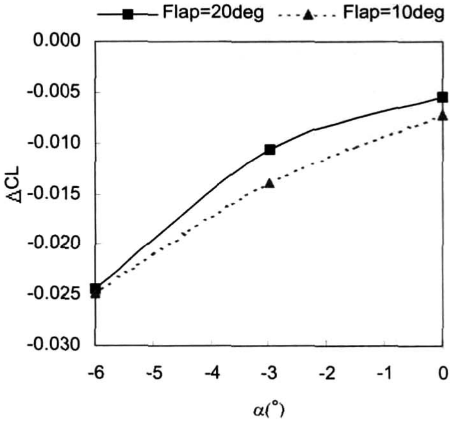

Fig. 6. Flap angle effect on the strut interference for the small windshield.

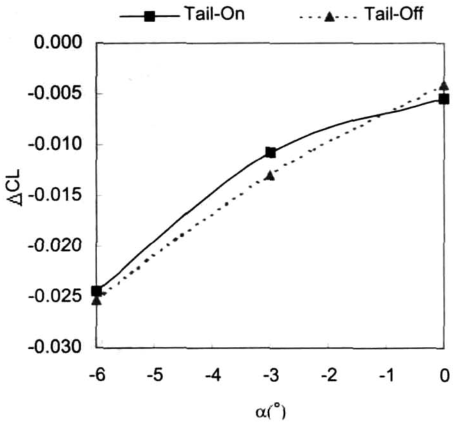

Fig. 7. Tail effect on the strut interference for the small windshield. (Flap=20.0°)

Figure 7 shows the tail effect for the case of the flap angle 20.0° on the small windshield. The tail effect on the strut interference is different from the flap effect.

From these results, it is verified that the strut interference is highly dependent on the flap angle and the tail as well as on the pitch angle(Alpha). Generally speaking, strut interference varies with the model configuration and the model attitude. The former one excludes the global correction method as the alternative to the image method. The later one excludes the NLR method[1] also.

At this point, the recommendable way to correct the strut interference is the image method with reduced parameters. Before the main test, the interference effect of each parameter can be evaluated from the interference study. The extra runs for the image method can be reduced by neglecting parameters which affect minor influence on the interference.

Conclusion

From the calculation of the strut interference with CMARC in respect of lift coefficient, we can conclude as follow;

1) The 3-run image strut method works well for correction of the strut interference even for the large windshield case. This means that the interference between the windshield and its image is not severe to deteriorate the correction results.
2) The strut interference is dependent on the model configuration (flap angle and tail) and attitude(pitch angle). So, the simple correction method independent of the model configuration or the model attitude is not feasible.
3) In order to reduce the extra run in the 3-run image method, the interference effect of each parameter can be evaluated by a simple calculation like a panel code. From this pre evaluation, some parameters affecting minor influence on the interference can be neglected and the extra runs for the image method can be reduced.

This conclusion is based on lift analysis by the panel code. But the viscous calculation will not change these conclusions, though the amount of the interference can be changed. In the future, the viscous flow analysis with Navier-Stokes code will be done and interference of drag and moment will be investigated also.

Acknowledgments

This study was partially supported by the University of Washington Aeronautical Laboratory. The author thanks Scott Eberhardt and Brian Geppert for their help.

References

1. Burning, L.R., Simplified Correction Procedure for (Wing) Strut Influence on the Symmetric Aerodynamic Coefficients, Memorandum AX-91-006, NLR, 1991.
2. CMARC, Three-Dimensional Low Order Panel Code, Version 2.1, AeroLogic, 1997.
3. Labruje, Th.E., Maarsingh, E.R.A., and Smith, J., Evaluation of Measured-Boundary-Condition Methods for 3D Subsonic Wall Interference, NLR-TR-88072-U, NLR, 1988.
4. University of Washington Aeronautical Laboratory Technical Guide to the Kirsten Wind Tunnel, http://www.aa.washington.edu/uwal/uwal.htm