REVISED OSTIV GROUND LOADS STANDARDS

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Introduction

Concern has been expressed regarding the adequacy of the shock-absorption and emergency-landing standards to which sailplanes are designed.

Analysis of sailplane accidents in Germany carried out by TUV Rheinland for the periods 1983-1986 and 1987-1989 [1] showed that 6% of the accidents were fatal and 15% involved serious injury. Of those for which the reports contained more detailed information, spinal injuries were mentioned in about 50% and may have occurred in more.

Drop tests of specimens of cockpits of typical and reinforced construction, suitably instrumented and containing instrumented dummies, made at FHS Aachen [2], showed that it can be advantageous to make the foremost part of the cockpit of lower stiffness than the main part - it then acts as a crumple zone and absorbs some of the energy of the crash.

Waibel [3] referred, inter alia, to the sudden large increase in load that occurs if the landing gear bottoms, which it will do at a slightly increased rate of descent if it only just meets the specified standard of 1.5 m/sec.

In view of the above, the Sailplane Development Panel (S.D.P) has for some years made an intensive study of both emergency (crash) conditions and shock-absorption in normal landings. Also the OSTIV standards [4] were incomplete as no nose-wheel or tail-skid-impact cases were included. It was therefore decided to review the ground loads standards in their entirety.

This paper describes briefly the changes now made, the reasons for them, and some historical details.

Shock Absorption

In the original standard (1962) the rate of descent in the level landing condition was 1.0 m/sec; in 1966 a reccomendation for 1.4 m/sec was added, and in 1971 the standard was made 1.5 m/sec, at which value it has remained until this year. Throughout, the standard has been that in an airborne landing (wing lift balancing the weight) at Design Maximum Mass the acceleration at the centre of mass must not exceed 4g and the shock-absorbing elements must not be fully compressed.

No condition for which the full compression may be reached, in other words no reserve energy absorption capacity, was specified, as it is in aeroplane standards (FAR, JAR).

Also, curiously, it is not made clear whether the 4g value relates to the landing gear load or to the total acceleration on the usual scale on which level flight is

1.0, as used for manoeuvres and gusts. Both British [5] and Polish [6] standards, two of the base documents from which the OSTIV standards were derived, were written in terms of the landing gear load (at 3g and 4g respectively). It was formerly assumed that OSTIVAS was to be interpreted similarly. However Waibel [3] and Neumann [7] take the other view, that 4g should mean total, that is 1g from the wing lift and 3g from the landing gear reaction. The relation can be conveniently expressed:

$n = 1 + \Delta n$, where

n = total load factor including the wing lift contribution

Δn = load factor contribution due to the landing gear load.

The S.D.P. believes the latter interpretation to be correct, and that the standard should be suitably reworded.

Incidentally, both the above points apply also to JAR 22 [11].

The standard has now been amended in four respects. First some reserve energy absorption capacity is prescribed, by specifying a slightly increased rate of descent for full compression, so that the sudden increase in vertical load at full stroke cccurs not in a "standard" heavy landing but only in an extra heavy, but non-crash, landing; the chosen increase in rate of descent is 10%. Also, for this condition, it is accepted that the landing gear may yield though it must not fail; in this respect the new standard follows [5] and light aircraft standards [8]. Methods by which suitably controlled collapse may be achieved are described in [3].

Secondly, some degree of mass variation is now taken into account. In the past, the emphasis has been on structural safety rather than crew comfort, and designing for maximum mass was considered sufficient. It is accepted that with a given landing gear a light pilot gets a harder ride than a heavy one. However, the advent of jettisonable ballast rather changed things; it cannot be entirely accidental that the worsening injury statistics have largely coincided with the (often considerable) increase in sailplane mass resulting from the carriage of water in ever greater quantity. If the load-deflection curve is linear, for a given rate of descent, Δn is inversely proportional to the square root of the mass; on a sailplane that can increase its total mass by 50% by carrying ballast, and that is designed so that 4g (n) is just reached at maximum mass, then without ballast the acceleration would be 4.67g – a substantial increase.

Implementation of the above factors involves providing more stroke. The table shows Δn and compression δ in mm at the bottom of the tyre for the 50% example, designed to the previous and new standards, for without- and with-ballast conditions, equivalent to landing and take-off mass respectively. The last column shows the ultimate load factor on the main structure at take-off mass.

Case	v m/sec	Without ballast		With ballast		Ultimate load factor
		Δn	δ	Δn	δ	
Previous standard	1.5	3.67	62.5	3	76.5	4.5
New (basic R/D	1.5	3	76.5	2.45	93.6	3.67
standard (inc'd R/D	1.65	3.3	84.1	2.69	103.2	4.04

In the above example the increase in stroke is 35%. However, the structural load is 10% less. On a no-ballast sailplane, the extra stroke would be 10%.

Thirdly, for two-seaters used for instructional purposes (most of them) a slightly increased (basic) rate of descent, namely 1.6 m/sec, is specified. This is on account of the fatigue effect on instructors who make many landings in a day. Not only the initial touch-down shocks but the effect of surface roughness during the ground rolls affect the physical loading on the pilot in a cumulative way. For high-performance two-seaters not used for training purposes this does not apply, and such sailplanes are treated in the same way as single-seaters.

Fourthly, the self-launching powered sailplane (S.L.P.S.) whether it has one seat or two, does considerably more ground running than a single-seat pure sailplane. It normally taxies to the launch point, and from the landing point; it has longer, sometimes much longer, take-off runs. In two-seat form it is often used for training, sometimes making several landings (touch and go) in the course of a single exercise. It has therefore been treated in the same way as a two-seater pure sailplane.

Landing mass is always critical for n and Δn, and take-off mass for stroke (and, of course, structural strength). It is therefore necessary only to specify maximum n for the former and non-full compression for the latter.

The new standards are summarised below:

(l) At landing mass	$n \leq 4$ ($\Delta n \leq 3$)
(2) At take-off mass	Tyre/strut not fully compressed
(3) Rate of descent	Single seater Two seater & SLPS
Basic	1.5 m/sec 1.6 m/sec
Increased	1.65 m/sec 1.76 m/sec

(4) Structure to meet safety factor 1.5 at take-off mass except that landing gear may yield at increased rate of descent.

Normal Landing Conditions

The standards for these have been extended in three respects.

First, the tail-down case is now applied to the main landing gear as well as to the tail wheel.

Secondly, loads on each wheel of landing gear incorporating two of them (on the same lateral axis) are specified. For laterally separated wheels the reduced-mass method of JAR 22 (in principle that employed for tail wheels) has been adopted, except that a downward limit of 0.5 is specified for the reduced-mass factor, as if it were lower the second side to make contact with the ground would have to absorb more than 0.5 of the total kinetic energy, and so would be the critical one. For twin co-axial wheels, only a few centimetres apart, the second tyre to touch will normally start to deform before the first one reaches full compression, and therefore begin to pick up some of the energy and load. The precise fraction cannot be determined in the same way, and will vary with the lateral slope of the ground (or the bank of the sailplane) and tyre geometry. A distribution of 2/3 on one wheel and 1/3 on the other has been chosen as being sufficient to look after practical cases.

Thirdly, specific nose-wheel/skid cases have been added. The two flight cases correspond to the main-wheel ones, without and with side load, but with the vertical load derived by the reduced mass method assuming $\Delta n = 3$. These are considered more appropriate than those of JAR 22, which have been copied from FAR 23, and seem more appropriate to aeroplanes. The ground case, to deal with loads arising from the sailplane being pushed across ridges or ruts, is the same as in JAR 22, which in this case seems quite appropriate.

It may be noted that the Δn constant differs from that taken in the tail-wheel case, which is 4; this has been accepted on the grounds that the latter has led to satisfactory tail-wheel designs without imposing undue weight and cost penalty.

Supplementary Conditions

A tail-wleel impact case has been prescribed, to look after the load arising when, the sailplane having landed and come to rest with nose wheel touching the ground, the pilot gets out and allows the tail to fall without restraining it. The case is the same as in JAR 22, including the let-out clause where the centre of mass in all conditions is aft Gf the main wheel.

However it is not applied to sailplanes having a single main skid, for which there would be difficulties in specifying the initial attitude, and which is not likely to be used much, if at all, in future.

The wing-tip landing is now included under this heading. The foremost point of application of the lateral force of the balancing couple is now given correctly as the main wheel.

Emergency Landings

The original standard (1962) prescribed only occupant ultimate inertia loads, equivalent approximately to 8g forwards and 4g upwards and downwards. In 1971 these cases were stated as accelerations and made 9g and 4.5g respectively, and a sideways case of 3g added. It was also stated that the occupants should have "every reasonable chance of escaping serious injury in a crash landing" under those conditions, and to supplement this the accelerations were also prescribed for loose equipment supports.

At the same time, a head-on landing case was introduced, under a separate heading, that is, not classed as an emergency(!) In this, at an ultimate load of 6 times the weight acting rearwards and applied to the nose, the fuselage could be damaged but only to the extent that the occupants were not injured. In 1983 the load direction in this case was changed to rearwards and upwards at 45°, to conform with JAR 22 (the origin appears to be the German LFS [9]. In 1976, a 15g forwards inertia case was added for engines situated behind the occupants.

From 1986 onwards various changes to the inertia accelerations were made; the current values are 7.5g upwards, 15g forwards, 6g sidewards and 9g downwards for the occupants and 1 1/3 times those values for loose equipment and for rear-mounted engines unless, in the latter case, the mountings could be shown to fail in sucn a manner that the engines will not enter the cockpit area.

Additional cases were that in a landing with wheels retracted (when applicable) and in a complete turnover (when possible) the occupants were to be protected under loads corresponding to 3g vertically and a coefficient of friction with the sround of 0.5.

The standards have now been amended in one very important respect. This is the augmentation of the so-called head-on landing case by prescribing that the main part of the cockpit, from the foremost control-column mounting aft, must now withstand 15 times the weight, while the more forward part, although still meeting the 6W standard, should at the higher load collapse in such a way as to absorb as much energy as possible. This provision is made in recognition of the fact that it is sometimes possible to save the occupant's spine and hence life even if the legs are broken, as pointed out by Segal [10]. The 6W case is associated with "serious injury" as before; the 15W is associated with "fatal injury". As far as I know this is the first time that the latter term has been used in an airworthiness standard. 6W, as before, refers to Design Maximum Mass; 15W refers to maximum mass without jettisonable ballast, on the grounds that accidents of the sort for which the new case is designed to provide safeguard will mostly happen with ballast gone. The latter will not always be true, but to apply the case to the mass with ballast could cause undue difficulties, and the standard adopted was judged to be a practical compromise between the desirable and the feasible.

Some changes in arrangement and terminology in this case have been made. The principal ones are that the case is now included in the emergency-landings section, the term "head-on landings" being dropped, as in JAR 22, and that "every reasonable chance" has been changed to "a high probability of" as being slightly less indefinite. Also "loose items" has been changed to "removable equipment" as being a more accurate description "loose" is exactly what it should not be!

Concluding Remark

The actual text of the revised standards is to be found in Amendment No 4 to OSTIV AS 1986, expected to be in print at the same time as this paper.

References

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[3] Waibel G. Is it Necessary to Up-date the Landing Gear Requirements? Technical Soaring, Vol 15 No 4.

[4] OSTIVAS OSTIV Airworthiness Standards for Sailplanes. OSTIV Secretariat, c/o DLR, Wessling, Germany.

[5] BCAR British Civil Airworthiness Requirements, Section E, Gliders, 1960.

[6] Polish Airworthiness Requirements for Civil Aircraft, Part G. 1959.

[7] Neumann D. Uber den Einfluss von Fahrwerk und Bodenunebenheiten auf die Beanspruchung von Segelflugpiloten, ZLR-Forschungsbericht 94-06.

[8] FAR 23 FAA Airworthiness Standards: Normal, Utility, Acrobatic and Commuter Category Airplanes.

[9] Lufttuchtigkeitsforderungen fur Segelflugzeuge.1966.

[10] Segal AM. Jump or Bump Part 1. Sailplane and Gliding. Vol XLII No 6, Dec 1991-Jan 1992.

[11] JAR 22 Joint Airworthiness Requirements - Sailplanes and Powered Sailplanes.