THE HANDLING CHARACTERISTICS OF SAILPLANES - PART 2

by BERNARD PAIEWONSKY

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Lateral Directional Modes

The discussion so far has been confined to the motions of the aircraft in the longitudinal sense. The principal variables were the angle of attack, pitch angle, and the velocity. The lateral directional stability is concerned with the motions in roll, yaw, and sideslip.

The primary lateral controls of the airplane are the ailerons. Deflection of the ailerons produces both rolling moments and yawing moments. In many cases the yawing moments are adverse in the sense that they are opposite to the direction that one wishes to go. If the ailerons are deflected to cause a roll to the right adverse yaw will cause the nose to swing around to the left. Favorable aileron yawing moments would cause the nose to swing in the direction of the roll. The rudder is used to produce yawing moments and to control the sideslip angle. In turn entries the rudder is used to cancel any adverse yaw of the ailerons. The criterion usually applied to sailplane ailerons states that good ailerons are able to reverse a 45 degree banked turn in five seconds or less using the rudder to coordinate the turn. This maneuver is usually performed at Vs min. This type of requirement is more appropriate to soaring techniques than the type that imposes numerical requirements on the peak roll rate of the aircraft. The typical sailplane rolling maneuver is a bank and stop maneuver with the usual bank angles being less than 45 degrees.

The aileron stick forces for sailplanes are usually high for a given roll rate due to the large wing span. It is possible to reduce these stick forces by means of aerodynamic balance and differential gearing. Recent studies have shown that large span, narrow chord ailerons are effective in producing large rolling moments for a given stick force. Spring tabs can be used on ailerons to help reduce the stick forces. This technique has not been used to any great extent on sailplanes although their use on powered aircraft has indicated beneficial effects. The maximum stick forces due to sailplane ailerons should be kept less than 15 lbs. It is very desirable to have the stick forces similar for both fore and aft and side movements. Combinations such as very sensitive elevators and heavy ailerons should be avoided. Certain aileron floating characteristics can cause an autorotational motion of the aircraft with the ailerons free, but this is a remote possibility.

It should be noted that all of the foregoing discussion applies to airplanes that are considered very rigid. There is a very close relation between the aeroelastic behavior of the sailplane and the rolling performance actually attained. The existence of aeroelastic phenomena such as aileron reversal, divergence of wings, and flutter is a fact of life that the sailplane designer must face with courage. The calculations can be long and tiring but they are worth doing carefully.

The lateral-directional response of an aircraft disturbed from equilibrium is characterized by three distinct modes of motion. One mode is called the rolling mode and is a very rapid convergence. It is known as the rolling mode because it is most apparent in the first few seconds of the response to an aileron deflection. The characteristic time for this mode depends upon the roll damping and the moment of inertia in roll.

Another mode is known as the spiral mode and it shows up mainly in the roll angle and yaw rate responses. With the controls locked a spirally unstable airplane will gradually diverge in an ever tightening spiral path. This motion is usually slow and the pilot can correct for it easily. The spiral stability influences the control positions that the pilot must hold in steady turns. It seems desirable to have the spiral mode neutrally stable so that only small control deflections need be maintained in turns. Large dihedral effect and low directional stability favor spiral stability. This combination however tends to destabilize the third mode. Spiral stability is usually hard to obtain at high lift coefficients. This is advantageous for sailplanes as most circling takes place at low speeds and low spiral stability is desired there.

The third mode of motion is a moderately damped oscillation usually of short period. It is called the Dutch Roll mode. It is usually a combination of rolling and sideslipping and can be very annoying in rough air. It may be thought of as a directional oscillation under the action of an equivalent spring (directional stability) and damper (Damping in yaw). This oscillation in sideslip is coupled through the dihedral effect (rolling moment due to sideslip) to the roll angle. Some hand waving is usually needed here to illustrate the Dutch Roll mode. Sailplanes with tails can be designed to have good Dutch Roll characteristics without too much difficulty. The principal parameters are the vertical tail volume and the dihedral effect. Simple approximate methods are available so that the designer can make a rapid estimate of the Dutch Roll period and damping. Close aerodynamic balancing of the rudder plus friction in the control system can cause sustained snaking oscillations similar to the porpoising longitudinal mode. Both the Dutch Roll and the spiral mode can be changed considerably by the mass distribution and aerodynamic floating characteristics of the free rudder.

The Roll Response To Aileron Deflection

One of the most important handling qualities is the dynamic response of the aircraft to aileron control. This response is related to the same stability derivatives affecting Dutch Roll, etc. In cases where Dutch Roll is well damped but the aircraft is spirally unstable, the response to a step aileron input with three degrees of freedom is a rapid roll with small oscillation to a new roll rate followed by divergence. In spirally stable aircraft with lightly damped Dutch Roll, there is a near reversal of the roll rate after the initial build-up. This would be very annoying to a sailplane pilot as it becomes very difficult to roll the aircraft in precise fashion. This roll rate reduction is associated with C_{L_β} and C_{n_p}.

Large C_{L_β} (dihedral) and small C_{N_β} (directional stability) make this