FLUTTER ANALYSIS DURING THE DESIGN OF SAILPLANES

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Summary

The practical application of the flutter analysis during the design of the sailplane is presented. Preliminary calculations are done in parallel with technical documentation. Ground vibration test and stiffness measurement results are used for data correction and computing model verification. The precise flutter clearance calculation finally decided the design of the sailplane. Results of KR-03 PUCHATEK sailplane analysis are presented as example.

Introduction

Sailplane design process requires a lot of optimization to find the best solutions, meeting also flutter requirements. Small sailplane design offices have to look for inexpensive methods of design. The solution has been found in an extensive computing analysis in all stages of the design process, and in using selected calculation methods, interactive, user-friendly software and cheap personal computers.

Vibration and flutter calculations are applicable in early design studies. Designers have the possibility to make preliminary verification of the flutter properties for proposed design solutions. It is possible in this stage to determine limits of parameter changes, thus allowing the design team to form the sailplane structure. Input data corrections are performed by measurements on the sailplane prototype. Comparison between ground vibration tests and calculation results is the final verification (or correction) of the mass and stiffness data.

The detailed flutter clearance calculations finally determine the design option for the sailplane structure.

Flutter analysis-Practical application in design

Practical flutter analysis was applied during the design of the two-seater, metal, training sailplane KR-03 PUCHATEK, worked out in PZL KROSNO design office.

Flutter analysis includes calculations made in OBR PZL MIELEC and ground vibration tests made in Aviation Institute, Warsaw. Text flights, confirming correct flutter properties of sailplane, were made in PZL BIELSKO.

The methods applied in calculation and data processing and the software used are described in (1,2,3,4). The software was prepared in Institute of Fundamental Technological Research, Polish Academy of Sciences. All programs, input/output and computer graphics software were worked out in OBR PZL Mielec. Since 1986, all flutter calculations have been made with IBM compatible personal computers.

The flutter analysis consists of the following steps:

- -preliminary analysis,
- -ground vibration tests of prototype,
- -input data corrections,
- -detailed flutter analysis,
- -flight tests.

Selected important results and the relating design decisions are included in the next sections.

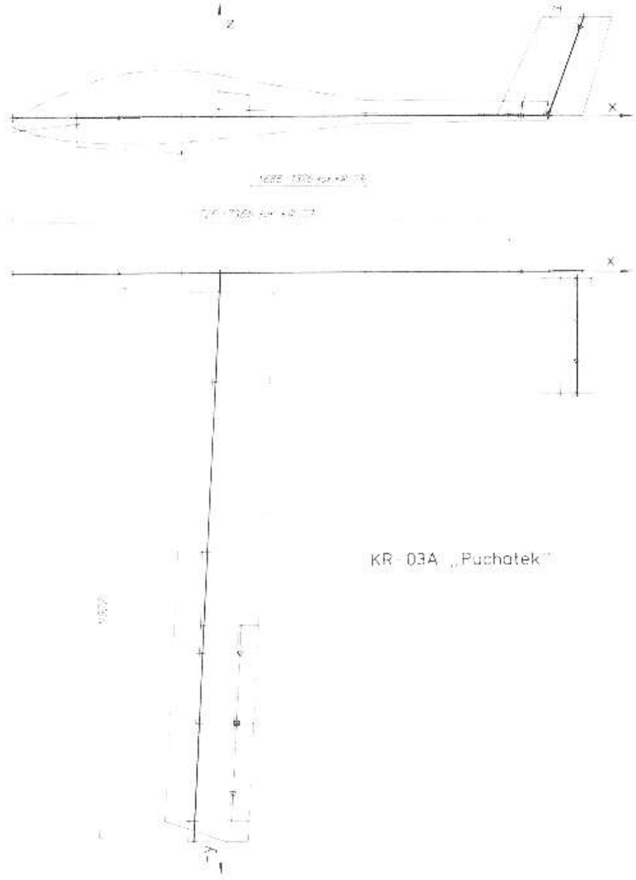

FIGURE 1. Graphic illustration of geometric data.

Preliminary flutter analysis

Flutter analysis began after the design reached the point where it was possible to set up geometric, stiffness and mass data for flutter calculations. A beam model of the sailplane structure was used in vibration computing and for flutter calculations the classic V-g method with non-stationary two-

Beam axes of the stiffness model are marked with thick lines. Equivalent stiffness was calculated assuming, that the sailplane parts are thin-walled prismatic bars. Equipment masses and non-stiffness elements masses were added to masses of stiffness structure. Influence of elevator and aileron control circuits mass and stiffness paramenters on sailplane flutter properties has been investigated. Example results are shown in Figure 2. The calculations give preliminary indication of required ailerons and elevator mass balance (or aft fuselage stiffening). The suitable solution has been introduced to the technical documentation, including also other changes to the structure design, for example lengthened aft fuselage to meet longitudinal stability.

Ground vibration tests

Ground vibration tests were done on the prototype of the sailplane. Vibration frequencies and modes were measured for sailplane operating mass configurations and for some different mass balance of elevator, rudder and ailerons. The tests were made generally for control circuits fixed in the cockpit. Some tests were done for free control circuits and for control surfaces fixed to the main structure. Differences between calculated and measured frequencies, as the result of inaccuracy of preliminary calculations and design changes were confirmed.

Input data corrections

Small input data corrections were done on the basis of measurements of the sailplane mass characteristics. Major changes were introduced in the stiffness data. After detailed analysis of the design documentationa and ground vibration tests, the following corrections were made to the stiffness data:

- -wing torsion stiffness reduction (generally 20% and in airbrake region 40%);
- -fuselage torsion and side bending reduction (20%);
- -flexibility in wing-fuselage connection by antisym metricdeformation;
- -control circuits stiffness changes to compare with

the ground vibration tests frequencies.

The results of normal modes calculation (both preliminary and corrected), compared to ground vibration frequencies, are shown in Table 1.

Example vibration modes are shown in Figure 3.

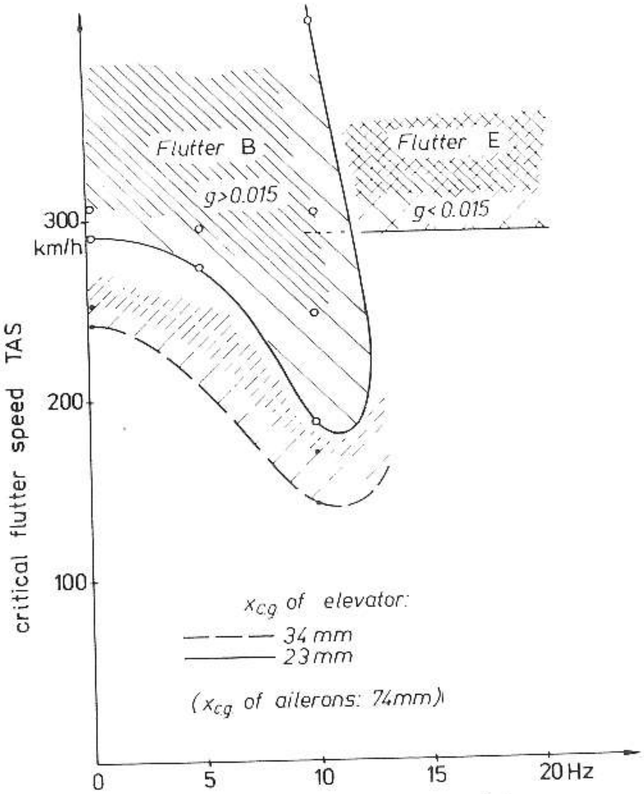

FIGURE 2. Symmetric flutter (influence of elevator mass balance and control circuit stiffness).

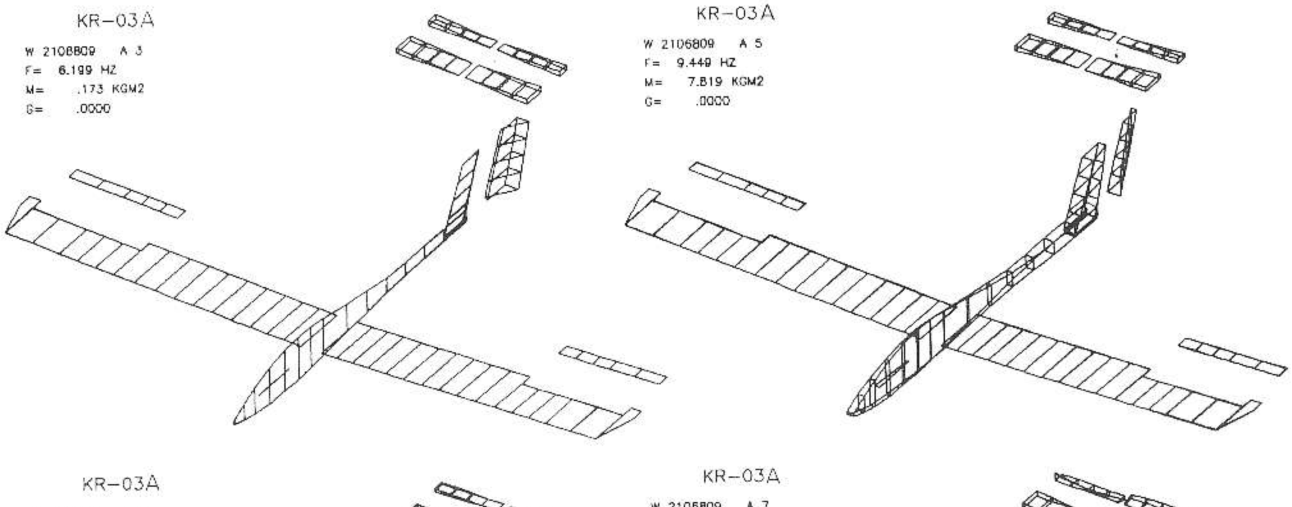

FIGURE 3. Antisymmetric vibration.

Vibration modes description	KR-03	KR-03A (long fuselage)	
	preliminary calculation	vibration test	corrected calculation
SYMMETRIC MODES:			
wing bending (I)	3.46	3.39	3.37
wing bending (horizontal)	-----	7.73	7.69
elevator rotation	0.1......18.4*	11.4	11.4
aileron rotation	13.9.....18.0*	11.8	11.9
fuselage bending	12.6	12.4	12.5
wing bending (II) + aileron rotation	18.6	16.1	16.6
wing torsion + aileron rotation	24.5	19.2	19.3
tail plane bending	33.3	23.2	23.3
wing torsion + aileron rotation (opposite)	27.7	23.8	28.0
aileron bending + torsion	57.0	32.1	28.0
wing bending (III)	48.0	38.3	38.4
ANTISYMMETRIC MODES:			
wing- fuselage yaw	5.8	4.34	4.36
rudder rotation	0.1.......9.8*	5.99	5.97
tail plane bank	9.9	6.14	6.20
aileron rotation	0.2.....20.1*	7.18	7.15
tail plane-fuselage yaw	-----	9.41	9.45
wing bending (I)	11.5	10.4	10.5
fuselage bending and torsion	18.3	15.6	14.7
elevator rotation and torsion	-----	16.4	16.3
wing torsion + aileron rotation	23.8	19.0	18.2
fuselage torsion and bendcing	21.6	20.8	21.7
wing bending and aileron bending and torsion	27.0	26.4	25.2
wing bending (II)	32.6	34.3	31.6
wing bending (horizontal)	-----	34.5	36.9

*parameters in calculation

TABLE1. Vibration frequencies (Hz)

Detailed flutter analysis

The sailplane computing model, obtained after mass and stiffness data corrections, was adequate for the detailed flutter analysis. The flutter mode (sailplane oscillating motion at flutter speed) can be shown on the complex plane. The moduli and vector orientation define the energy participation and the phase-shift of particular vibration modes, respectively, in the resultant sailplane vibrations. Symmetric and antisymmetric flutter modes are shown in Figure 4. Only vibration modes which are important in the flutter case analysed need be selected and used in the calculation. Flutter modes can also be animated on the graphic screen. In Figure 5, the sequence of four views, showing the successive sailplane deformations in the first half of full flutter vibration period, is presented. The specified sailplane calculation model gives the possibility of performing extensive parametric investigations. The KR-03 sailplane designers were interested in reducing the aileron mass balance. Parametric analysis shows it to be possible. Results are presented in Figures 6 and 7. The calculated results were verified by flight tests. No flutter vibrations could be excited in the speed range testes.

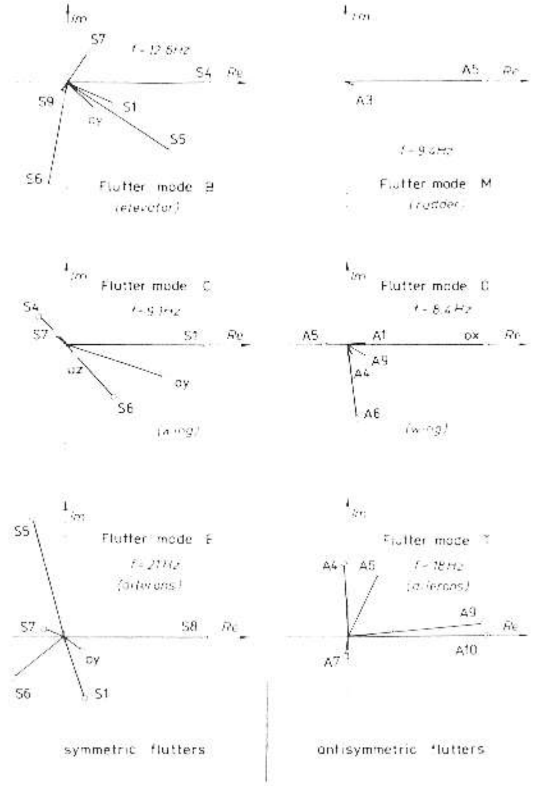

FIGURE 4. Flutter modes.

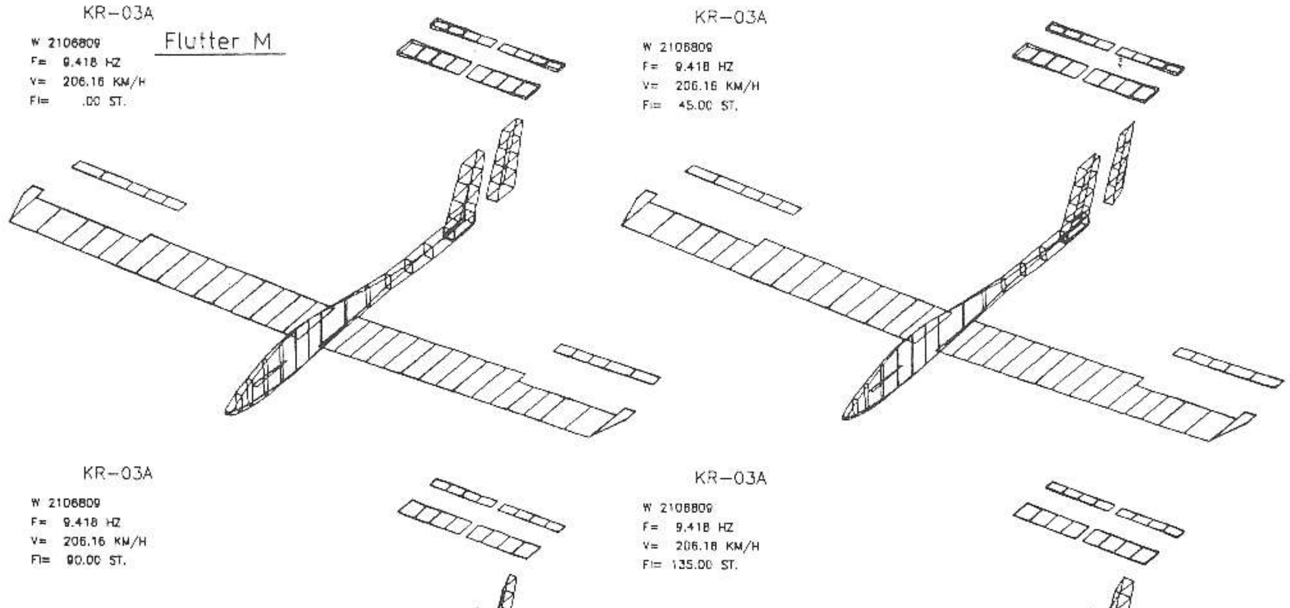

FIGURE 5. Sailplane deformations at the calculated flutter speed.

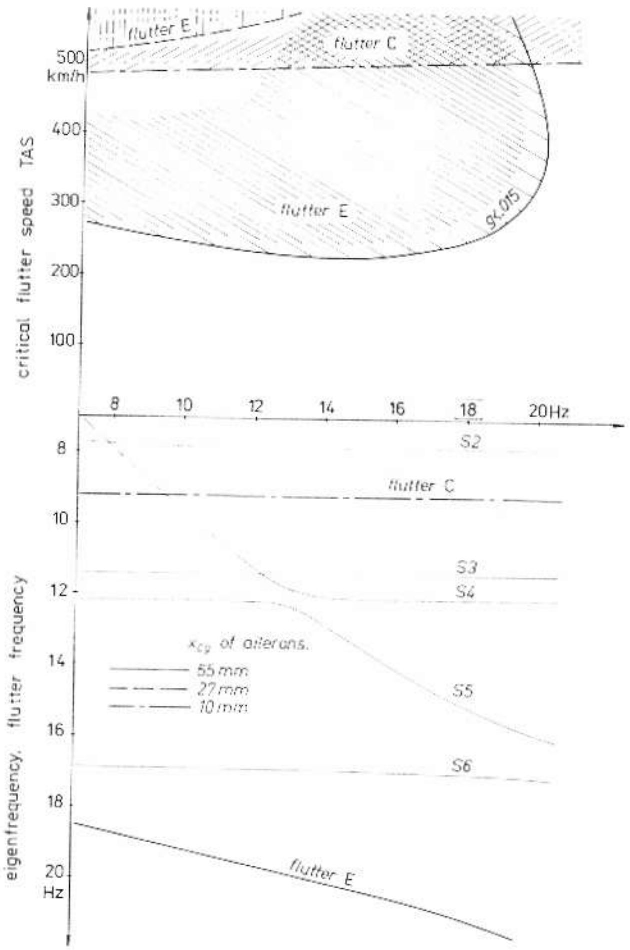

FIGURE 6. Aileron frequency and mass balance influence on symmetric flutter.

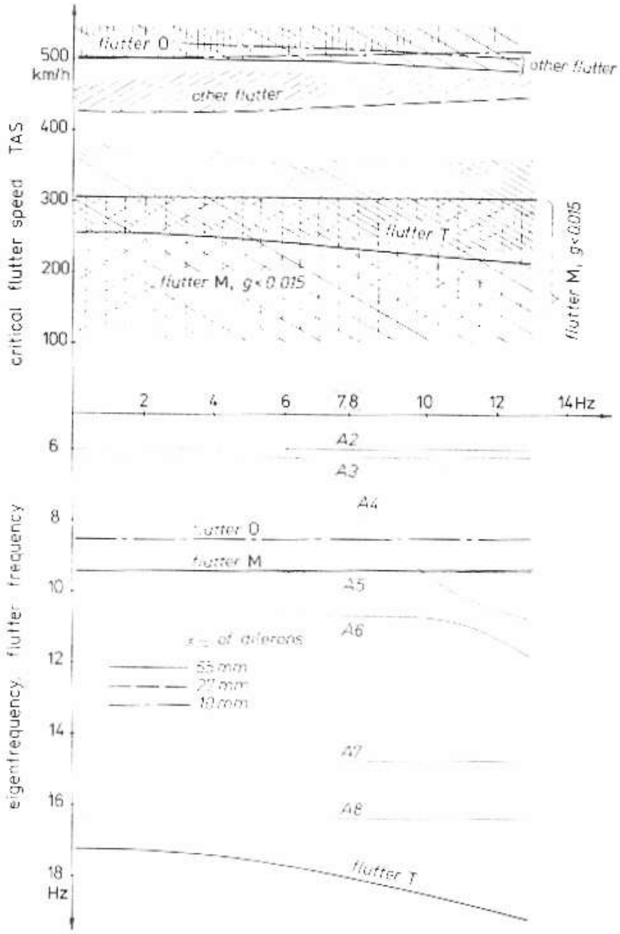

FIGURE 7. Aileron frequency and mass balance influence on antisymmetric flutter.

Conclusions

Practical flutter analysis can be efficiently applied to all stages of the sailplane design process. Preliminary analysis helps to find design solution satisfying flutter requirements. Input data and computing model corrections, after prototype ground tests, permit the effective investigation of design parameter influence upon flutter. Low cost of the analysis can be achieved by using personal computers, suitably selected calculation methods, and user-friendly software.

References

1. Nowak, M.: A New Method of Calculating the Natural Vibrations of a Free Aeroplane. ICAS Paper No.72-05 (1972).
2. Nowak, M., Potkanski, W. : Flutter Analysis of Light Aeroplanes. (in Polish). Prace Instytutu Lotnictwa 62, 3-38 (1976).
3. Potkanski, W. : Flutter Analysis of Light Aircraft. Acta Mechanica 62, 105-112 (1986).
4. Chajec, W., Potkanski, W. : Fluter Analysis of Gliders. OSTIV Publication XVIII (1985).