lutter in Glider Structures

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e intention of this lecture about flutter of sailplanes is to e some idea of the potential danger of this phenomenon r sailplanes and how it may be prevented.

Flutter can be described as the phenomenon, that an aero-ane wing or tail surface may exhibit violent oscillations with creasing amplitude if a certain speed, the flutter speed or itical speed is exceeded. Since the oscillations are related the airspeed, it is evident that the flow around the profile ays an important part. The question arises, how this can ad to such an unstable behaviour.

First consider a plain wing, which can only perform bend-g oscillations. If this wing has got an initial vibration, for stance by a gust, the relative airspeed of the wing can be omposed of the steady flow velocity (airspeed) and an alter-ating normal velocity due to the motion of the wing (fig. 1).

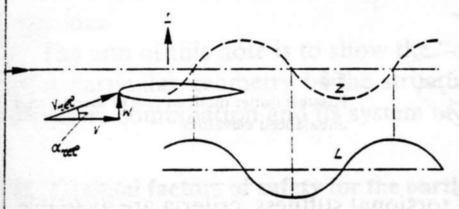

Fig. 1
Lift variation for pure bending vibration

Thus the profile has an alternating angle of incidence which roduces a lift force acting against the wing motion. This neans that the motion is damped by the aerodynamic forces, or in other words, the air flow withdraws energy from the vibrating system.

However, if the wing is fitted with an unbalanced aileron, an initial bending vibration will cause aileron oscillations too, due to the aerodynamic and the inertia forces acting on the aileron. A flutter condition will now exist, if the aerodynamic forces corresponding to the aileron motion put more energy into the system than the aerodynamic forces due to bending motion withdraw from it. This is e.g. the case, if during the larger part of the downward motion of the wing the aileron is deflected upward and reverse.

Whether this amplitude ratio and the phase difference are favourable for flutter or not has to be calculated by means of the equations of motion of the system, but this is beyond the scope of this lecture. However, in general it can be said that flutter may result from the combined action of two or more different modes of vibration.

One of the simplest types of flutter is the so-called bending-torsion flutter of a wing (or a tail surface). As is expressed already by the name, this type occurs under the combined action of bending and torsional vibrations of a wing. In this case the results of a flutter calculation can be plotted as is shown in fig. 2. Here a non-dimensional flutter speed, viz. the speed of flight divided by the product of the torsional frequency and the chord is plotted against the ratio of the bending frequency over the torsional frequency of the wing. Since for nearly all practical configurations the torsional frequency is at least twice the bending frequency, it can be derived from

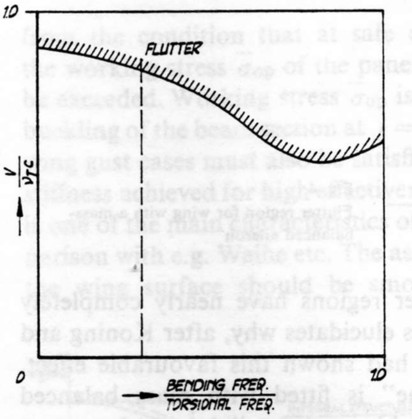

Fig. 2
Variation of critical speed with ratio of bending to torsional frequency

this diagram that the actual flutter speed is nearly proportional to the torsional frequency. Thus, to prevent this type of flutter we have to provide for sufficient torsional stiffness. In this light, the introduction of laminar profiles with their stiffer skin, will act favourably.

For a wing fitted with an aileron three possible combinations of degrees of freedom may lead to flutter, viz. wing bending-aileron rotation; wing torsion-aileron rotation and wing bending-wing torsion. Which type will actually happen depends mainly on the amount of mass balance and the values of bending-, torsional- and aileron frequency. Fig. 3

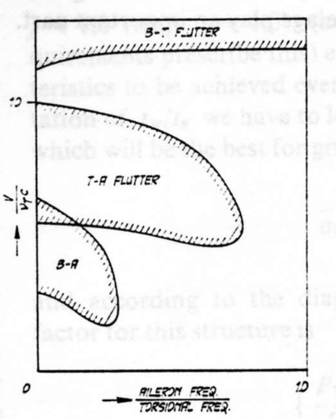

Fig. 3
Flutter region for a wing with an unbalanced aileron

gives a typical example for an unbalanced aileron. In this figure the non-dimensional flutter speed is plotted against the ratio of aileron frequency and torsional frequency. The lowest flutter speed is obtained in the case of bending aileron flutter if the aileron frequency equals the bending frequency of the wing. By sufficiently increasing the aileron frequency, this type of flutter can be avoided and then the flutter speed is determined by wing torsion-aileron rotation. For high values of the aileron frequency, this type of flutter vanishes also and then the system behaves like a wing with fixed aileron.

Thus this figure stresses the importance of the aileron frequency in the case of an unbalanced aileron. In this light it is not surprising, that in the Netherlands a sailplane exhibited violent bending aileron flutter when the aileron cables were unsufficiently tightened.

The improvement in flutter characteristics by means of complete mass balance of the aileron is shown on fig. 4.

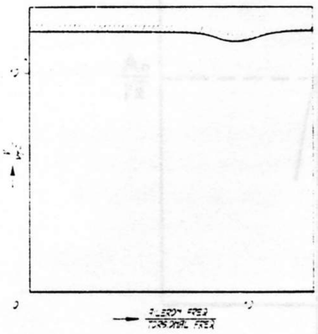

Fig. 4
Flutter region for wing with a mass-balanced aileron

Both B-A and T-A flutter regions have nearly completely vanished in that case. This elucidates why, after Koning and von Baumhauer in 1922 had shown this favourable effect, nearly every "motorplane" is fitted with mass balanced ailerons. It must be stressed here, that sailplane designers are asking for trouble if they are building sailplanes with unbalanced control surfaces, because the flutter characteristics of unbalanced control surfaces may be very sensitive to minor changes in the structural properties. Such changes may occur very likely during the long life of a sailplane. This can be illustrated by a very recent flutter accident in the Netherlands. Some weeks before this lecture was held a well-known sailplane lost both ailerons just at the never exceed speed. The latter was taken at 75% of the speed, at which flutter occurred during a type test, required by the Netherlands Airworthiness Board. In spite of this the recent accident happened.

With respect to tail flutter very often the bending and torsion of the rear part of the fuselage play an important part. One of the oldest flutter cases has been reported already in 1916 by Lanchester. In that case, flutter occurred under the combined action of fuselage torsion and antisymmetric elevator deflections (fig. 5). Lanchester proposed to make a stiff rod between both elevators, so that the antisymmetric motion was impossible. Since that time, most airworthiness requirements ask for such a connection. However, it can be imagined, that this may be neglected in sailplanes fitted with a V-tail. If then accidently some new construction should be designed, with a thin rear part of the fuselage and with unbalanced elevators, a real possibility for flutter at fairly low speeds has been created. Therefore it seems desirable to balance the control surfaces of such a tail construction.

To prevent flutter of sailplanes adequate airworthiness requirements may be a great help. In the course of this lecture, it has been shown that it is possible to prevent flutter by:

a) mass balance of control surfaces,
b) sufficient torsional stiffness.

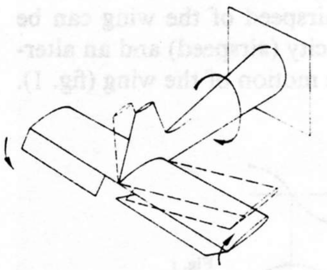

Fig. 5
Possible flutter mode in case of disconnected unbalanced elevators

For the amount of torsional stiffness, criteria are available, which can be incorporated into the requirements. Also the mass balancing of the control surfaces can be expressed easily by simple requirements. Finally the requirements should contain measures of inspection which ensure that the sailplane remains in its original condition.