Fig. 2 Particle traces over the flap element at the wind-tunnel wall, unswept case with tab.

Fig. 3 Total lift coefficient vs sweep angle.

Fig. 4 Relative tab effectiveness for three sweep angles.

Conclusions

A numerical study of lift-enhancing tabs on three-dimensional high-lift systems was performed. Lift-enhancing tabs have been computationally shown to improve the lifting capability of high-lift systems at three leading-edge sweep angles, 0, 15, and 30 deg. The lift coefficient at 10-deg angle of attack is increased by 5, 27, and 36%, respectively. The results for the unswept case were compared with experimental data and the lift increments caused by the tabs agreed closely.

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Spanwise Camber and Quasisteady Effects During Wing Rock

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Introduction

AN inviscid computer model has been used to aid in further understanding and evaluation of the slender wing rock phenomenon. The inviscid model has been coupled with the rigid body equation of motion in oscillations to simulate the fluid–structure interaction. The investigation focuses on an isolation of quasisteady effects on a delta wing through an application of the roll-rate boundary condition. In addition, spanwise camber changes through differential flap deflection was investigated.

Methodology

The computational analysis for this study was performed using a modified inviscid model developed by Arena and Nelson.[1] The modifications made by Ize and Arena[2] allowed the model to be used to study the quasisteady effects and the spanwise camber during wing rock. It was shown that the essential characteristics of the unsteady delta wing can be captured by modeling only the primary flow characteristics, which is based on experimental results. Validation of the model can be found in Ref. 2. The solution to the present model is obtained by using a panel technique where the body geometry is represented by a distribution of constant strength sources and vortices, allowing for arbitrary specification of spanwise boundary

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conditions. The quasisteady aerodynamic calculations are accomplished by fixing the wing at a given roll angle, and applying the roll-rate boundary condition while holding the model fixed. This is accomplished over a range of roll angles and roll rates consistent with the time history obtained during wing rock simulation.

Results

Quasisteady Effects

Utilizing the roll-angle and roll-rate information from wing rock time histories, quasisteady runs were accomplished as discussed in the methodology. Figure 1 is a plot of the unsteady and the quasisteady roll moment vs roll angle. Unlike the unsteady equivalent, there is only one direction with regard to the hysteresis for the quasisteady plot. The direction of the moment trajectory is in the counterclockwise direction.

This is significant in that it is clear from the sense of the loop that quasisteady effects alone cannot sustain wing rock. The clockwise loop is indicative of a destabilizing or unstable system from an energy analysis standpoint, as shown by Nguyen et al.[3] This system clearly cannot undergo wing rock.

Analysis of the vortex behavior provides insight into the roll moment results. For the spanwise vortex position there is very little variation between the unsteady and quasisteady runs. Quasisteady effects do not significantly affect change spanwise vortex position. This was expected because there is little hysteresis in spanwise vortex position during wing rock.

The behavior of vortex strength for the quasisteady and unsteady runs is shown in Fig. 2. As discussed in Ref. 1 the apparent affect of the vortex strength hysteresis during wing rock is to generate the damping lobes necessary to limit the oscillation and produce a limit cycle. As can be seen in the figure the direction of the hysteresis is the same; however, the magnitude of the hysteresis is reduced.

The variation of the normal position of the vortices for the unsteady and quasisteady effects is shown in Fig. 3. The normal vortex position data show that there is a significant difference between the unsteady and quasisteady hysteresis behavior. It can be seen that the direction of the hysteresis for the quasisteady runs are opposite to that observed during wing rock.

The results observed in the vortex position data are significant in that they suggest a rational for the hysteresis behavior observed in the quasisteady simulations. In the quasisteady case, the hysteresis in vortex position normal to the wing is opposite to that observed in the unsteady case, which suggests that the hysteresis in the normal vortex position is caused by a convective time lag. This is important because it indicates that the instability causing wing rock is caused primarily by unsteady effects, and the quasisteady boundary condition can only generate a damping contribution to the motion.

Fig. 1 Unsteady and quasisteady roll moment coefficient vs roll angle.

Fig. 2 Vortex strength for the unsteady and quasisteady runs.

Fig. 3 Normal vortex position for the unsteady and quasisteady runs.

Fig. 4 a) Roll-angle time history when flaps are deflected and b) flap deflection time history.

Fig. 5 Damping effect of roll moment of wing rock control.

Fig. 6 Normal vortex position during control of wing rock.

Spanwise Camber Effects

In a previous study by Roberts and Arena[4] steady and unsteady effects of asymmetric leading-edge flap deflections on the 80-deg wing were discussed. In the present effort flaps are activated in an antisymmetric sense, proportional to roll rate. The effect of the flap deflections on the wing rock oscillation, can be seen in Fig. 4a. Several cycles of steady-state wing rock are shown prior to flap activation. Antisymmetric flap activation proportional to roll rate occurs at a nondimensional time of approximately 60 as shown in Fig. 4b, after which the motion rapidly decays. The behavior of the moment hysteresis for this time history may be seen in Fig. 5. During the cycle of the wing rock oscillation before control is turned on, the cycle still exhibits the three major hysteresis loops, indicating that the limit cycle motion has reached steady state. When control is turned on, the roll moment rapidly decreases in a counterclockwise spiral toward zero moment, indicating the significant damping contribution added by the flap activation. An explanation for the resulting damping after flap activation may be seen in Fig. 6, which is a plot of the normal vortex position during control of wing rock. The left vortex only is shown for clarity. During wing rock, the large time lag that was discussed previously is observed. After the flaps are activated, the lag is quickly eliminated. The variation of spanwise camber caused by the flaps that results in a damping of the wing rock motion should be noted. As seen in Fig. 4b, the flap on the downward-going wing is deflected downward, and vise versa on the upward going wing.

Conclusions

The goals of the present study were to assess the roles that the unsteady boundary condition and spanwise camber play in wing rock, and to apply these concepts in developing a control strategy for alleviating wing rock. Simulation data have been collected that indicate not only the quasisteady and dynamical aspects of the model motion, but a wide range of data that are indicative of the fluid physics involved. Results indicate that quasisteady effects have a damping effect on the motion primarily because of the hysteresis behavior of vortex position normal to the wing. Additionally, spanwise camber when applied proportional to roll rate has been shown to be capable of alleviating the wing rock motion by mitigating the lag in normal vortex position.

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Definition of Primary Flight Reference

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Introduction

THE terms primary flight reference (PFR) and primary flight display (PFD) have been widely used but never clearly defined. Head-up displays (HUDs) were advertised as PFRs, but required the presence of other approved head-down PFDs in the cockpit. The terms PFR and PFD are controversial and raise red flags to many in the field. The civil cockpit design document[1] does not use the term (nor does it address see-through displays).

The definitions of PFR and related terms are seen as key to the development of flight display standards, designs, and evaluation techniques. Otherwise, approval of novel displays will continue to be subjective with vague and varying criteria.

Historically, HUDs were weapon-aiming sights. Beginning as simple reflecting gun sights, advances in technology allowed the inclusion of flight data in a virtual image that appears to float in front of the pilot's windscreen. In spite of the display of flight data, early HUDs were not developed as general flight instruments, but as weapon-aiming devices.[2]

At the same time civil applications of the head-up display concentrated on the landing approach, beginning with Klopf-

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