Load Relief for Light and Small Sailplanes?

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Abstract

This paper addresses the question if relief from load and speed requirements as given by OSTIVAS is possible. The answer is important for designers of very light or small sailplanes and gliders, as a relief may allow a lighter structure. The answer depends primarily on the weather conditions the aircraft is operated in and, even more, on the aerodynamic quality of the aircraft in question. Actual OSTIVAS and JAR-22/CS-22 cover operation in rough air defined by 15 m/s gusts and smooth air defined by 7.5 m/s gusts. Operation is not approved in lee-wave rotors, thunderclouds, visible whirlwinds and severe turbulence near mountain. After another review of the background of OSTIVAS, the author concluded the turbulence of the air mass operated in dominates the load factor together with the aerodynamic quality of the sailplanes. The manoeuvre loads and speeds are set so they remain below the gust loads. Only sailplanes designed for aerobatic manoeuvres must withstand high load factors just below human tolerances. The highest design speed depends on aircraft weight and minimum drag. So, very light and relatively high drag sailplanes may be approved with relief from OSTIVAS load and speed requirements. The OSTIV Sailplane Development Panel must decide whether an adequate amendment to OSTIVAS is feasible or specific Airworthiness Standards for very light and small sailplanes must be drafted.

Nomenclature

The nomenclature is the same as used in OSTIVAS, JAR-22 or CS-22.

Introduction

OSTIV President Loek M. M. Boermans asked the Sailplane Development Panel (SDP) to investigate "if OSTIVAS can be revised such that sailplanes heavier and considerably lighter than covered by this standard could be approved." In an attempt to answer this charge, in a first paper[1], the author defined the basic criteria for airworthiness requirements and, then, in a second paper[2], he evaluated the development of OSTIV Airworthiness Standards traced in the OSTIV Publications. The second paper covers the often asked question if very light manned sailplanes or gliders may get relief from the high load factors which must be demonstrated for Category Utility or even higher for sailplanes intended for Category A, Aerobatics.

Load Factor versus speed requirements

In Airworthiness Category A, applicable to sailplanes for aerobatics, the required limit load factors are $n = +7$ and $n = -5$ with a safety factor of 1.5, which results in ultimate load factors of + 10.5 and – 7.5. A load factor of 7 in manoeuvres lasting several seconds is close to the human tolerances in a seated position. So, for small and lightweight sailplanes intended for aerobatics, load relief seems not to be possible. However, the question must be asked if very light sailplanes can maintain enough kinetic energy for prolonged high load level manoeuvres at all.

For Airworthiness Category U, called "Utility", three other criteria are the background of the load factors versus speed requirements:

- The highest design speed depends on the maximum mass and the minimum drag at high speed in a "clean configuration".
- Rough air turbulence of the atmosphere must be applied to the normal operations speed range (marked by a green range on the airspeed indicator). For smooth air, reduced turbulence is applied and this speed range is marked yellow on the airspeed indicator.
- A drag increasing device to increase the rate of sink is required to escape fast rising air masses and of turbulence stronger than the quantified rough air such as experienced in thunderstorms, lee-wave rotor clouds, visible whirlwinds like tornadoes etc.

OSTIVAS, JAR-22 and CS-22 give the same definition for the maximum design diving speed

$$V_D\,(\text{km/h}) = 18\,(M/S\,C_D)^{1/3}$$

As for C_D at diving speed, the lowest drag configuration of the sailplane has to be applied as a margin against unintended overspeeding. For a typical para-glider with a stall speed of V_{S1} = 8m/s, a V_D of about 40 m/s equivalent to 5 V_{S1} can be estimated.

When typical data for a para-glider are used to calculate a gust load diagram according to OSTIVAS 3.26, the figures differ much from those experienced in sailplane design. The para-glider mass ratio is about 1.2 compared to about 20 for 15m-Class Sailplane. Also, the gust alleviation factor in turn is only 0.16 compared to about 0.7 for a 15m-Class Sailplane. Further, for a +-15 m/s vertical gust at V_B = 20 m/s and a +-7.5 m/s vertical gust at V_D = 40 m/s, a low load factor of n = 1 +-1.04 is calculated. Note that a para-glider must never experience negative load factors as the para-wing collapses. This calculation shows that para-gliders are not affected by turbulence according to sailplane requirements.

Contrary to sailplanes, para-gliders and hang-gliders do not have air brakes for approach to landing nor for high speed escape from strong updrafts.

The performance for approach to landing of para-gliders is about equivalent to that of a sailplane with the air brakes fully extended which must not have a glide ratio better than 7 in 1. Note that OSTIV Training and Safety Panel (TSP) regards this requirement to be too weak and opts for lower approach performance for sailplanes.

A review of the sailplane requirements for high speed and air brakes extended shows that a rate of sink of about 30 m/s at never-exceed-speed must be demonstrated, which in turn allows escape from uncontrollable updrafts under or inside clouds.

Historic review of the gust load requirements for sailplanes

The statement given above, that para-gliders and hang-gliders, if flown properly, are not affected by atmospheric turbulence in a dangerous way, questions if the requirements are applicable for sailplanes to very light para-gliders and hang gliders.

For many years, the author has worked with airworthiness requirements of aircraft and he could not find the background of the gust load requirements. For example, during his studies at Darmstadt University, he used gust load statistics from DVL (about 1930), RAS (June 1958) and NASA (1959) [3] but this source gave no hint to the origins of the current gust load requirements. While designing the Concordia sailplane in Tennessee, he luckily found first background literature on the subject issued in 1962. When the author noticed that the gust load requirements for sailplanes, small airplanes and airliners were basically the same, he tried to get relevant NACA reports and was happy to find NACA Report 1206[4] and NASA Technical Note D – 29[5]. Also interesting German literature from H. Krummhaar, AVA Goettingen 1958 was consulted.

NACA report 1206 explains the advantages of the gust load formula we use today and re-calculates V-G (speed versus load factor) data recorded 1933 to 1950. NASA TN D-29 reports standardized "effective gusts " U_e derived from gust load measurements made between 1947 and 1958 using the new gust formula to reduce the data. The result of 4.8 million miles of flight is a strongest "effective gust" of 53 ft/s, which is encountered only every 700,000 miles. The largest load factors were recorded at low altitude, between 0 to 5000 ft.

The author has suggested using the same formula as used for the data reduction to calculate the gust loads for new aircraft design. Since that suggestion, the gust formula has been successfully used for all civil aircraft. Fifty feet-per-second (50 f/s) is equivalent to about 15 m/s and these values are the effective gust speeds which have been entered into the requirements. Such a high vertical effective gust is encountered every 320,000 km of flight at low altitudes, 5000 feet and below.

J. B. de Jonge from The Netherlands presented his paper "Gust alleviation factors for sailplanes"[6] at the OSTIV Congress in June 1965. In his conclusions, de Jonge regarded the OSTIVAR of that time, based on Polish requirements, as modern and not too different from the new formula. However, he asked for investigations of high altitude gust cases and the effects of structural flexibility to gust imposed sailplane loads. During the same OSTIV Congress, Max Hacklinger of Germany read a paper about "Investigations on the Gust Loading of Flexible Sailplanes"[6]. As other authors had mentioned before, he stated that there is a "critical gust" which may lead to overload. He named it the "resonance gust" for the fundamental wing bending mode. He recommended to carefully determine the rough air speed and winch towing limitations for sailplanes with low fundamental wing bending frequencies.

Triggered by the concern of de Jonge and Hacklinger, the author carefully checked the background of the current gust load requirements and found that the high altitude gust is well covered by the statistical data and also the resonance problem of gust and flexible structure. The aircraft collecting the data of vertical acceleration were more or less flexible too.

So, gusts being close to the resonance gust were encountered and recorded from time to time including the resonance effects. The author's opinion is strongly backed by a paper written by Peter Chudy[7] "Response of a Light Aircraft Under Gust Loads".

Using a detailed structural model and adequate aerodynamic panelling for a 14 m span sailplane made from fiber laminates with a maximum weight of 320 kg, Chudy calculated both the "worst case" gust as required by the Pratt – Walker formula and adequate gusts capturing the stochastic nature of continuous turbulences together with the effects of structural flexibility.

Applying the JAR-22/CS-22 discrete 15 m/s gust to the sailplane, Chudy found a load factor increment of 4.53 whereas the dynamic calculation resulted in a marginally higher load factor increment of 4.56. This result shows that the current airworthiness requirements are still applicable to light and small sailplanes. The static strength is well covered.

However, when fatigue loads are evaluated, the Pratt – Walker formula fails to calculate a load spectrum. Here the application of a power spectrum of turbulence relevant for the operation conditions is most promising. As for the fatigue case, the flexibility of the aircraft in question may become more important.

Applicability of the Pratt – Walker formula to Para- and Hang-Gliders

From the wide data base including slow and fast, stiff and flexible, light and heavy aircraft in all parts of the world and at all altitudes, there is no objection in using the formula for very light and small aircraft. Depending on the design diving speed, calculated gust load factors may be low and therefore not critical.

Can lower manoeuvring loads be allowed for Para- and Hang-Gliders?

In the beginning of soaring there was a difference in manoeuvre load factors and speeds for "Gliders" and "Sailplanes", the "Gliders" having a load relief. It is the impression of the author, that the high gust loads for aerodynamically efficient sailplanes were so dominant that the manoeuvre loads could be set higher thus simple aerobatic manoeuvres could be allowed, even in Category U. For low aerodynamic efficiency, a lower load level for manoeuvring loads can be tolerated. It is a question to the OSTIV SDP if such a major change of OSTIVAS is desirable.

A view into current strength requirements for para-gliders shows that strength requirements for opening shock loads for the parachute are by far controlling. The author believes that para-gliders come from another world of experience and history. To include hang-gliders into OSTIVAS, however, seems to be possible when a lot of operational requirements are added and marked in the way powered sailplanes are covered by additional requirements or standards.

Concluding remarks

The question put in the title of this paper can be answered quite easily. Depending on the aerodynamic quality of a lightweight hang-glider or a light and small sailplane, the designer can find out with little effort if their project fits into OSTIVAS or not. To calculate the performance potential of the projected aircraft is much more demanding but a must (and most fun) for the designer of a project. When the gust loads according to the Pratt – Walker formula are noticeably less than $n = +5$ or $n = -3$, the certifying authority should be contacted to allow adequate relief in manoeuvring load factors.

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