FATIGUE LIFE CONSIDERATIONS FOR GLIDERS OPERATED IN AUSTRALIA

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INTRODUCTION

The fatigue life of gliders has not been a concern of operators until recent times, mainly because the majority of them were constructed with a basic structure of wood, and both experience and calculation[1] have shown that the fatigue life exceeds any likely period of intensive use.

Metal gliders made from aluminum alloys like powered aircraft do have a finite life[2,3] and in some instances this has proven to be quite short[4]. The recent promulgation of a 3750 hour life limitation by the Czech Authorities for the L-13 Blanik glider[5] had the effect of grounding 8 gliders from the Australian fleet total of 100 Blanik gliders.

Composite structure gliders could also have a finite life; however, the earlier designs using glass and epoxy resin usually had low working stress levels after meeting stiffness requirements, and hence the problem may be alleviated to some extent.

Neither the OSTIV[6] or any other glider design requirements specify either fatigue substantiation tests or supporting fatigue life calculations. However, Germany has a minimum fatigue standard for fiberglass components.[7,8]

The safe or economic fatigue life of gliders is of particular concern to Australian gliding clubs and commercial operators because the very favorable flying conditions enable them to achieve annual usage rates far in excess of their northern hemisphere counterparts.

SERVICE USE IN AUSTRALIA

An examination of the statistics on the flying done by Australian clubs shows a steady increase in the average number of hours flown each year, Fig. 1. (Note: Statistics are published annually by the Gliding Federation of Australia (G.F.A.) in the June issue of Australian Gliding). The reduction in the launch rate since the late 1960's can be attributed both to the introduction of aerotowing, which is the only method acceptable to the Department of Transport on Government and licensed airfields, and also because of the increase in performance capability of active gliders. Of the 709 gliders on the Australian Register (1978) which are currently airworthy and in service, 325 are constructed of glass reinforced plastic (G.R.P.), 221 from timber and 163 from metal.

The majority of gliders being imported into Australia are of G.R.P. construction and these represent by far the most popular type of construction for fleet replacement. The growth of Australian gliding for clubs and gliders during the past 20 years is depicted in Figure 2. The 1977 total of 780 gliders includes all gliders that have been entered on the Register, including those not necessarily actively in use, i.e., not holding current certificate of airworthiness. However, the statistical base on which reliable data was available for analysis (1977 year) was only 538 gliders. The data base termed "Statistical Population" for all years covered in the analysis is shown in Fig. 2.

Clubs which have full time operators, i.e., gliding 7 days per week, have achieved a significant increase in glider utilization which is not apparent from Figure 1. Data on operations for the more active weekend clubs and the full time operations are given in Tables 1 and 2. A comparison of the annual utilization rates given in Table 1,with the national fleet average given in Figure 1,indicates that the average active weekend club glider flies approximately 50% more hours annually and achieves approximately 30% more launches than the national average. For the past 3 years each 'active' weekend club glider has flown on average approximately 300 hours annually and achieved approximately 600 launches per year.

There is a much greater increase,of course, in the case of the full time operators who achieve a utilization of about twice the national average. Data for full time operations during 1977 are given in Table 3. The greatest usage achieved, by one of the training gliders in the most active club, of 8 times the national average hours and launches, is shown together with data for 4 other training gliders in Table 4.

SERVICE HISTORY

In order to be able to produce the best estimate of fatigue life it is necessary to adopt an approach which would require the collection of data for glider operations on a number of items such as:

1. Method of launch - winch or aerotow
2. Duration of flight
3. All-up weight versus time
4. Period of aerobatic flight
5. Period of cross country flight
6. Period of training flight
7. Period of local soaring
8. Period of wave flying
9. Temperature versus time for the glider flight
10. Period of exposure to ultra violet light
11. Normal acceleration, i.e., load factor counts

The gathering of such data would be difficult, to say the least, in a gliding club situation. However, the flight logs give good data for the first 3 items. The installment of a counting accelerometer has proven quite practicable for routine recording of flight loads spectra for gliders.[9,10]

Some work has already been done in Australia in this regard. An indication of gust loading at altitudes up to 2000 ft. AGL can be obtained from the Fatique Meter counts observed in a Piper PA18 Super Cub tow plane[11] shown in Figure 3. Also shown for comparison is the data from Reference 9 together with 114 hours of Australian data for a Blanik glider.

FATIGUE LIFE ESTIMATION

Currently available methods of fatigue life calculation only enable the estimate of lives for conventional aluminum alloy structures; furthermore, the accuracy of the estimates is dependent upon the relevance of the available data.

A considerable amount of fatigue data has been collected and embodied in the ESDU Data Sheets.[12] The most reliable method for identifying the fatigue critical regions is to conduct a full scale test applying fatigue loadings closely representing those experienced in service. In the absence of a test it is necessary to make a detailed stress analysis of the structure and,if possible, confirm this with inflight strain measurements.

There are a number of approaches available to the fatigue life estimator,of which the most commonly used as a basis for the calculations are:

1. Evaluate a nominal stress for the fatigue critical area and use fatigue data for complete structures.
2. Obtain a local critical area stress and stress concentration factor and use notched material fatigue data.
3. Assume that the fatigue critical areas are represented by the Heywood joint data contained in the ESDU sheets and use this data together with a nominal critical area stress.

Australian experience has shown that a conservative estimate of fatigue life may be made for conventional aluminium alloy structures utilizing a service loading history of Fatigue Meter readings coupled with the Heywood Curve 'A', and the cumulative damage hypothesis HI (peak count method) proposed by the Aeronautical Research Laboratories.[13]

The above calculations produce an estimate of the life to failure (collapse of the structure), and a scatter factor must be applied in order to arrive at a safe service life in the case of non-redundant structures.

The Department of Transport[14] has found by experience a number of scatter factors that are applicable to conventional aluminium alloy structures, ranging from 5 for lives determined by calculation using conservative data, down to 3 when the results from a number of spectrum load tests on full scale specimens, based on data of high confidence, are available.

Using the H1 fatigue damage hypothesis, coupled with the measured Australian load history for the Blanik glider (Fig. 3) and the Heywood Curve 'A', the relationship between 1-g nominal stress and safe life (scatter factor of 5) has been calculated for a typical aluminium alloy wing structure and is shown in Figure 4.

The figure shows the effect of the G-A-G cycle of 4 landings/hour for a 15 minute average flight time and 2 landings/hour for a 30 minute average flight time. Also shown for comparison is the result of using the OSTIV load spectrum given in Figure 3 for a 15 minute average flight time.

The long fatigue life of wooden glider structures mentioned earlier has been proven in practice, and the safe service life is dependent upon the durability of the glue used for bonding and the fatigue life of the metal fittings. The stress levels in the fittings are not high and coupled with the relatively low strength steel used in their manufacture result in a slow rate of crack propogation and long critical crack length. In addition, most fittings are easily inspected enabling non-destructive inspection techniques to be applied at the annual or major inspections. The G.F.A. requires all fittings to be removed for complete inspection every 20 years if this can be achieved without damaging the basic structure.

In the case of composite structures, data needs to be gathered which will enable fatigue life predictions to be made similar to those for metal structures. A number of manufacturers are known to have conducted fatigue tests on G.R.P. wing structures[15,16] and this data, when available, in conjunction with other data from laboratory type specimens, could be used for service life predictions.

The G.R.P. structures tested have shown that under the loading spectra investigated the life to failure for these structures will be in excess of 9000 hours. However, these tests did not simulate exposure to ultra-violet light which is expected to have a degrading effect. The resulting safe life is determined on the basis of the scatter factor applied which, owing to the above effects, may be greater than the German recommended scatter factor of 3.0.

PREDICTIONS OF SERVICE LIFE IN AUSTRALIA

From the usage data contained in the tables and figures, it can be deduced that by assuming a safe flying life of 3000 hours or 15,000 launches the Australian gliding clubs of 20 years ago could have expected their metal gliders to remain in use for periods ranging from 30 to 60 years. Ten years ago, due to increased utilization, this would have reduced to 20 to 30 years. In 1978 this is back to about 15 years which is still a reasonable length of time. Fortunately, the introduction of aero tow launching coupled with the increased flying performance has reduced the number of flights made each year, thus reducing the number of G-A-G cycles.

However, in the case of the more active clubs and full time operators there is a very severe limitation of service life based on an hourly basis, ranging from 6 years for the average down to less than 3 years for those with the highest utilization. These short lives are the result of very good flying conditions in Australia which enable some sites to achieve 360 flying days for the year, with the inland soaring centres reaching average flight times of almost an hour.

A further factor which may reduce the life of Australian glass fibre or carbon fibre reinforced plastic gliders, is the increased exposure to ultra-violet light. Although it has been standard practice to place gliders in hangars or trailers at the end of each day of flying, because of mild weather conditions many owners are merely tieing down in the glider parking area.

The above practice also allows other degrading factors to become effective, such as corrosion and water damage. Many operators do not appreciate that the resins used are hygroscopic, and as much care must be taken with a modern fibreglass sailplane as with the 20 year old wooden glider.

DISCUSSION

Many fleets of civil and military aircraft are required to be flown to the full extent of their economic fatigue life. To achieve this life the flight load history of each and every aircraft must be measured using fatigue meters, multi-channel recorders, and logging of significant parameters.

Since gliding is a sporting activity such procedures would not be feasible for club gliders, and hence data must be gathered on typical operations to arrive at an average load history which can then be used to determine safe flying life or inspection intervals.

Fatigue meters have now been installed in 2 Blanik L-13's and one IS28B in order to gather such data, and by reference to the flight log sheet information will be available on the percentage of solo to dual flights which are a measure of weight or stress.

In the case of solo gliders capable of carrying water ballast the situation is more complex, and operators should seriously consider keeping a record of the number of flights for which the water tanks were filled before take-off.

For full time operators there are various courses of action open to them including:

1. Rapid changeover of gliders, i.e., sell gliders to clubs with a low annual utilization after a year or so.
2. Base charges on the shorter (calendar) operating life.
3. Monitor and record those parameters affecting fatigue life, i.e., install fatigue meters in each glider and record take-off weight and purpose of flight in addition to the duration and number of flights.

CONCLUSION

The high utilization of gliders in Australia, compared with that in other countries, when coupled with safe fatigue lives of about 3000 hours results in glider replacement times of less than 3 years for many operators.

REFERENCES

[1] Obee, K.R., "The Fatigue Life of Wooden Gliders," 9th OSTIV Congress, Argentina 1963, *OSTIV Publication VII.*

[2] Patching, C.A., "Establishing the Structural Integrity of Aging Gliders," 12th OSTIV Congress, Texas 1970, *Technical Soaring*, Vol. 2, October 1971.

[3] Patching, C.A., "Fatigue and the Life of a Glider," *Australian Gliding*, June 1977.

[4] Gedeon, J. & Kalman, G., "Service Life Extension Possibilities by Fatigue Tests on Used Sailplanes," *Technical Soaring,* Vol. IV, No. 4, November 1977.

[5] Mandatory Bulletin No. L13/045, Omnipol, Prague, Czechoslavakia, July 1977.

[6] OSTIV Airworthiness Requirements for Sailplanes, September 1976.

[7] Standard for Structural Substantiation of Sailplane Parts Consisting of Glass Fibre Reinforced Plastics. *Luftfahrt-Bundesamt Abteilung Technik,* 1/30 March 1965.

[8] Airworthiness Requirements for Sailplanes and Powered Sailplanes (LFSM), *Luftfahrt-Bundesamt,* Germany, May 1946.

[9] Chernov, V.V., "Results of Research in the Field of Structural Strength Limits for Sporting Gliders," 10th OSTIV Congress, England 1965, *OSTIV Publication VIII.*

[10] Stafiej, W., "Flight Measured Load Factors," 13th OSTIV Congress, Yugoslavia 1972, *OSTIV Publication XII.*

[11] Aeronautical Fatigue, Review of Civil Aviation Activities, April 1973 to March 1975, *Aeronautical Engineering Report SM-75,* Department of Transport, Melborne, March 1975.

[12] Engineering Sciences Data, Fatigue Sub-Series, ESDU London.

[13] Payne, A.O., "Determination of the Fatigue Resistance of Aircraft Wings by Full Scale Testing," *Full Scale Testing of Aircraft Structures*, Pergamon Press, London 1960.

[14] O'Brien, K., Torkington, C., Benoy, M. & Douglas, R., "Fatigue Certification of General Aviation Aircraft in Australia," *S.A.E. Paper No. 720311,* National Business Aircraft Meeting, Wichita, March 1972.

[15] Franzmeyer, F.K., "Structural Testing of Glass Fibre Sailplane Wings," *Sailplane and Gliding,* Vol. XXI, No. 1, 1970.

[16] Stafiej, W., "Fatigue Test Program for the Wing of the Jantar SZD 37 Sailplane," *Technika Lotnicza i Aestronautyczna,* Vol. 27, July 1973.
Abstract (English) published in *International Aerospace Abstracts,* American Institute of Aeronautics and Astronautics Inc., New York, Ref. A73.39245.

TABLE 1. FLYING FOR 'ACTIVE' WEEK-END CLUBS

Year	No. Clubs		No. Gliders	Hours	Launches	Annual Rate		
	Total	'Active'				Hours/ Glider	Launches/ Glider	Mins./ Launch
1970	73	6	27	7863	16585	291	614	28
1971	77	7	32	9797	21338	306	667	27
1972*	81	11	82	17034	30900	207	377	32
1973*	84	10	75	14717	24848	196	331	35
1974	89	4	21	5549	10691	264	509	31
1975	92	9	40	11569	22146	289	553	31
1976	94	8	40	12426	21132	310	528	35
1977	99	8	38	10767	26005	283	684	25

* Includes private owner flying.

'Active': Flying more than 1000 hours per year.

TABLE 2. FLYING FOR FULL TIME COMMERCIAL AND CLUB OPERATIONS

Year	No. Ops.	No. Gliders	Hours	Launches	Annual Rate		
					Hours/ Glider	Launches/ Glider	Mins./ Launch
1970	4	33	11479	26782	348	811	25
1971	4	35	14176	31734	405	907	27
1972*	3	32	15226	35861	476	1120	25
1973	5	44	20213	45517	459	1034	27
1974	5	50	19787	46549	396	931	25
1975*	3	33	16085	39577	487	1199	24
1976	5	55	28195	72353	513	1315	23
1977	6	77	36851	72011	478	935	31

* No data available from one operation.

TABLE 3. FLYING FOR FULL TIME OPERATIONS

Operation	Gliders	Hours	Launches	Hours/ Glider	Launches/ Glider	Mins./ Launch
Narromine *	13	7088	9044	545	599	54
G.C.V.	16	7584	16877	474	1054	27
Southern X	14	6600	17682	471	1263	22
Adelaide S.C.	8	4914	12624	514	1578	19
Waikerie	10	4905	8264	490	826	35
South. Riv.	16	5860	8470	366	529	41
Total	77	36851	72011	-	-	-
Average	-	6142	12000	478	935	31

* Includes private owner flying.

Narromine	-	Narromine Soaring Centre, N.S.W.
G.C.V.	-	Gliding Club of Victoria, Benalla, Vic.
Southern X	-	Southern Cross Gliding Club, Camden, N.S.W.
Adelaide S.C.	-	Adelaide Soaring Club, Gawler, S.A.
Waikerie	-	Waikerie Gliding Club, S.A.
South. Riv.	-	Southern Riverina/Sportavia, Tocumwal, N.S.W.

TABLE 4. DUAL SEATER (IS28B) OPERATIONS DURING 1977 (G.C.V.)

Glider	Total		Mins/Launch
	Hours	Launches	
VH-GVV	867	2525	21
-GVW	868	2233	23
-GVX	879	2413	22
-GUY	1142	3223	21
-GVZ	1130	3294	21

Annual Average - Hours/Glider - 977 Hours
Launches/Glider - 2737 Launches

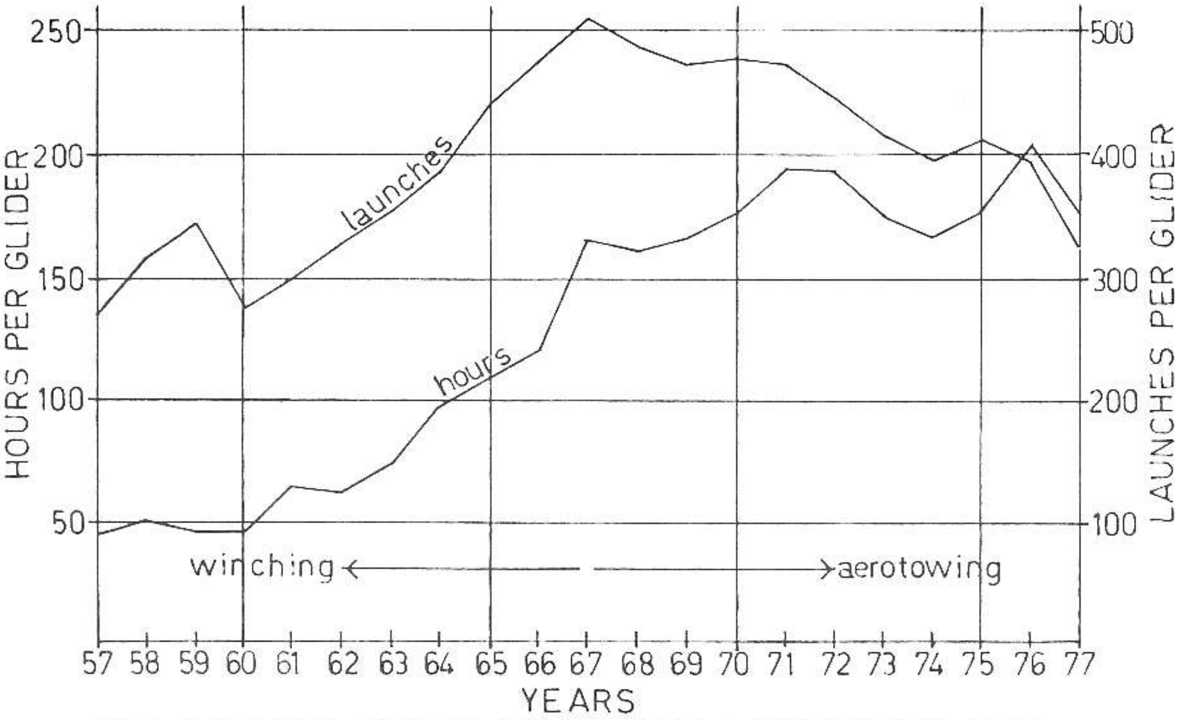

FIG.1 AVERAGE ANNUAL HOURS AND LAUNCHES FLOWN

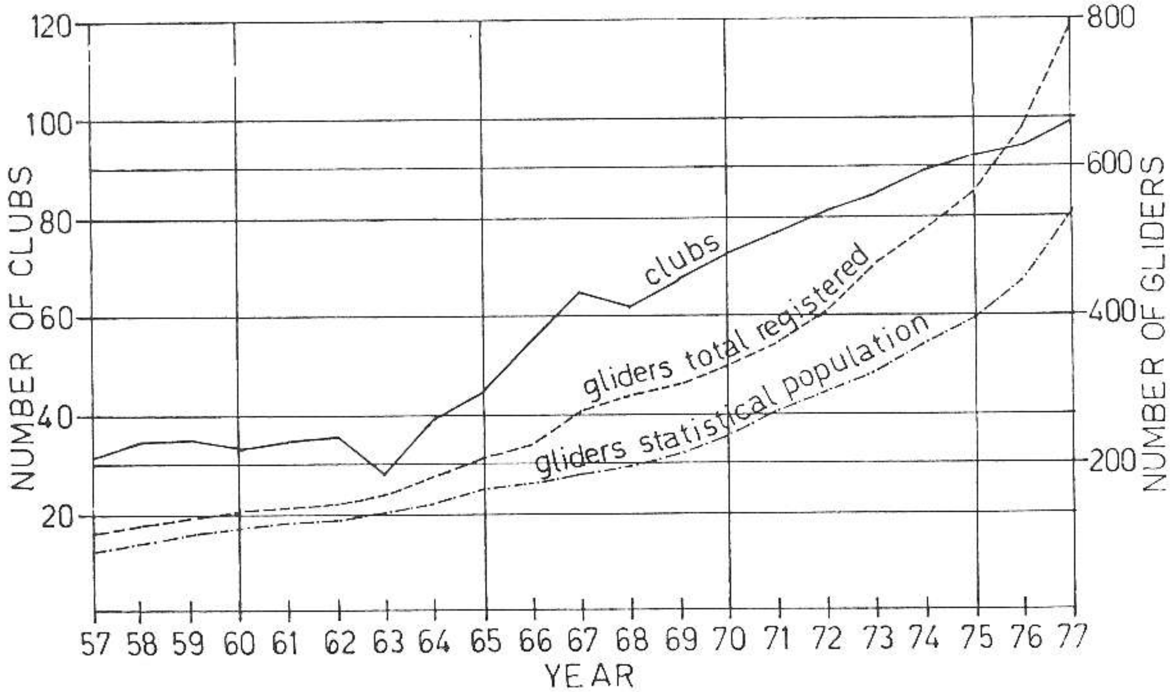

FIG.2 20 YEAR GROWTH OF CLUBS AND GLIDERS IN AUSTRALIA

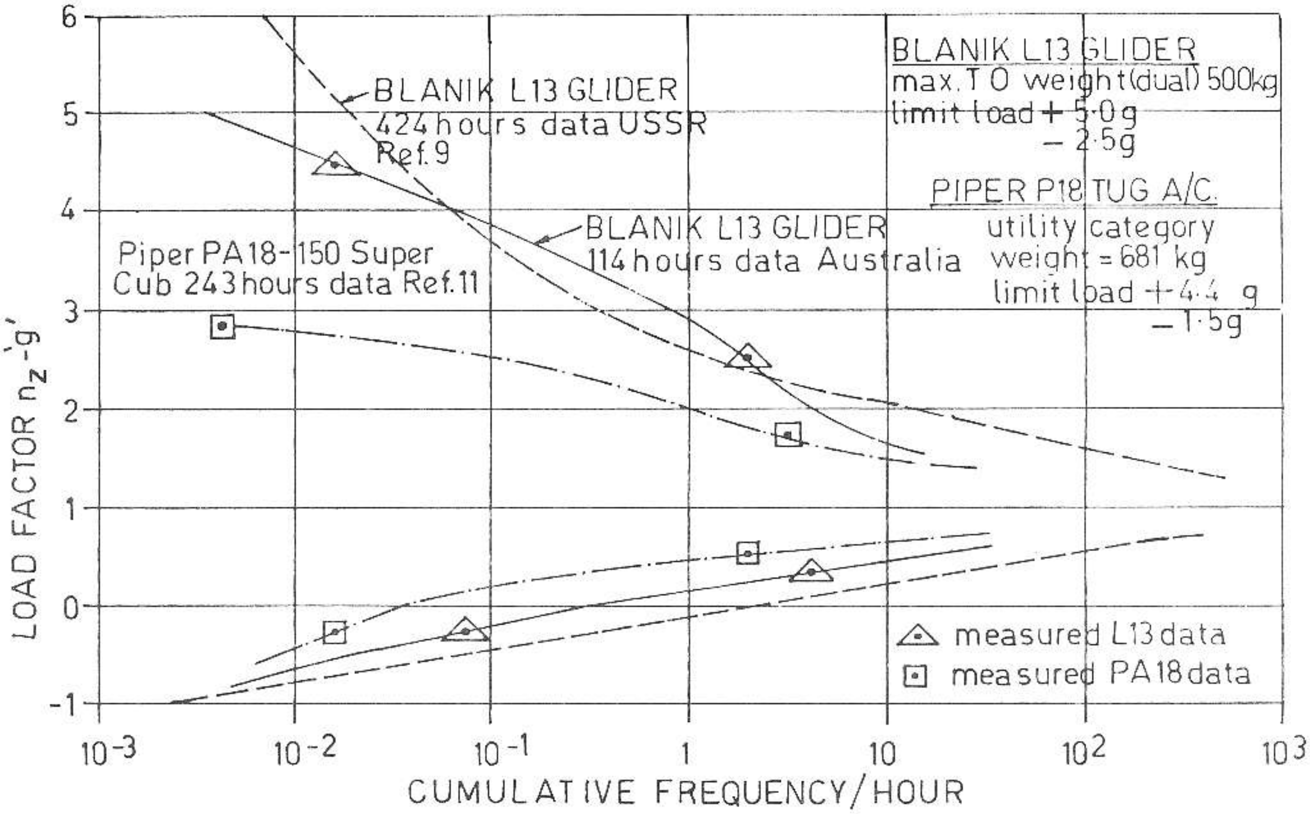

FIG.3 FLIGHT LOAD SPECTRA FOR GLIDER AND TUG

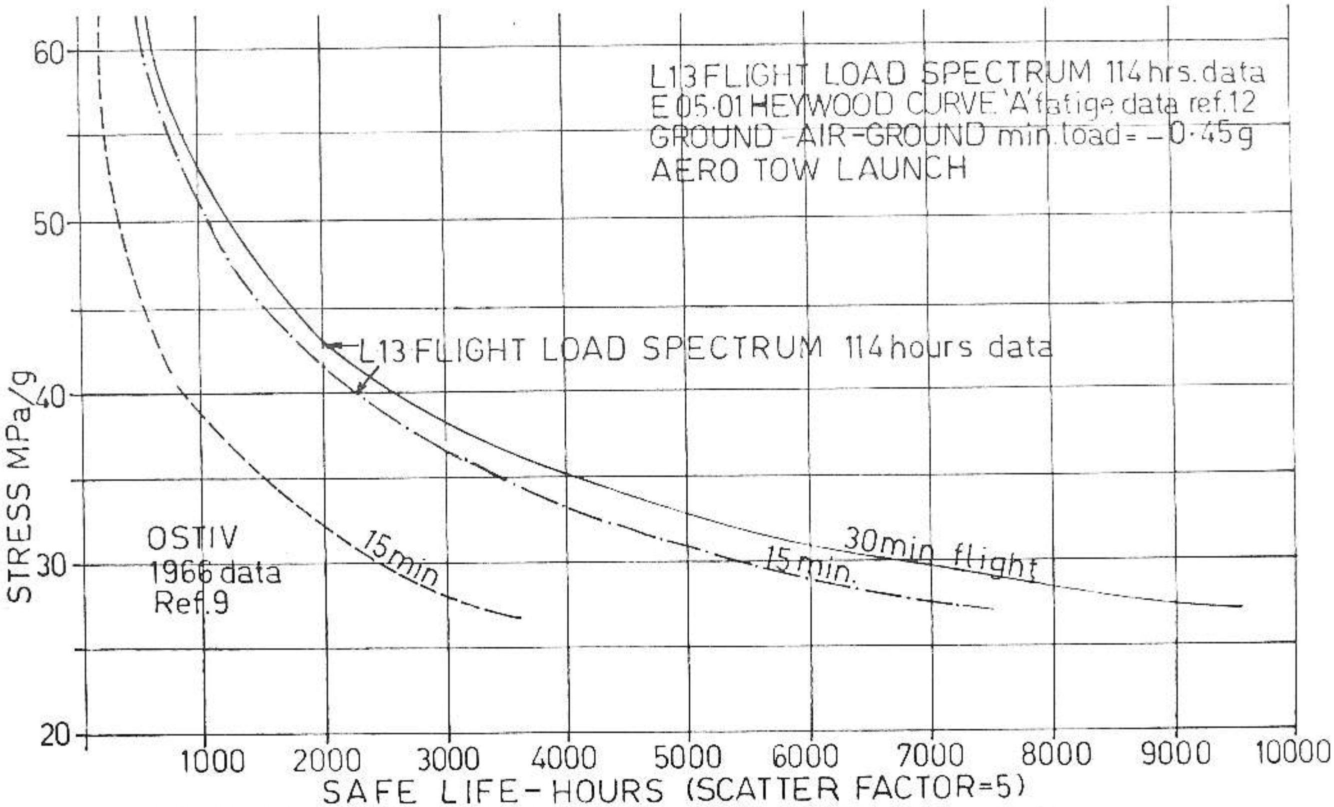

FIG.4 SAFE FATIGUE LIFE ALUMINIUM ALLOY WING