FLIGHT MEASURED WING LOADING SPECTRUM IN AEROBATICS ON SZD-51-1 "Junior" CLUB-CLASS GLIDER

by Dr. Ing. Wieslaw Staffiej

PZL-Bielsko, Poland

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Summary

The problem of flight tests of wing loading spectrum for gliders is discussed. The method of load recording and of flight data processing are described for aerobatics as a fraction of the operational pattern. The measured load spectra for particular manoeuvres and the method of using them as the input data for the ground fatigue test programme are for a particular example, namely the SZD-51-1 "Junior" club-class glider.

Introduction

The operational loading spectrum for a glider wing consists of a number of loading situations among which aerobatics are important. To determine real loading values a method of in-flight measurement has been developed at the SZD-Factory, Poland.

As a result of flight tests the measured loading data for particular manoeuvres have been gathered and transformed into the numerical values, to plot the spectrum in the form of wing loading factor "n_w" versus number of cycles "H".

Measuring procedure

During manufacturing of the wing the strain gauges have been glued to the spar boom at the root end and connected into the system of an electrical closed bridge. The signals from the strain gauges have been registered on magnetic tape, giving a continuous record as a function of time.

The replay of the record, by means of the computer program, gives the diagram of signal value versus time. To find the correlation between the signal and the load level a calibration was performed during the ground static test of the particular wing being tested in flight.

The wing was loaded with the bending moments corresponding to the selected values of wing loading factor "n_w" taking into account the lift and mass distributions along the semispan. The records of signal for a known bending moment corresponding to the particular load factor "n_w" permit correlation between the signal value and load factor for both positive (up) and negative (down) wing bending. The basic value of $n_w = 1$ was assumed to correspond to the bending moment of wing produced by the lift equal to the glider in-flight weight minus the wing structure weight. For load factors $n_w \neq 1$ the bending moment was taken as directly proportional to "n_w".

The ground calibration of the measuring system was chosen to avoid errors resulting from non-linear electrical signals from the strain gauge, due to the eventual non-linear strains of the spar boom, especially at higher stress levels in glass-epoxy composite material.

To check possible errors in the ground simulation of in-flight loading, the calibration was repeated in flight. On the basis of on-board accelerometer records the glider was pulled to particular load factors and the signal values were compared with those obtained in the ground static test. No significant deviations between the two calibrations were found.

On earlier tests the load factor was measured at the glider c.g. (Ref. 3). This, however, did not describe the wing response on the loading applied.

FIG. 1 Illustration of Load Factor Level

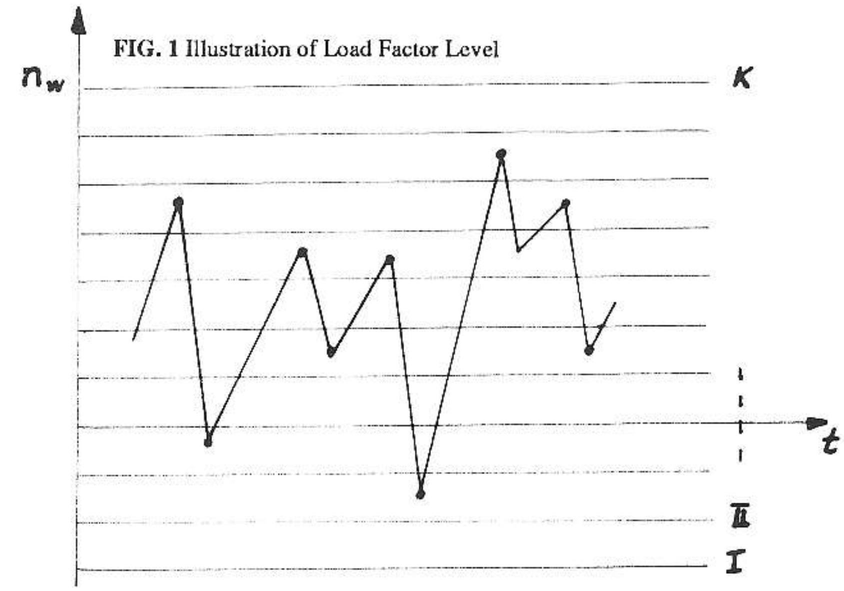
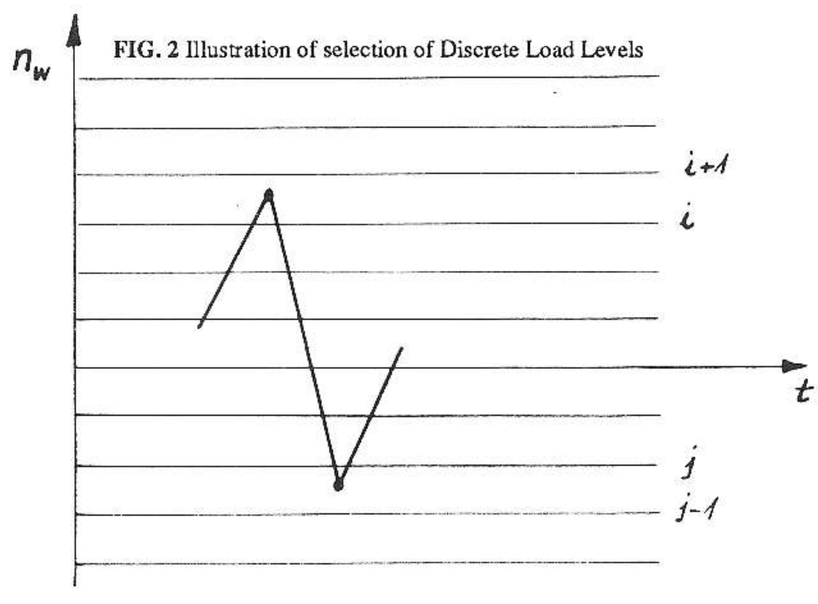


FIG. 2 Illustration of selection of Discrete Load Levels



Record transformation

The peak values of loading factor versus time are of stochastic nature (Ref. 1) and need to be collected in some order (Ref. 2). Therefore, the continuous record was analyzed by means of network of load factor levels: I, II . . . . K (Figure 1) taking discrete intervals of $\Delta n = 0.25$. The peaks between the levels "i" and "i + 1" were counted as the "i + 1" value for maxima, and as "j−1" for minima. (Figure 2).

Flight test programme

The measurements were repeated several times for each of the selected manoeuvres (as listed in table 1) to obtain average loading characteristics. The flight test programme for SZD-51-1 "Junior" club-class glider contained five manoeuvres of basic aerobatics, namely: spinning, loop, stall-turn, spiral and quick half-roll-half-loop, allowed in the flight limitations for the glider certified in "U" category.

Table I

Manoeuvre	Repetitions
spinning	34
loop	25
spiral	28
stall turn	26
quick half-roll-half-loop	31

Table II

Manoeuvre	F_Y Amount per year	F_{LT} Amount per life time of 1000 hours
spinning	225	1125
loop	145	725
spiral	190	950
stall turn	30	150
quick half-roll-half-loop	115	575

The numbers of repetitions were selected on the basis of up-to-date experience in flight tests to gain sufficient data to minimize the error in the determination of average values.

Data processing

For the data processing, a computer programme was developed. The load peaks for all the repetitions of particular manoeuvres were summarized for every load level I, II.......K.

To obtain spectra of a general nature, the number of measured load cycles were normalized (extended) for 100 manoeuvres. For example the value of "H_{100}" for loop (25 repetitions in table I) is obtained by multiplication of all the recorded cycles by 100/25 = 4.

The "100 manoeuvres" spectra are presented on diagrams of $n_w = f(H_{100})$. On Fig. 3 the spectra for stall-turn, spinning, loop and half-roll-half-loop are shown. For all of them the basic load factor is $n_{bas} = 1$. For the spiral (Fig. 4) the basic load factor is $n_{bas} = 1.5$ since the glider is banked (Fig. 5) so that the average bank angle is $\varphi = \arccos(1/n_{bas}) = \arccos(1/1.5) = 48.25°$.

Resultant spectrum in aerobatics

The spectra on Figs. 3 and 4 apply to the particular manoeuvres normalized for 100 repetitions.

The resultant spectrum for the simulation of aerobatics on the ground fatigue test should be based on the operation pattern of the glider (Ref. 4).

The convenient way of programming is to design a basic spectrum for 1000 hours lift time of a glider. For other life times, e.g. 6000 hours, the 1000 hours spectrum cycles should be multiplied by 6.

The average flying hours completed by a glider within one year was assumed to be 200, for which the life time of 1000 hours is reached in 5 years. During training in aerobatics in Poland, the average numbers of each manoeuvres performed on one glider during one year were noted. For 1000 flying hours life time these numbers should be multiplied by 5

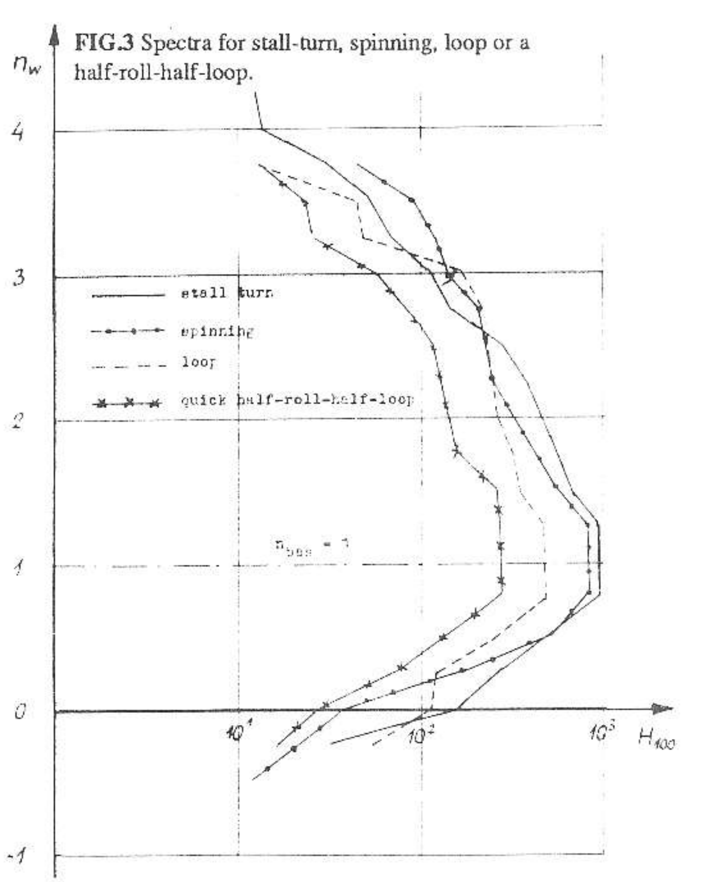


FIG.3 Spectra for stall-turn, spinning, loop or a half-roll-half-loop.

FIG.4 Spectra for spiral manoeuvres.

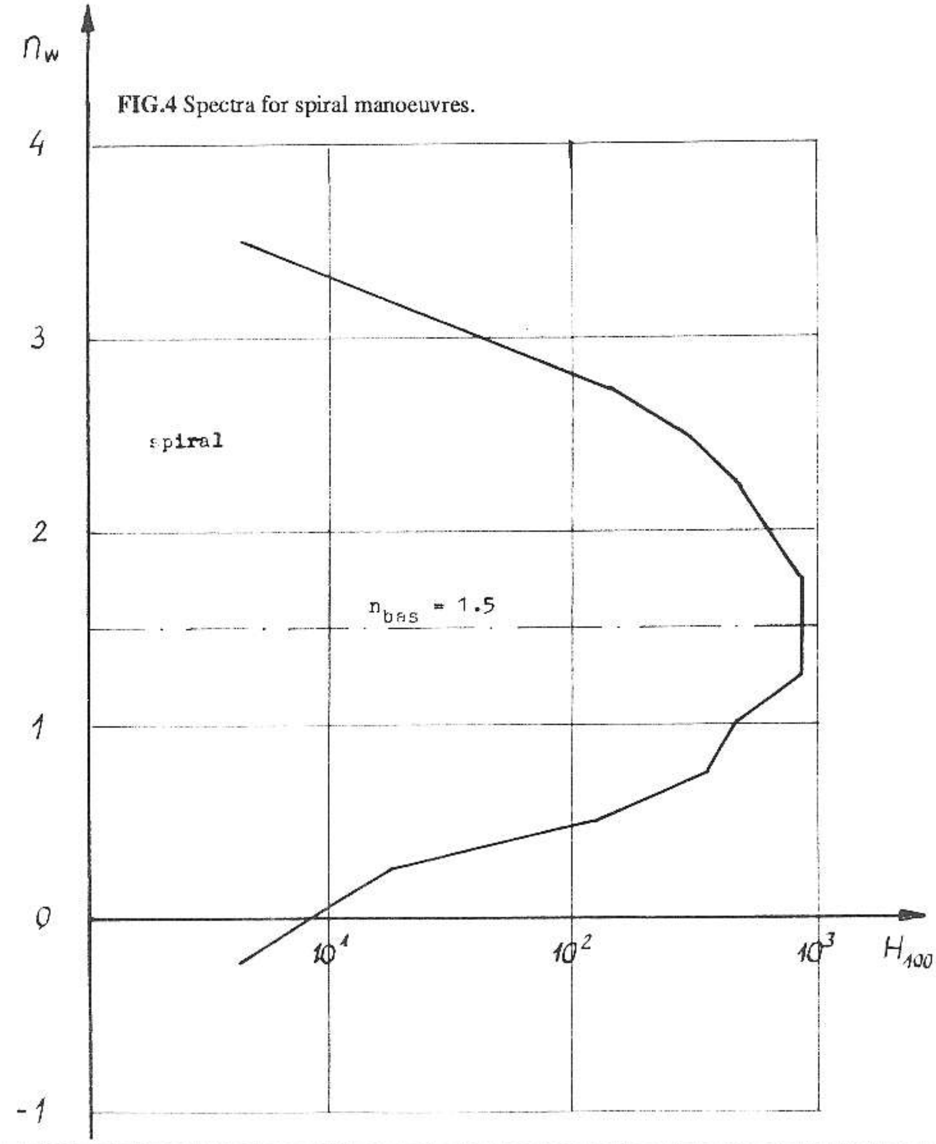
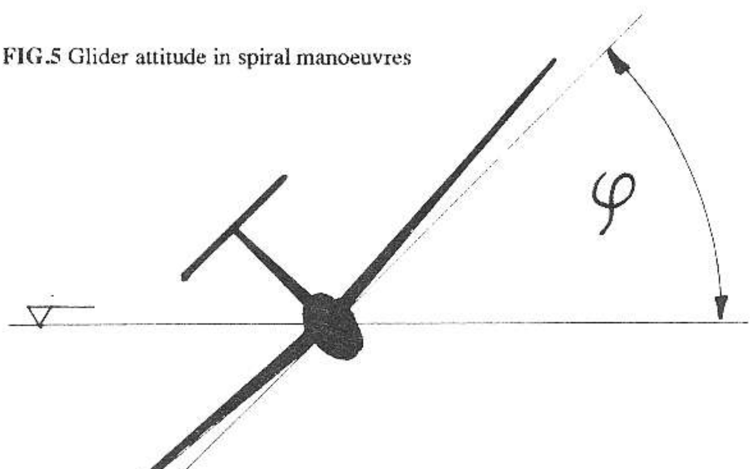


FIG.5 Glider attitude in spiral manoeuvres



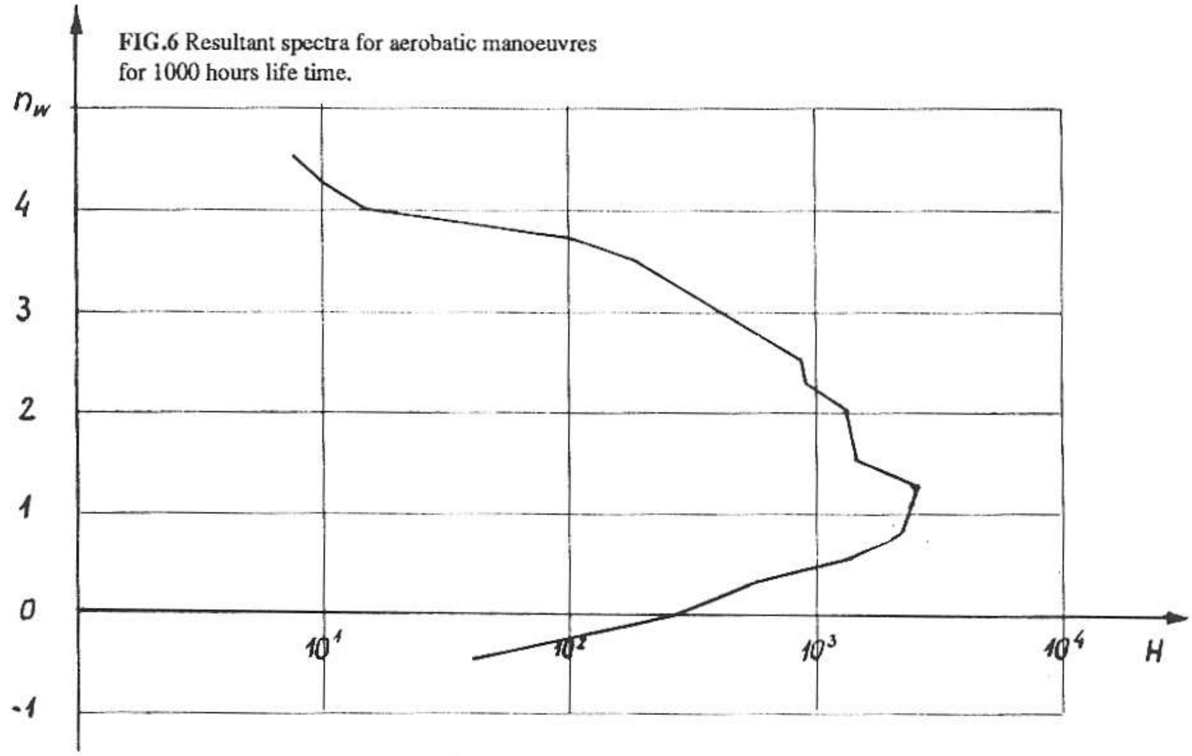


FIG.6 Resultant spectra for aerobatic manoeuvres for 1000 hours life time.

(Table II). The cycles defined for 100 manoeuvres (H_{100}) should be multiplied by the factor: $k_{LT} = F_{LT}/100$ to obtain the total 1000 hours life time cycles for every manoeuvre. (For F_{LT} values see table II.) The sum of: $H_{LT} = k_{LT} \cdot H_{100}$ for all the manoeuvres gives the resultant cycle amount for the 1000 hours spectrum (H).

The resultant spectrum in aerobatics for 1000 hours life time in the form of a diagram of $n_w = f(H)$ is shown on Fig. 6. This spectrum can be used as the input data for designing the ground fatigue test programme.

Conclusions

The allowed life times of composite gliders are established on the basis of ground fatigue test results. The load spectrum patterns measured in flight are the input data for designing the fatigue test programme. To obtain the loading pattern for the overall operation range (aerobatics being only a fraction of it) it is necessary to measure the wing loading in flight.

The measurement programme, initiated in Poland, aimed at determining the loading statistics comprises tests of:

- aerobatics,
- wing launching,
- aerotowed flight,
- free flight in smooth air and gust conditions,
- circling in thermals (clouds included),
- ground run at take-off and landing,
- taxiing on grass-surfaces and runways.

The first step, i.e., aerobatics, has been completed and the results are presented in this paper. It is intended to make corresponding investigations for the other steps, and to present the results in the future papers.

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