The Influence of Aileron Flexibility and Mass Unbalance on the Flutter Speed

By Jerzy Maryniak, Chair of Mechanics,
Warsaw Institute of Technology

Presented at the 10th OSTIV Congress, June 1965,
South Cerney, England

1. Introduction

The trend to increase the speed and reduce the weight of gliders results in an increased danger of flutter. The influence of local lack of rigidity on the flutter speed requires further study.

The present paper contains a computation based on resonance tests of a prototype glider, of the influence of aileron flexibility and mass unbalance on the flutter speed.

The analysis is performed taking for computation the first torsional mode and the first two flexural modes. In each of these cases rotation of the aileron about its hinge line is taken as the second degree of freedom.

The Templeton method (1) is used for thecomputation of the flutter speed.

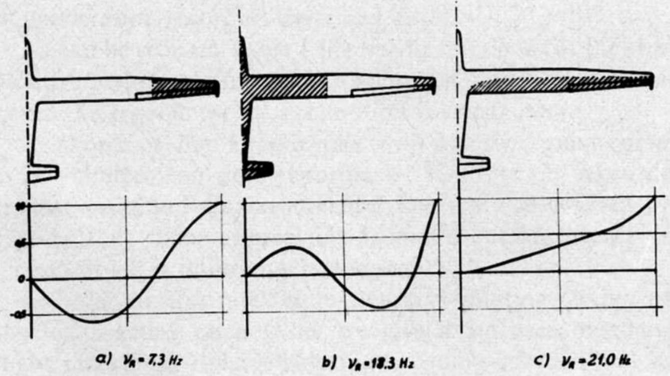
The theoretical basis of the computation being widely known and described in detail in (1, 2, 3, 4), we shall confine ourselves to presentation of the data and results and an analysis of the latter.

2. Data for Computation of the Flutter Speed

The frequencies and the corresponding modes of natural vibration of wings are assumed from resonance tests of the "S" prototype glider described in (6).

Fig. 1 represents the vibration modes, the deflection and twist functions assumed for computation being shown below the contours of gliders.

Fig. 1. Fundamental skew-symmetric natural vibration modes: *a)* First flexural mode, 7,3 c. p. s.; *b)* Second flexural mode, 18,3 c. p. s.; *c)* First torsional mode, 21,0 c. p. s.



a) $\nu_R = 7{,}3$ Hz b) $\nu_R = 18{,}3$ Hz c) $\nu_R = 21{,}0$ Hz

The deformation of the aileron (the twist) has been computed on the basis of the results obtained by resonance tests on the wing at the frequency of 21.0 c. p. s. (the first torsional mode), ref. (6). This computation has been performed for an aileron of variable flexibility determined by the flexibility index φ. Thus

$\varphi = 0$—rigid aileron;
$\varphi = 1$—real aileron;
$\varphi = 2$—aileron having twice the flexibility of the real aileron.

Fig. 2 shows the twist functions of the aileron assumed in the computation.

The masses and stiffnesses of the aileron drive elements are disregarded. The aileron is assumed to be flexible and to rotate freely.

For the unbalanced aileron the centre of gravity is located at 18,7% of aileron chord downstream of the hinge line. The computation has been performed for the position of the centre of gravity varying from + 18,7% to — 5%.

This enables us to see the influence of aileron unbalance on the flutter speed.

3. Computation Results of Flutter Speed

3.1. Case I

There are two degrees of freedom:

1. Bending according to the first flexural, skew-symmetric vibration mode of the wing with frequency 7,3 c. p. s. (fig. 1).

2. Free rotation of the aileron which is assumed to be balanced and have variable flexibility (fig. 2).

The results obtained are presented in fig. 3.

From the graph it is seen that increased flexibility of the aileron results in a distinct decrease of the flutter speed. The cross in fig. 3 indicates ν_F of a rigid unbalanced aileron.

3.2. Case II

This case also concerns flutter with two degrees of freedom:

1. Wing twist according to the first torsional mode, with frequency 21,0 c. p. s. (fig. 1).

2. Free rotation of the aileron which is assumed to have variable unbalance and flexibility.

The results are presented in figs. 4 and 5.

Fig. 4 represents the influence of varying unbalance of the aileron with the real flexibility ($\varphi = 1$) on the flutter speed. It is seen that the flutter speed is least in the case of the unbalanced aileron. Fig. 5 shows the influence of aileron flexibility on the flutter speed.

From the diagrams of fig. 4 and fig. 5 it is seen that increased flexibility of the aileron and unbalance (or insufficient balancing) both result in lower flutter speed.

3.3. Case III

In this case a more detailed analysis of flutter has been done. The two degrees of freedom under consideration are:

1. Wing bending according to the second skew-symmetric vibration mode, with frequency 18,3 c. p. s.
2. Free rotation of the aileron which is assumed to have variable unbalance and flexibility.

The results are presented in figs. 6 and 7.

Fig. 6 shows the variations of flutter speed and frequency as functions of aileron flexibility and unbalance. The diagram shows that this type of flutter is characterized by increased flutter speed for increased flexibility of the aileron. The flutter frequency (ν_F) is lower than the resonance frequency (ν_R). Lower unbalance and increased flexibility cause higher flutter frequency up to the value obtained in resonance tests.

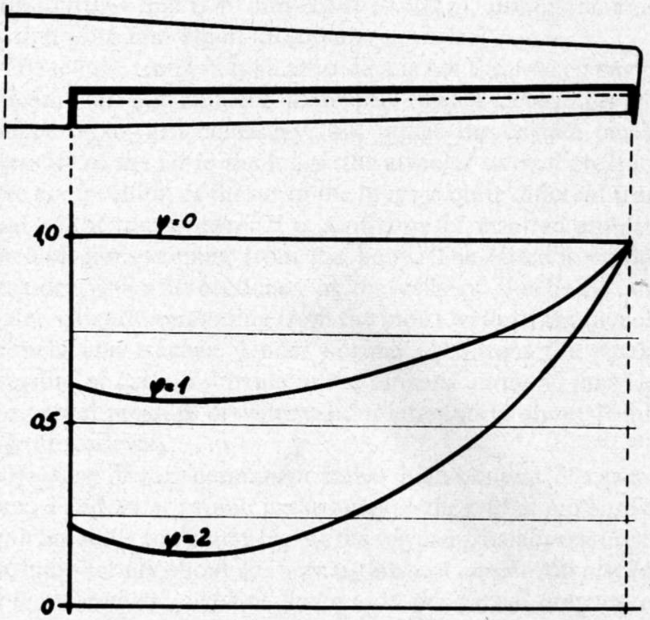
The contour diagram of flutter speed presented in fig. 7 shows in an instructive manner the flutter limit with the degrees of freedom described above.

This diagram of flutter speed as a function of two parameters (flexibility and unbalance) enables the selection of the best structural parameters to be made in order to keep the flutter speed for the modes considered at as high a level as possible.

4. Conclusions

By analysing the above results we see that for the glider under consideration the minimum flutter speed is obtained for low-frequency natural modes (the first flexural mode of the wing and the rotation of the aileron). This conclusion has been verified by the results of Ref. (5) where, in the case of flexural-torsional flutter of a wing (first symmetric flexural mode and first torsional mode) velocities of the same order have been obtained. The degree of flexibility of the aileron does not influence the flutter speed in a regular manner however.

Fig. 2. Torsional deformation of an aileron



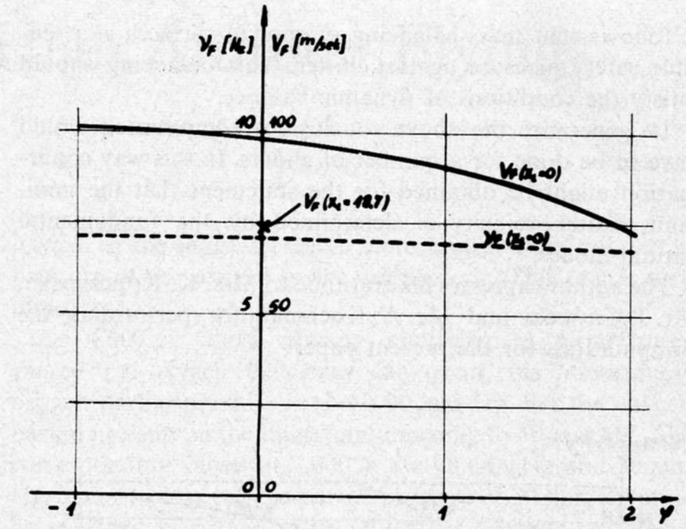


Fig. 3. Relation between the flutter speed and the flexibility coefficient φ in the case of a balanced aileron (Flutter type: First flexural mode, free rotation of the aileron)

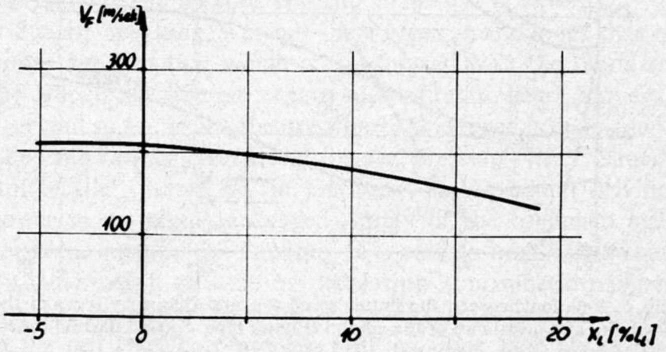


Fig. 4. Relation between the flutter speed ν_F and the degree of unbalance x in the case of an aileron with the real flexibility ($\varphi = 1$) (Flutter type: First torsional mode, free rotation of the aileron)

If the flexibility of the aileron is assumed to be twice as high as the real value the flutter speed drops by some 9 to 20% depending on the type of flutter. If the aileron is assumed to be rigid the flutter speed is higher by 9% in Case I, while in Case II there is no flutter. In Case III the flutter speed is always lower than for the real aileron.

It follows that in computations of flutter speed the aileron should not be assumed to be rigid, or the result may by erroneous in the unsafe direction.

The degree of unbalance of the aileron is important for increasing flutter speed. By balancing the aileron the flutter speed can be increased by 34 to 58% in Case I and II, complete security against flutter being ensured in Case III.

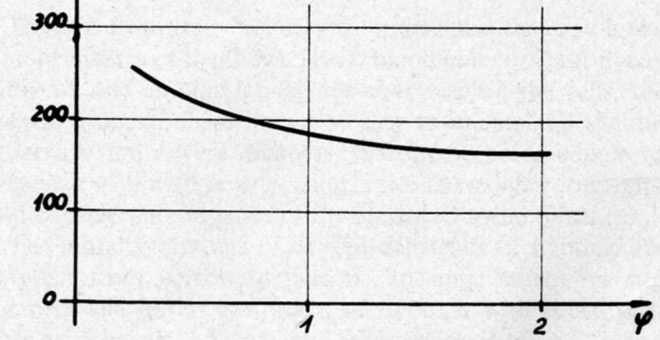


Fig. 5. Relation between the flutter speed ν_F and the flexibility coefficient φ in the case of an unbalanced aileron (Flutter type: First torsional mode, free rotation of the aileron)

It follows that mass-balancing of control surfaces is a sensible safety measure against flutter. This balancing should satisfy the conditions of dynamic balance.

To generalize the above conclusions computation would have to be done for a number of gliders. In this way confirmation might be obtained for the statement that the minimum flutter velocity is determined by the fundamental natural modes.

The author expresses his gratitude to Mrs. K. Kopczynska, Mr. J. Gawecki and Mr. A. Kochman for performing the computations for the present paper.

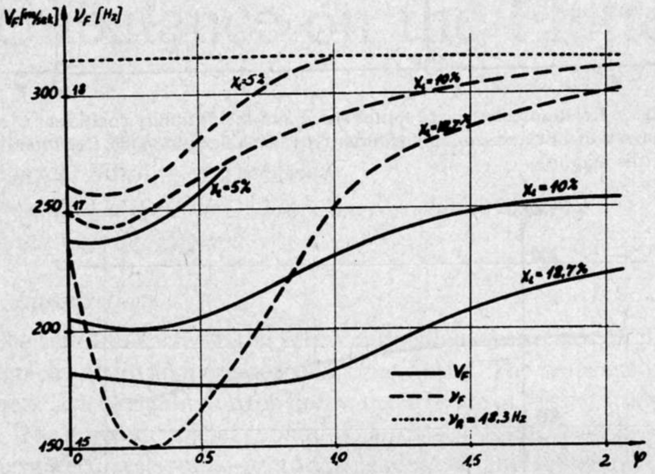


Fig. 6. Relation between the flutter speed ν_F and frequency ν_F and the flexibility and unbalance of the aileron (Flutter type: Second flexural mode, free rotation of the aileron)

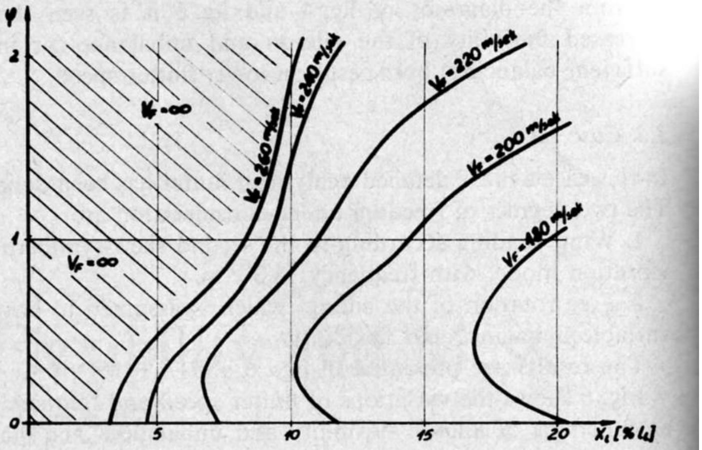


Fig. 7. Contour diagram of flutter velocity ν_F in function of the degree of unbalance and the flexibility coefficient φ (Flutter type: Second flexural mode, free rotation of the aileron)

References

(1) *H. Templeton:* "The Technique and flutter calculation", CP No. 172, A. R. C. Technical Report.

(2) *H. Bisplinghoff, H. Ashley, B. Halfman:* "Aeroelasticity".

(3) *J. Duncan:* "The Fundamentals of Flutter".

(4) *Y. C. Fung*, "An Introduction to the Theory of Aeroelasticity".

(5) *W. Lanecka-Makaruk, J. Maryniak*, "Flutter Problems of Glider Wings", Technika Lotnicza 10–11, 1964.

(6) No. 36 and 36a Report of the Chair of Flight Mechanics, Warsaw Technical University. Resonance Tests of the "S"-Glider (unpublished).