Comparison of Shock Wave Interaction for the Three-dimensional Supersonic Biplane with Different Planar Shapes

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1. Introduction

A fundamental problem preventing commercial transport aircrafts from supersonic flight is the creation of strong shock waves occurring during cruising condition, which result in lower aerodynamic efficiency and stronger sonic boom felt on the ground. It is important to create the airplane configuration to be able to reduce the shock wave, because the strength of the shock wave depends on the fuselage weight and volume, i.e., configuration.

Recently, the supersonic biplane theory[1] suggested by Adolf Busemann, as shown in Fig. 1, has been attracting attention because his theory has two important features. One is that the shock wave propagated to the ground can be significantly reduced since the biplane cancels out the shock waves occurring from the leading edges so as to interact with the expansion waves generated at the vertices each other. The other feature is that the shock wave cancellation results in very low wave drag, compared to a conventional monoplane with the same thickness.

This research compares the shock wave interaction and the drag of three-dimensional supersonic biplane configurations with different planar shapes and taper ratios through the CFD simulations.

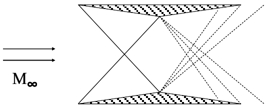

Fig. 1 Supersonic biplane (Busemann biplane) at design Mach number

2. Computational methods and conditions

In this research, a three-dimensional unstructured flow solver named TAS code (Tohoku University Aerodynamic Simulation code) is employed to analyze the flow fields. The three-dimensional compressible Euler equations are considered as the present governing equations.

Each three-dimensional configuration to be investigated has the same reference area ($S/c_{ref} = 2$) and the same wing span ($b/ c_{ref} = 2$). The wing sections also have the same airfoil, composed of two triangular airfoils with thickness chord ratio of 0.05. In this time, the generated two-dimensional oblique shock wave's angle is 41.8 degrees. The clearance of the biplane z/c is set to 0.5054, after considering the shock wave diffraction involved in the shock wave interaction. There are four types of three-dimensional biplane configurations, classified according to the planar shape: trailing-edge-tapered wing, both-edge-tapered (leading and trailing-edge-tapered) wing, leading-edge-tapered wing and caret-type leading-edge-tapered wing. The trailing-edge-tapered wing and the leading-edge-tapered wing consist of the quadrilateral wing tapered at the trailing edge and the leading edge, respectively. The both-edge-tapered wing is the quadrilateral wing tapered at both the leading and trailing edges, so that the line connecting the vertices of each wing section is perpendicular to the freestream direction. The caret-type leading-edge-tapered wing is the quadrilateral wing tapered at both the leading and trailing edge, so that the angle of the leading edge at the side view is the same as the angle of the two-dimensional oblique shock wave. The above four different configurations are analyzed while changing the taper ratio at a freestream Mach number of 1.7 and angle of attack of 0 degree.

3. Results and discussions

The drag coefficients C_D of the four types of three-dimensional biplane configurations are compared for different taper ratios as shown in Fig. 2. As the results show, the drag-minimum biplane configuration is the both-edge-tapered wing with a taper ratio of 0.2.

In order to take a more detailed look at the shock wave interaction, Fig. 3 shows C_p contour plots on the wing surface at the shock wave interaction side, for the both-edge-tapered wing with a taper ratio of 0.2. The Mach cone occurs at the wing root and disturbs the shockwave interaction. The reflected shock wave hits in front of the trailing edge. However, the pressure behind the vertices is higher than that in front of the vertices at the mid-span section. And the area influenced by the Mach cone near the wing tip is reduced than that of the rectangular wing. As the result, its drag coefficient is not so high.

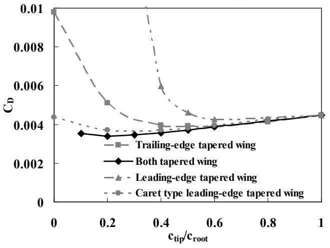

Fig. 2 Comparison of drag coefficients for four biplane configurations with different taper ratios

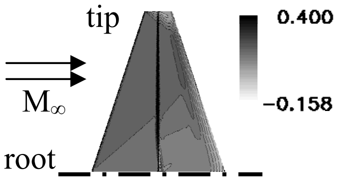

Fig. 3 C_p contour plots on the wing surface at shock wave interaction side of the both-edge-tapered wing with a taper ratio of 0.2

Reference

[1] Kusunose, K., *et al.*, "A Fundamental Study for the Development of Boomless Supersonic Transport Aircraft," AIAA paper 2006-0654, 2006.