IS IT NECESSARY TO UPDATE LANDING GEAR REQUIREMENTS?

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1. STATE OF THE ART

In the past, the sailplane designers tried to improve the landing gear energy absorption. JAR-22 (Lit. 1) as well as OSTIVAS (Lit. 2) were updated and have been used as designer's guidelines. By use of bigger wheels the more severe requirements were met. Some designers use (mostly rubber) spring elements additionally.

Recently, Mr. Detlev Neumann from TU Braunschweig did landing gear tests, which demonstrate the state of the art. His results showed the current calculation methods — using static test data for tires and shock absorbers — normally resulted in landing gears complying with JAR-22 also if they were dynamically tested, see (Lit. 3). However, Mr. Sperber of TUV Rheinland reported at the 1990 DLR Segelflugsymposium that accidents, where pilots sustained back injuries, are increasing despite the designers efforts to produce better landing gears. His report (Lit. 4) gives the details. As Mr. Sperber's survey of LBA-data ended in 1988, the author of this paper asked the LBA if the bad trend continued. Mr. Kopp of the LBA will read a paper at the XXII OSTIV Congress which will confirm that the number of accidents with "hard landings" had increased whereas the total number of sailplane accidents shows a decreasing trend (Lit. 5).

2. ASSUMPTIONS AND POSSIBILITIES OF THE AIRWORTHINESS REQUIREMENTS

It must be stressed that the designers as well as the airworthiness requirements, imply that any landing should be done with the landing gear extended. Hangar flying hearsay still spreads the idea that there are some cases when it is favorable to land "gear up." These rumors should be strongly discouraged by our OSTIV-TSP colleagues.

The author also strongly stresses that his intentions are to improve the landing gear in the normal extended position. He is not willing to install a second energy absorbing system for those pilots who want intentionally to land gear up. He is, however, open to discuss shock absorbing material for seat cushions instead of conventional upholstery and improved seatpan design and/or material which is altogether integrated into a shock absorption system. Such improvement is possible under current airworthiness requirements.

3. CRITICAL VIEW ON THE CURRENT REQUIREMENTS

Both JAR-22 and OSTIV AS require that the glider acceleration does not exceed 4g when the sailplane touches down with max. mass at a rate of sink of 1,5 m/s. An acceleration of 3g is recommended. If, however, the rate of sink is only slightly higher the landing gear bottoms, that is comes to the stop. The landing gear itself as well as the surrounding structure is designed in such a way that the required safety factor $j_{min} = 1,5$ is exceeded, rather than just reached.

As such components cannot be designed and built to very narrow tolerances, the average safety factor actually achieved will be in the neighborhood of $j \approx 2$ or more (see test results below).

If a designer strictly follows the current requirements he will design the landing gear for a rather stiff stop at $n = 1 + j * \text{delta}$ $n = 1 + 1{,}5 * 2 = 4$ (minimum), $n = 1 + 2 * 3 = 6$ (average) and $n > 7$ (maximum).

Because of the author's experience with collapsing landing gear struts for $n \approx 7$ there is a critical load level where backbone injuries may occur, perhaps aggravated by inadequate seating position and/or bad seat cushions.

Due to elastic response of the sailplane, the structure near the landing gear (where the pilot usually sits) will be more strongly

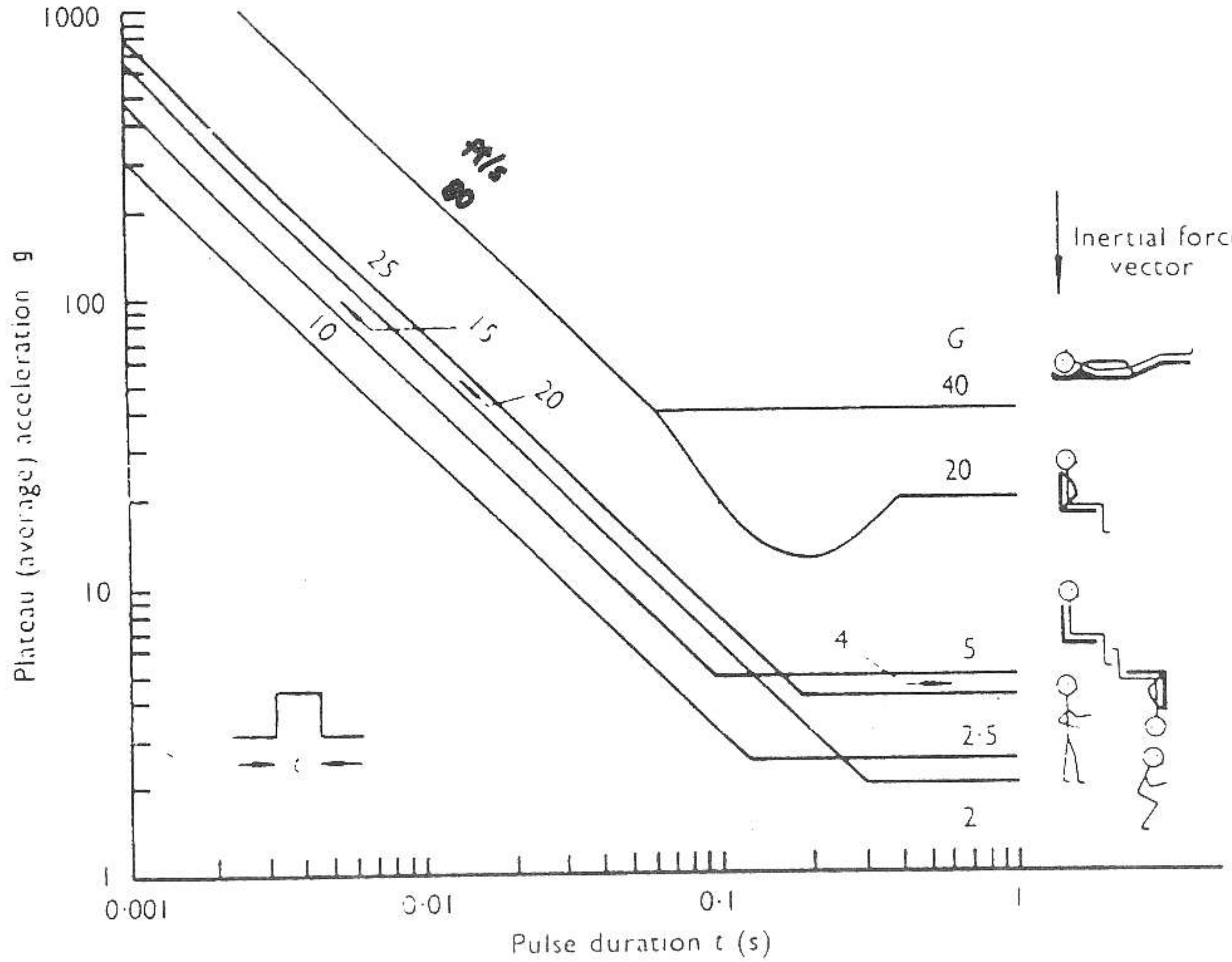

FIGURE 1. Printed from (Lit. 6). Tolerance to whole body impact in the attitudes and restraints illustrated in the inset diagrams. The inertial force vectors shown are generally perpendicular to the Earth's surface.

decelerated than for example the outer wings or the tailplanes. In other words, the pilot will feel higher loads than calculated before.

Dr. Tony Segal provided me with a paper which shows that the human body tied down in seating position has a lowest (minimum) load tolerance for a bloc type pulse of about 11g and of about 0,2 second duration, see (Lit. 6) and Figure 1. The reason for this is: "A pilot seated on an ejection seat has a natural frequency of oscillation in the vertical direction, when in the sitting position of some 5 Hz, so the critical pulse length is about 0,2 s."

A rough calculation of an "average JAR-22 landing" shows a pulse like diagram Figure 2. Depending on the stroke reserve to the stop of the landing gear, we will get for a "landing exceeding JAR-22 requirements" a pulse like that shown in diagram Figure 3. Although this pulse is shorter (owing to higher vertical speed) and of peak type shape, we end up definitely in the range where the dynamic response of the spine is unfavorable. Please note that providing longer stroke of the landing gear is perhaps not the answer for future requirements, as we may get closer to spine resonance. However, a shorter bloc type pulse would be more tolerable.

Also, most modern sailplanes are designed to carry water ballast. The landing gears, therefore, react more stiffly for landings with less than max. mass. This is favorable for landings with slightly higher sinking speeds than 1,5 m/s. However, if the landing gear is compressed to the stops, the loads definitely reach dangerous values.

4. DISCUSSION FOR A PROPOSAL TO CHANGE JAR-22 AND OSTIVAS

1. The design sinking speed should be slightly increased, resulting in stiffer suspension (higher tolerable accelerations). For the same stroke the energy absorption will be higher.

2. But, at the same time the surrounding structure in the case of fixed landing gears or struts next to the wheel, or of retractable landing gears, must be designed in such a way, that they will collapse in a controllable range of $1{,}2 > j > 1{,}5$. This feature is to avoid the hard stop resulting from current regulations.

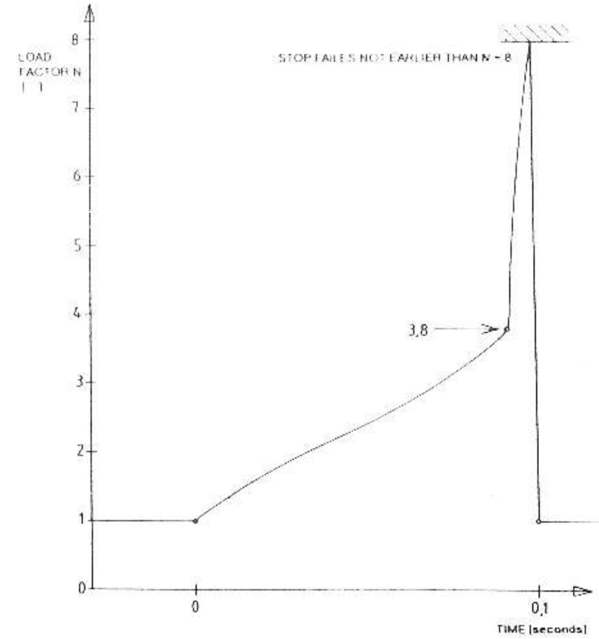

FIGURE 3. Load factor of Landing gear vs. time.

5. TESTS WITH DIFFERENT STRUT DESIGNS

Needless to say, that the author was interested to see what the situation is with his last design.

The design of the ASW-24 landing gear against overload is such that 4 struts should collapse without doing major damage to the other fuselage structure, see Figure 4. This, however, was

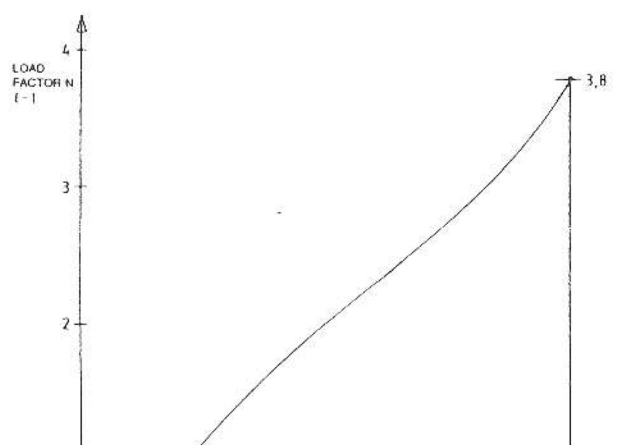

FIGURE 2. Load factor of Landing gear vs. time.

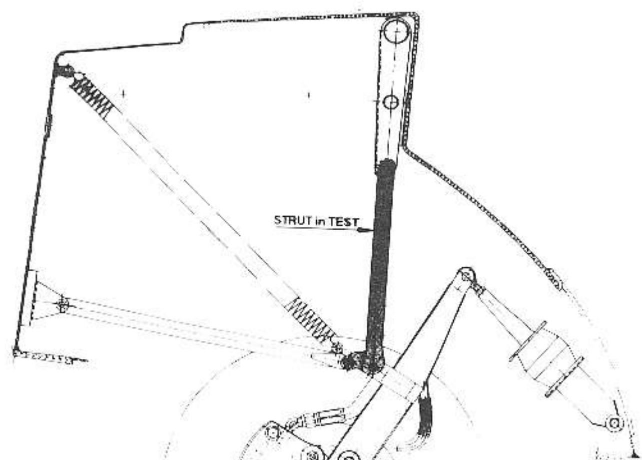

FIGURE 4. ASW 24 Landing Gear Assembly.

the idea; in real operation the landing gear failed in other places. On one occasion, one strut failed as intended by buckling and the pilot reported a light compression of his backbone. Because of the knowledge of (Lit. 6) we can explain how this could happen. So, we are definitely in a situation where a landing gear easily complies with JAR-22 but is too hard if the stops are reached due to overload.

As a basis of the tests, three serial struts were tested in compression. They failed in buckling at an average load of 4315 kp = 43,3 kN. The calculated buckling load according to Johnson's criteria is only 2249 kp, using the conservative "LBA-approved" stress values for the material.

The test results were very disappointing, however, representative for our conservative calculation methods.

5.1 STRUTS WEAKENED BY DENTS (DIMPLES)

Despite several approaches in varying the dimple depth and pattern only about 5 mm compression stroke could be achieved before (eccentric) buckling occurred. An average compression load of about 2500 kp per strut (peak load: 3600 kp) can be assumed. This results in an energy absorption of 2*2500*0,005 = 25 mkp = 245 Nm.

This means that the rather simple modification increases the energy absorption of the ASW-24 landing gear by about 25%. On top of that, high load peaks are avoided but there is no more deflection before the stop is reached and the landing gear will totally collapse at higher loads. Figure 5 shows an average and a good example for a dented (dimpled) strut.

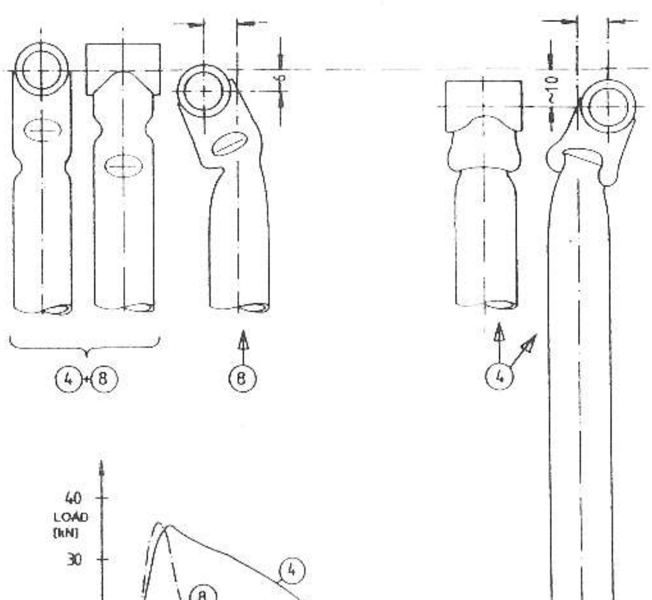

FIGURE 5. Struts weakened by dents (dimples).

5.2 STRUTS WEAKENED BY HOLES

In an early stage this idea came up. However, it was ruled out as uncontrollable corrosion problems were expected. The latter problem is not solved year; however, the results are promising and retrofit by customers will be rather easy by a technical bulletin.

Figure 6 shows a good example of a strut notched by holes. Also, here buckling could not be prevented. The energy absorption was about the same as for the struts with dimples but the stroke was about 7mm (compared to 5mm for the dented strut and nearly zero mm for the standard strut) and the average load was 1800 kp (Peaks: 3000 kp). From both tests one can learn that the existing strut is unfavorable as the buckling load is too close to the load level where failure is expected. A larger diameter tube with thinner wall would be more promising.

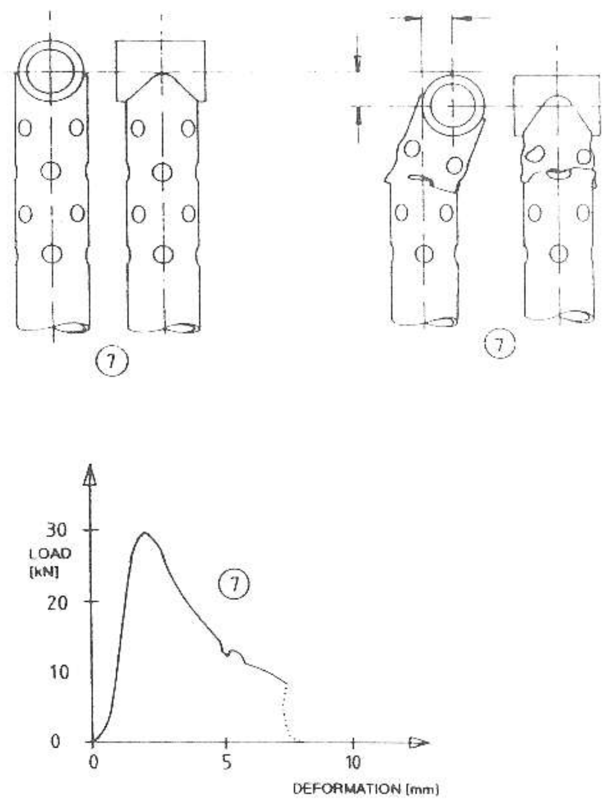

FIGURE 6. Struts weakened by holes.

5.3 TELESCOPE STRUTS

A last series of tests is more promising. A series of shear bolts was installed into a telescopic strut. The energy absorption is very good. A first attempt demonstrated ≈ 12 stroke at average 2100 kp load. See Figure 7.

For 2 struts an energy absorption of

$$2 * 0{,}012 * 2100 = 50{,}4 \text{ mkp} = 494 \text{ Nm}$$

can be assumed, nearly doubling the value of the (rubber suspended) landing gear. The disadvantages of this strut are:

1. Uncontrollable friction caused by corrosion of the telescope.
2. It does not fit anymore into the ASW-24 landing gear, so retrofitting is not possible without major change of the landing gear.
3. It does not comply with JAR-22 as first permanent deforma

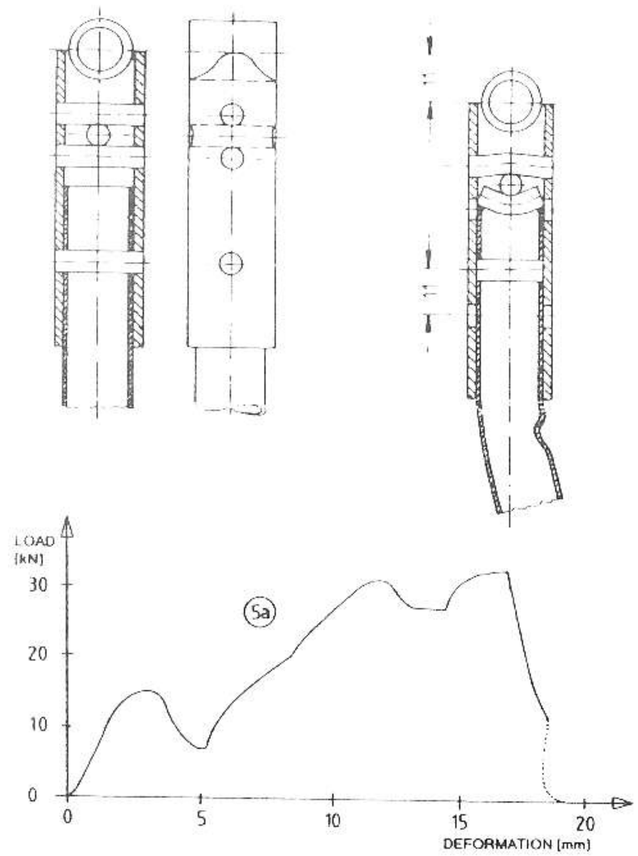

FIGURE 7. Telescope strut with shear pins.

tion occurs at too low a load.

The last point is also the one which makes it difficult to use the other weakened struts, as change of the requirements has to be discussed first.

6. CONCLUDING REMARK

The author is well aware that his proposal needs careful discussion with competent people before a proposal for the OSTIV-SDP or the JAR-Study Group can be written. He, therefore, asks for contributions to be sent to his address.

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LITERATURE

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