PATTERN OF GLIDER OPERATION

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1. Introduction

To establish the life-period of a glass-fibre glider structure within which safe operation can be guaranteed it is necessary either to perform a ground fatigue test or, alternativly, to have the test statistics adequate enough, collected as a result of observations of ships having similar design features. The fatigue tests performed up to now are insufficient to create satisfactory statistics, so the acceptable form of proof of safety depends now on the positive result of a ground fatigue test.

Since the tests are both expensive and prolonged in time the life-period for the whole structure is established on the basis of a test performed on the wing only. This glider component is considered as the representative one in respect of the high level and variety of stresses arising in the structure under complex loading.

To design the fatigue test program it is necessary to collect the following data:
- the value of load factors and variation of their level,
- the frequency of occurrence of particular levels of the load
- the pattern of glider operation in various conditions.

Information on the first two items is contained in technical documentation, test flight data and measurements done in normal club operation. The definition of the operational pattern is a more difficult task and requires the investigation of the following data sources:
- the individual operation documents of gliders used in average conditions,
- the opinions of users, especially pilot's reports on the history of particular competition or training flights, related to the tasks given and meteorological conditions met,
- the opinions of instructors concerning typical schooling flights,
- the intensity of flying during the season,
- the appreciation of technical service quality.

2. Definition of "pattern of glider operation"

The way in which the glider is operated is defined as "pattern of operation". This pattern for high performance sailplanes when compared with school and training gliders or aerobatic ships differs in the characteristics.

The lack of statistics sufficient to allow for designing the average loading spectrum for each of the above glider groups creates the real problem in programming the ground fatigue tests.

The characteristics of an operational pattern comprise the following factors:
- those independent of the operation (design features),
- those depending on the operation (ecology conditions, manner of operation).

Both factors need the discussion.

3. Elements of pattern

3.1 Design features

The load level is influenced by the following factors:
- the mass of the glider (with or without water ballast, with or without additional equipment, mass of the crew members etc.),
- the aerodynamics of the wing (lift and drag coefficients, flap setting, other moveable wing devices),
- the geometry of the wing (span, area, mean standard chord, aileron and airbrake data etc.),
- the aerodynamics and geometry of the tail unit,
- the shape of the load envelope (manoeuvring and gust loadings),
- the flight limitations, as listed in the Flight Manual (permitted airspeeds, manoeuvres, take-off methods, restrictions etc.),
- the data on competition properties (speed polar, circling polar, McCready ring data, interthermal airspeeds etc.).

3.2 Ecology conditions

The ecology conditions in which the glider is operated concern two zones:
- the atmosphere in relation to all flight loadings,
- the take-off and landing surfaces in relation to ground loadings.

The loadings in flight involved by manoeuvres and gusts are defined by the formulas contained in Airworthiness Requirements for sailplanes and therefore do not need to be discussed.

The ground loadings depend on the quality of the ground surface and the shock-absorbing qualities of the undercarriage and of the whole glider structure. The ground reaction acting on the landing wheel introduces the inertia loading on the structure. The load level depends on the condition of the ground surface (smooth runways, rough fields, meadows, accidental stones, grooves etc.). Moreover the prolonged rain period during summer or the frozen ground in winter involve a further variety of loadings on the glider wheel. It is necessary to note that field landing is assumed to be the normal operational case for glider.

The statistics on glider ground run are very poor and related to field landing do not exist, so it is necessary to undertake measurements to obtain satisfactory data collection enabling one to design the load spectrum.

3.3 Way of operation

The general conception of the manner of operation comprises the following:
- the average amount of flying hours completed per year,
- the ratio of aerotowed take-offs to winch launches,
- the mass configuration (water ballast, crew mass etc.),
- the time fractions for the particular flight phases (schooling, training, competition flights etc.).

The correct prediction of the manner of operation is rather a difficult task since the life-periods of gliders range from 15–20 years. Prognosis of the trends in competition flying and training methods needs to be included in the far future. In such a situation the fatigue test programs have to be based on extrapolation of to days experience, but this leads to "prediction" of the glider history that may be too optimistic or too pesimistic.

The specialists responsible for the structural analysis tend to design the test program using rather the higher values of loadings to be sure that the safety level approved as a result of the ground fatigue test is not prejudiced. On the other hand the elevated loadings lead to a reduced life-period of the structure and hence lower market value as well.

Generally the operational characteristics of gliders should be analyzed with respect to two basic groups:
- competition and high-performance sailplanes,
- school and training ships.

4. Operation of competition and high-performance sailplanes

The operation pattern in this group is based on the following observations:
1. Sailplanes of this group are operated mainly in competitions or training tasks both having the characteristics of high performance flying.

2. The loadings met during the flight concern the average meteorological conditions and practical frequency of load occurring.
3. The competition or high performance sailplanes are flown by skilled and well trained pilots, so that controlling errors are minimized. Generally the loadings result from the gusts or from the manoeuvres necessary for tactical reasons (e.g. dolphin style flying).
4. The problem of establishing the ground loading spectrum requires the assumption on the number of take-offs and landings during the whole life-period of the ship. The following observations are helpful:
   a) Nearly all flights of this group of sailplane have the competition characteristics (the task in events as well as the training).
   b) The cross-country flights or the training around the airfield are performed in conditions allowing for a good sporting result. The interthermal airspeeds employed allow for obtaining the average cross-country speeds reaching 100 km/h, so a distance of 100 km is covered within 1 hour.
   c) The competition or training distance vary between 100 and 300 km. The longer ones are less frequent, so the average distance can be assumed as 200 km.
   d) On base of (b) and (c) one take-off should cover about 2 hours of flying. The sailplane, however, also makes many short flights (it is normal practice to repeat the take-off if the conditions are weak or if the pilot could not make contact with thermals). Taking into account also the first flights made on the type of sailplane or some air transportation (aerotowing from the fields' landing site back to the airfield) this time to distance ratio should be reduced. The general observation of club activity shows that the frequency of take-offs is: one take-off for one hour of flying.
5. The take-offs employ aerotowing as well as winch launching. The ratio of both take-off methods is difficult to be sure about. One country employs mainly aerotowing (eastern countries) the second one employs winch launching in most take-offs (western countries). To find the real and average conditions for high performance and competition group of sailplanes it seems to be correct to assume that $k_{at} = 0.6$ of take-offs are aerotowed and $k_{wl} = 0.4$ are winch launched.
6. Modern high performance sailplanes use water ballast to improve the performances. The flights are taken when the thermal intensity is sufficient for "water" flying, so nearly all take-offs are made with water tanks full. In the case of conditions becoming rather weak the water can be jettisoned in flight. In normal operational practice, however, the water is only jettisoned just before landing. Observation of the daily practice of club flying shows that water ballast take-offs concern $k_{wbf} = 0.9$ of flights and water tanks empty flights reach $k_{wbe} = 0.1$.
7. The parametres contained in item (5) and (6) are listed and combined in Table I.

Table I. Mass and take-off configurations as a part of the total glider life.

Mass configuration	Fraction of total glider life	
	winch launching	aerotowing
With water ballast	$k_{ww} = k_{wl} \cdot k_{wbf} = 0{,}4 \cdot 0{,}9 = 0{,}36$	$k_{aw} = k_{at} \cdot k_{wbf} = 0{,}6 \cdot 0{,}9 = 0{,}54$
Without water ballast	$k_{we} = k_{wl} \cdot k_{wbe} = 0{,}4 \cdot 0{,}1 = 0{,}04$	$k_{ae} = k_{at} \cdot k_{wbe} = 0{,}6 \cdot 0{,}1 = 0{,}06$

8. High performance gliders are flown when the thermal conditions are good. So it can be assumed that the thermal flying occupies a total time of $T_{th} = 0.95\ T_o$, where "T_o" denotes the total life-period of the sailplane.
9. The modern flying tactics employed during the competition or record flights comprises also the phase of "dolphin-style". This one is used when the cloud streets permit it.
   To design the average loading spectrum it is necessary to assume values for the fractions of particular phases of flying. The observation of competitions and discussion with top glider pilots resulted in the conclusions contained in Table II.

Table II. Particular flight phases as a part of the total glider life for high performance sailplanes.

Flight phase	Fraction of total glider life
Aerotowing	0,10
Thermalling	0,35
Interthermal flights	0,35
Final glide	0,10
Dolphin style	0,10

5. Operation of school and training ships

The definition of "school and training" gliders concerns the two-seaters used for schooling and basic training as well as single seaters used for gaining the skill and experience by beginners in gliding sport.

This group of gliders is operated in schooling and training tasks. The schooling tasks contain:
- learning of basic pilotage,
- schooling in thermalling,
- schooling in basic aerobatics,
- schooling in instrument flying (in blacked-out cockpit),

To the training tasks belong:
- night flying (if the glider is suitably equipped),
- training in basic performance (flights to obtain silver, gold or diamond badges),
- check flights with an instructor (at the beginning of each season or in other necessary cases),
- individual training in aerobatics.
- cloud flying (if the glider is suitably instrumented).

Fractions of the particular tasks are listed in Table III.

The other characteristics of the ships of this group are based on the following observations.
1. The gliders are flown by pilots of little experience, so the manoeuvring loadings due to the unskilled controlling are the dominating ones.
2. For schooling and training both winch launching and aerotowing are employed. In western countries about 80 per, cent in eastern about 20 per cent of take-offs are winch launched. It can be hoped that in the nearest future the winch becomes the dominating form of take-off, due to the energy crisis. In all countries winch launching is cheaper than aerotowing.
3. The school and training flights, when compared with the competition flights, are considerably shorter. The flight, when aerotowed, lasts about 20 minutes giving the frequency of 3 flights per hour. The winch launched flight (e.g.

Table III. Particular flight phases as a part of the total glider life for school and training ships.

Flight phase	Fraction of total glider life	Time of one flight (hours)
Learning of basic pilotage	0,300	0,250
Learning of thermalling	0,150	1,000
Learning of aerobatics	0,150	0,333
Learning of instrument flying	0,050	0,417
Check flights with instructor	0,100	0,250
Night flying	0,025	0,250
Cloud flying	0,025	0,500
Training in aerobatics	0,010	0,250
Training in basic performance flights	0,190	1,000

in basic pilotage schooling) requires about 5 minutes. Then the frequency is 12 flights per hour.

4. Maximum allowable cockpit mass for a two-seater is 180 kgs, but an average load is from 140 to 160 kgs.
5. Ground loadings of school and training ships occupy a considerable part of the loading spectrum. The shape of the spectrum of the ground run depends on the airfield surface conditions, shock absorbing features of the undercarriage and on the ground run distance. It is necessary to note that the ground runs for winch launching and aerotowing are of different length and this aspect should be taken into account.
6. In considering the ground loading spectrum taxying the glider by means of motor-car, tractor or by hand, should be investigated. These loadings may have an influence on the total fatigue life, especially when the airfields are long or when the start point is far from the hangar.
7. It is also necessary to consider the loading arising during the road transportation of the disassembled glider in its trailer. The value of this loading depends on the type of trailer, towing motor-car speed, condition of road, and method of securing the glider components on the trailer etc.

6. Conclusions

In this paper the attempt to define the "operational pattern" has been made a knowledge of this is necessary when the designer starts to prepare the fatigue test program. Even when he has the measured loading spectra for the particular phases of operation, the problem of participation of these phases in the total life spectrum needs to be solved.

In respect to the vast variation in glider operation, having regard to the local ecology, meteorology and economy conditions, a generalized "pattern of glider operation" is difficult to establish.

Those aspects discussed in this paper allow approximate determination of the ideal pattern, as far as the operational conditions can be predicted for the future on the basis of the tasks for which the particular glider is designed.