Numerical and Wind Tunnel Test Study on the Nacelle Integration for NAL's Experimental Airplane

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1. Introduction

Currently ,NAL SST Experimental Airplane Program has been progressed under the direction of NAL. The aircraft size of NAL SST is roughly 10% scale of assumed actual-size SST and the relative size of engine nacelle (that will be equipped under the wing) to the airframe is comparatively larger than that of the actual SST.

It means that the fraction of interference drag by the nacelle-integration to the entire drag become larger than that of the actual SST. So, NAL SST may have its own difficulty in the propulsion system integration and it supposed to be one of the major subject in the aerodynamics design of NAL SST.

To understand the nacelle-wing/body interference phenomena and to acquire the drag level of such SST configuration that have excessively large nacelles, the parametric study of wind tunnel test(WTT) and CFD analysis have been performed. (Fig.1)

2. Analysis Method

The WTT has performed at FHI high speed wind tunnel using FHI SST study configuration half model. The flow-through type nacelle that has 2-dimensional external compression type intake is installed under the wing in various geometry for parametric study. The nominal configuration was decided from preliminary study of nacelle installation by aerodynamics, structure and propulsion system, and was slightly different from NAL SST configuration. (Fig.2,3)

The CFD analysis has performed for similar configurations with WTT models. Analysis codes are overlapped multi block Euler solver and boundary layer correction has applied. The boundary layer calculations are carried out to estimate the friction drag.

3. Comparison of WTT and CFD

Numerical analysis and WTT show good agreement on trend of CL～AOA and the drag on clean configuration. The other side, in the drag on nacelle configuration, wind tunnel results are higher than CFD results.(Fig.4) This difference may be caused by flow separations (mostly occurred at end of diverter). Also there are difference between CFD and WTT on absolute value of L/D, but the trend of nacelle geometry change effect shows favorable agreement. (Fig.5) On the nacelle integration study, we intend to use differential value of each nacelle geometry, and not absolute value.

From these comparisons, each CFD and WTT could result the similar flow mechanism, and CFD analysis is effective to evaluate the various nacelle geometry.

4. Numerical Analysis Results

The various nacelle configurations(nacelle up/down, in/out, forward, and nacelle off) were analyzed to evaluate the effect of nacelle geometry by CFD in the condition of M=2.0, AOA=2.0deg. In the case of the nacelle on/off, nacelle-wing/body interference phenomena shows well in Cp contribution under surface.(Fig.6) The shock interference

area is very large compare to wing area, and especially very strong compression is occurred between right and left nacelles. At this area, the flow tube becoming narrow and moreover the shocks from nacelles colliding. Also the expansion at the trailing edge of wing produces drag.

Finally from the drag of each components, the next remarkable characteristics is shown. (Fig.7)

- The gap of wing-nacelle affects the drag of diverter and nacelle.
- The distance between left and right nacelle affects the drag of body and nacelle.
- The forward shift of nacelle affects the drag of wing.

5. Conclusion

1)The nacelle system integration study was carried out using numerical analysis and wind tunnel test.

2)CFD and WTT results show favorable agreement on the trend of nacelle geometry effect.

3)The basic characteristics of nacelle interference on large nacelle airplane configuration has been acquired.

As the result of this study, the guideline of nacelle geometry optimization was indicated.

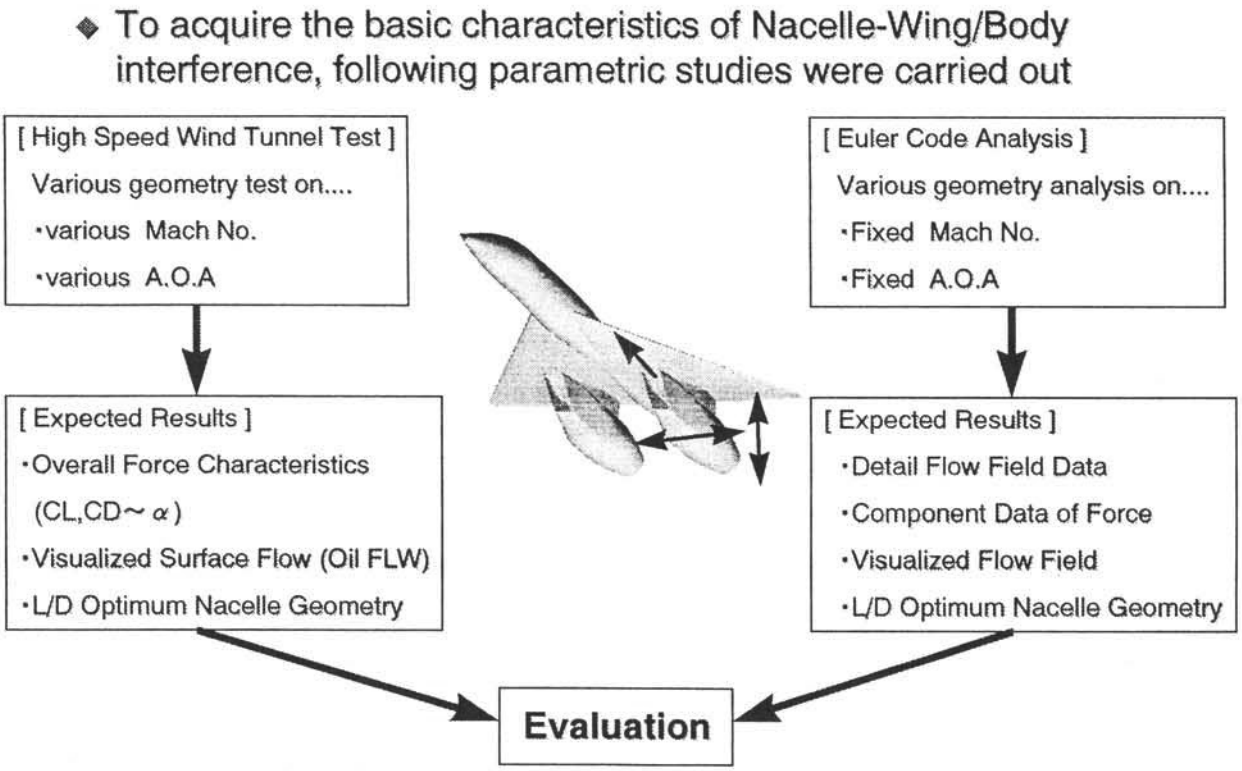


Fig.1 Parametric Study of Nacelle Geometry

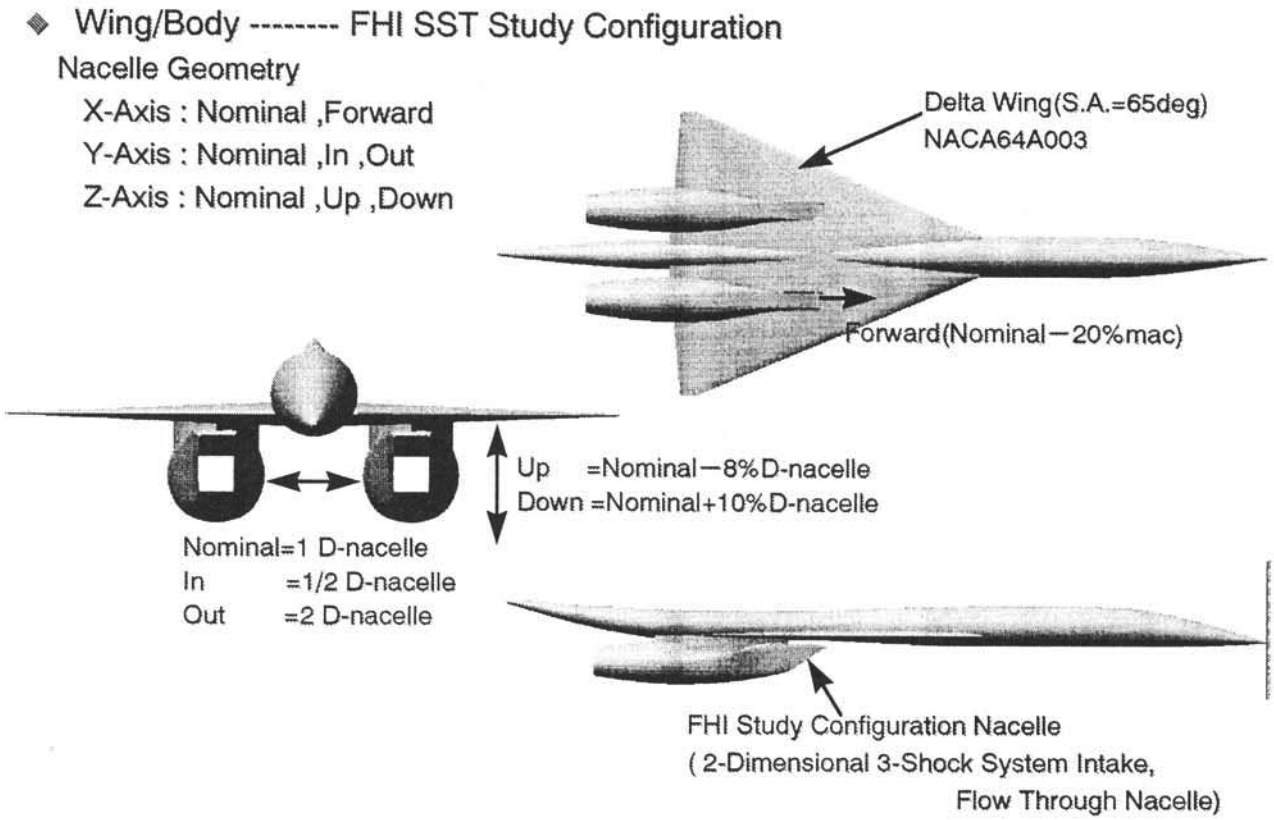


Fig.2 The Configuration

◆ Test Condition

- Model : FHI SST Study Config. Half Model
  Body Length=0.8 m , Span=0.3 m
  Flow Through Nacelle ,Diverter
- Mach No. : 1.4 , 1.6 , 2.0(Nominal Mach)
- A.O.A : -2 , -1 , 0 , 1 , 2 , 4 (deg)
- Meas. item : Side Wall 3-Axis Component Balance (CL,CD,Cm)
  Nacelle Duct P0 & Ps
- Nacelle Geometry : Clean , Nacelle On (Nominal,Forward,In,Out,Up,Down)

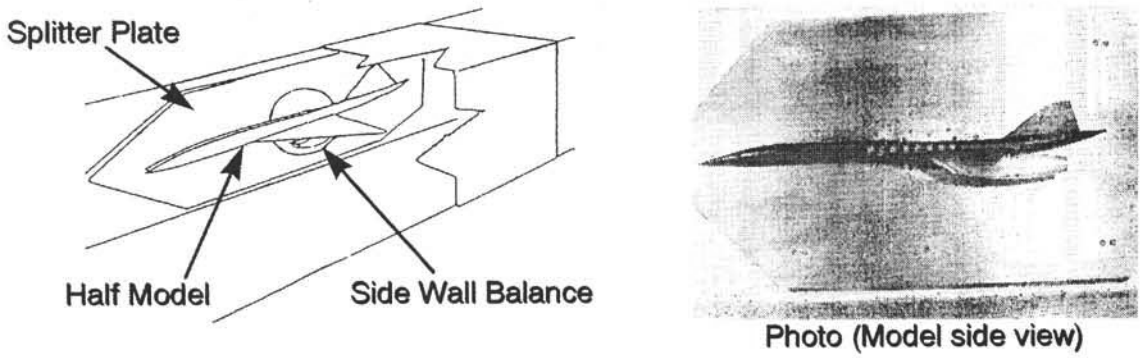


Fig.3 High Speed Wind Tunnel Test

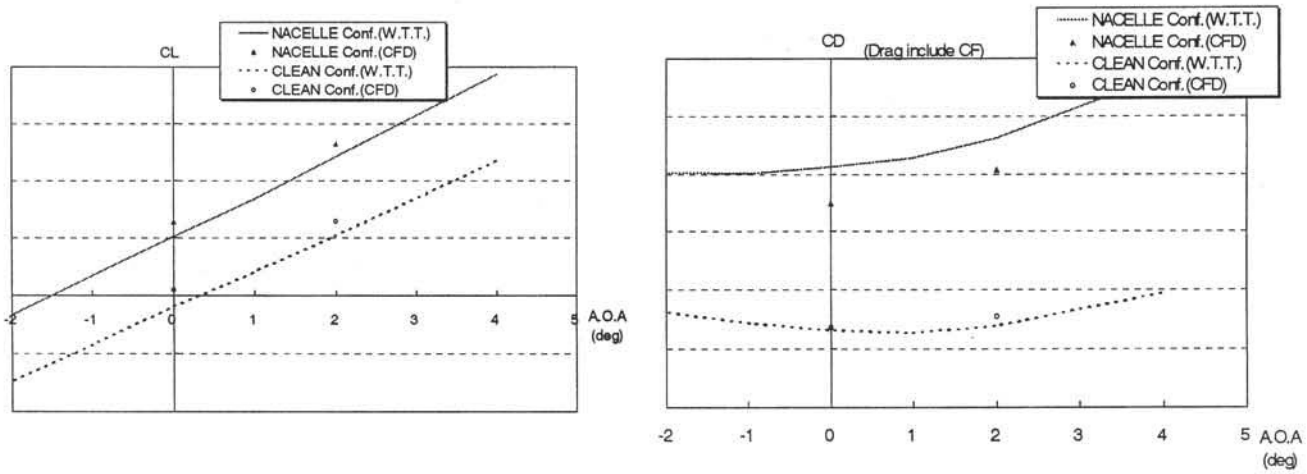


Fig.4 Results — CFD v.s. W.T.T (Lift&Drag)

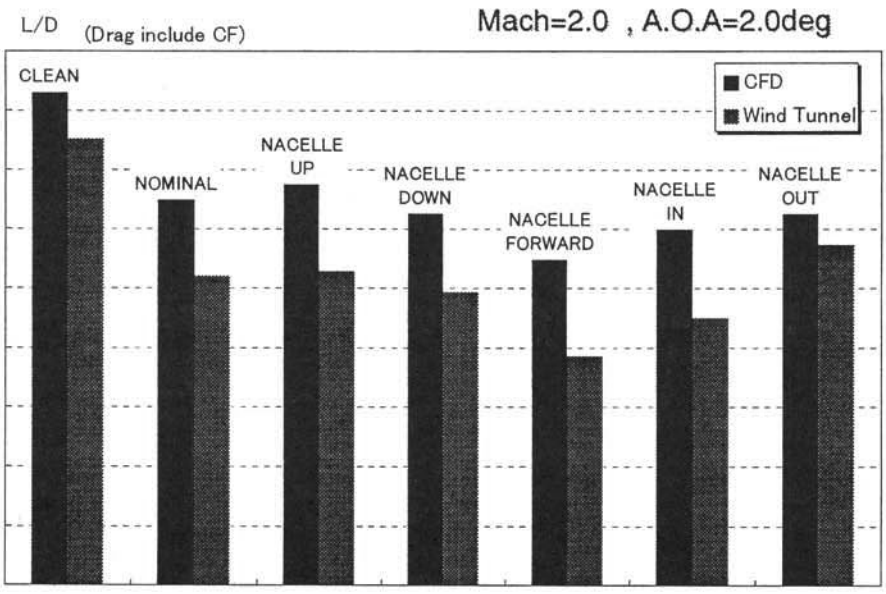
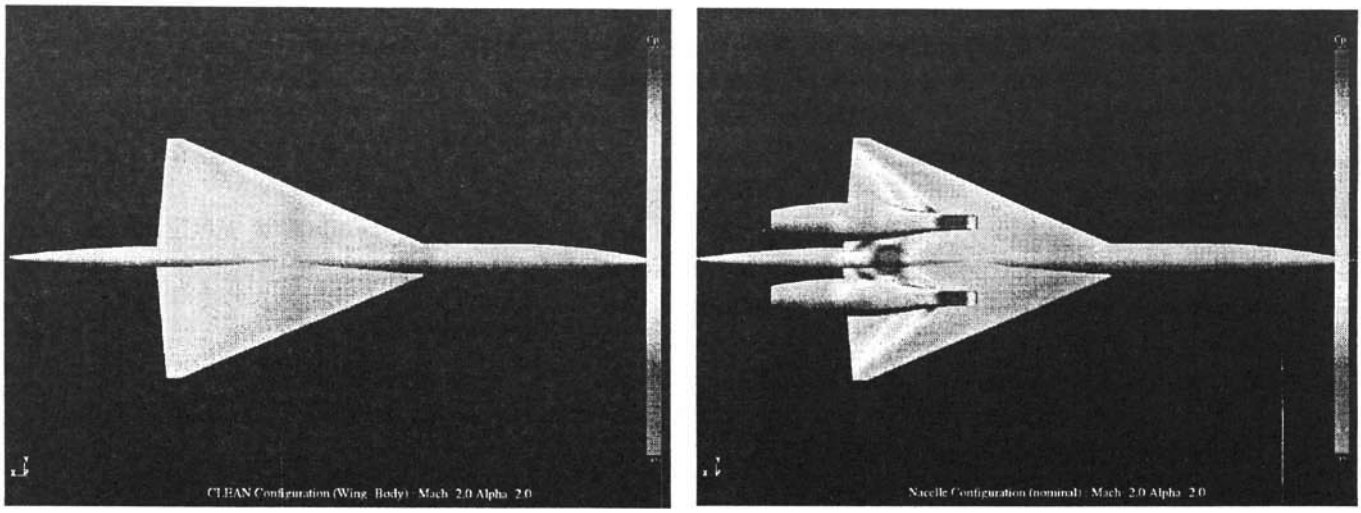


Fig.5 Results — CFD v.s. W.T.T (L/D)

Effect — Nacelle on/off

- Mach=2.0 , A.O.A=2.0deg



Clean Configuration Nacelle Nominal

Fig.6 Results —Numerical Analysis

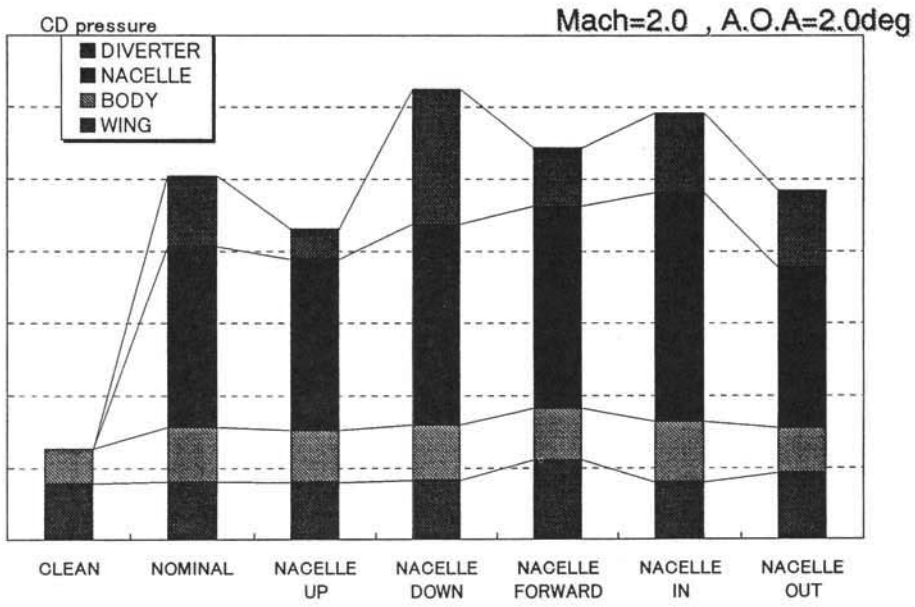


Fig.7 Results —Drag Components by CFD