NONLINEAR AEROELASTIC SIMULATIONS OF LOW-BOOM SUPERSONIC TRANSPORT AIRCRAFT

Kensuke Soneda* and Kenichi Saitoh

**Japan Aerospace Exploration Agency*
6-13-1 Osawa, Mitaka, 181-0015, Tokyo
Japan

ABSTRACT

Supersonic civil transport is showing signs of revival after a gap of more than 20 years since the Concorde retired. Key aspects of modern supersonic transport include low drag performance and low boom performance. Supersonic transport airplanes that satisfy these requirements result in very thin wings and a very long fuselage. This unique configuration influences the vibration characteristics of the airframes. Aeroelastic designers should consider the coupling of the fuselage bending when evaluating the flutter characteristics of the low-boom supersonic transport aircraft.

Supersonic transport aircraft experience transonic flight during climb and descent. The aeroelastic stability in this transonic regime is quite important for the supersonic aircraft, as unique nonlinearity could be observed. There is a so-called “chimney” region where the flutter speeds of supersonic transport wings drop deeply in a narrow Mach number range[1]. The influences of the unique configuration for low-boom supersonic aircraft on the flutter characteristics should be carefully investigated.

Japan Aerospace Exploration Agency (JAXA) has been working on the development of the low-boom design technology for the next-generation supersonic civil transport aircraft and has designed a conceptual 50-seat-class low-boom supersonic transport aircraft [2]. This study numerically analyzes the nonlinear transonic flutter characteristics of the conceptual low-boom supersonic transport aircraft designed by JAXA (S4-2nd). The finite element method is used to evaluate the structural characteristics of the S4-2nd airframe. Aerodynamic loadings are computed with computational fluid dynamics (CFD) to consider the nonlinear flow fields around the aircraft. Aeroelastic simulations are performed with the in-house CFD code FaSTAR-Move, and the nonlinear transonic flutter characteristics of S4-2nd are evaluated.

The following summarizes the current results and plans for the full paper.

The finite element model (FEM) is generated for S4-2nd. The wing and fuselage are modeled considering the detailed components such as skins and stringers. Tails, nacelles, and low-boom fins are modeled with shell elements. Different materials, including aluminum, titanium, and carbon fiber-reinforced plastic laminates, are used for each component, taking into account the necessary mechanical properties. The modal analysis is performed, and some example results are shown in Fig. 1. Most modes include the participation of fuselage bending, and the influences of the unique configuration are observed.

Euler-based CFD analysis will be used for aerodynamic load calculations. The computational grid is generated using HeldenMesh, which is shown in Fig. 2. This grid consists of 4.2M nodes and 24.1M elements. The flow conditions will be determined based on the mission analysis for the S4 aircraft. Figure 3 shows the flight profile for the climb phase.

Time-domain aeroelastic simulations will be performed within FaSTAR-Move, combining the vibration characteristics obtained by finite element analysis and the nonlinear unsteady aerodynamic loads calculated by CFD analysis. The nonlinearity in the region where the Mach

number is close to 1 will be intensively studied. The effect of the angle of attack will also be one of the key parameters for the discussion, and will be within the scope of this study.

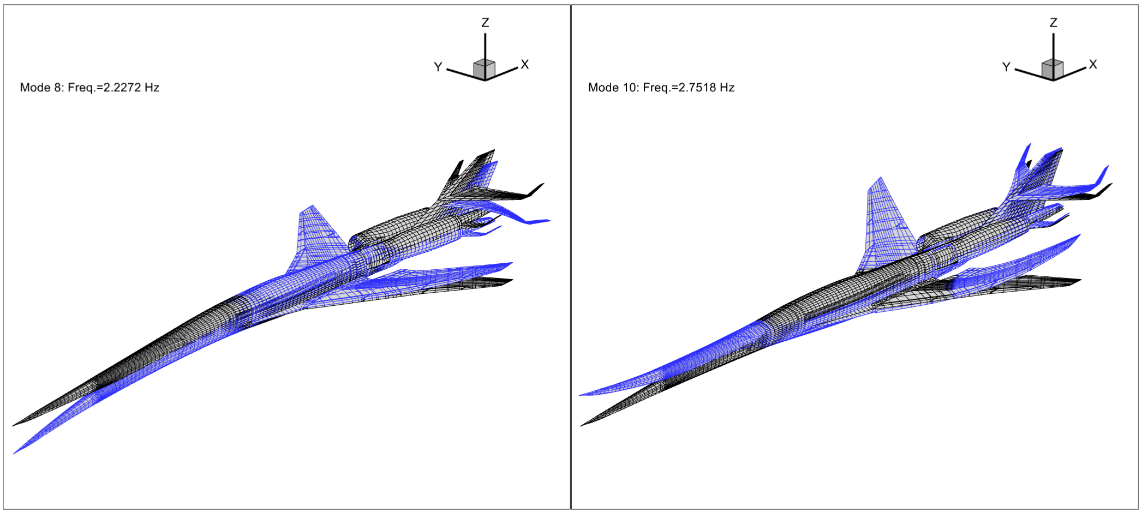

Fig. 1 Examples for modal analysis results of S4-2nd: Mode 8 (left) and Mode 10 (right).

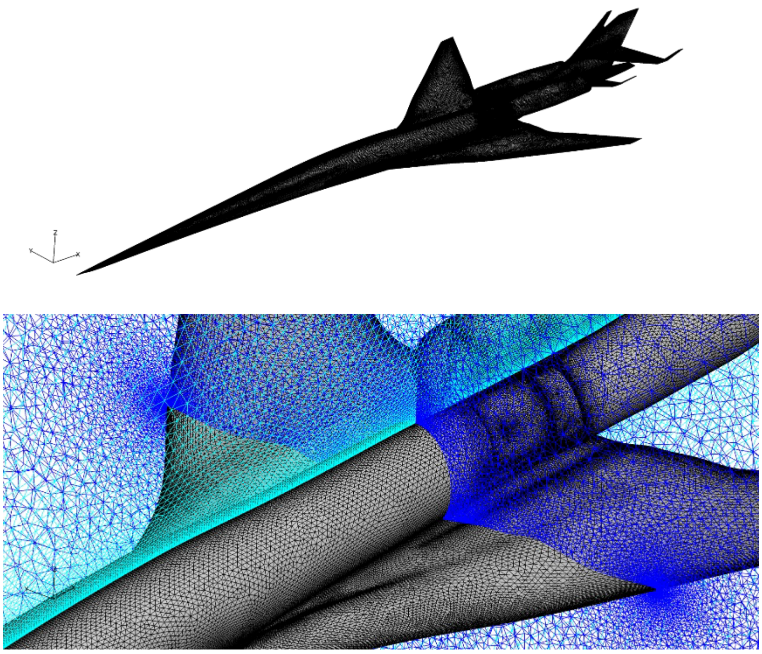

Fig. 2 CFD grid for S4-2nd: overview (top) and close-up (bottom).

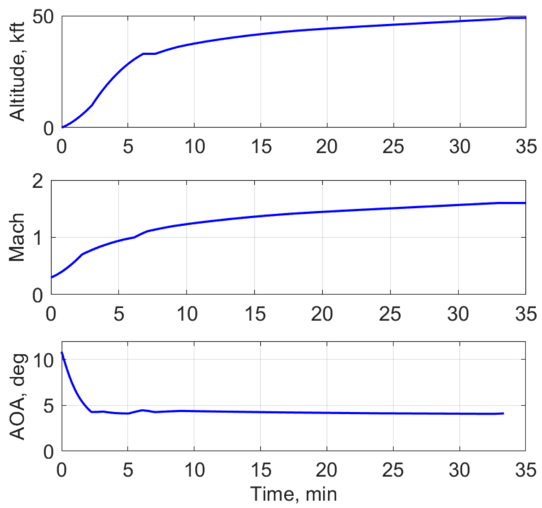

Fig. 3 Flight profile for the climb phase.

Reference

1. Silva, W., Keller, D., Florance, J., Cole, S., and Scott, R. "Experimental steady and unsteady aerodynamic and flutter results for HSCT semispan models," *41st Structures, Structural Dynamics, and Materials Conference and Exhibit*, 2000.
doi: 10.2514/6.2000-1697
2. Liebhardt, B., Lütjens, K., Ueno, A., and Ishikawa, H. "JAXA's S4 Supersonic Low-Boom Airliner – A Collaborative Study on Aircraft Design, Sonic Boom Simulation, and Market Prospects," *AIAA Aviation 2020 Forum*, 2020.
doi: 10.2514/6.2020-2731