In- Flight Airworthiness

Part One: …Safety in the Cockpit, Cushions and Harnesses

This first part in a series of articles concentrating on airworthiness related “in-flight safety issues” takes a look at the role of the humble seat cushion and it’s indispensable partner, the harness. The issues discussed are pertinent to both sailplanes maintainers and safety conscious pilots.

If you think that seat cushions do not involve important airworthiness and safety issues then think again, because a “good” seat cushion may one day save you from serious injury in a heavy landing and a “bad” one may lead to more than just uncomfortable flying on those long cross-country flights. Let’s first look at what a seat cushion should do.

Firstly, and not surprisingly, a seat cushion should provide comfort for the duration of a flight of several hours. Poorly designed cushions that create discomfort or that allow pressure points to bear on the occupier’s body accelerate the onset of physical and mental fatigue during long flights. This results in reducing pilot performance and impaired decision making capability.

Secondly, the seat cushion should absorb impact, rather than rebound it, in the event of a heavy landing, or more critically, in a crash scenario.

Thirdly, a seat cushion should not be highly compressible under normal flight-loads. Cushions that compress to a small percentage of their normal unloaded volume are hazardous during winch launches, turbulence and high-G manoeuvres. When such a cushion is loaded by the seat occupant’s body under the acceleration of high-G loads the harness can be ineffective and the occupant may be displaced to adverse seat positions.

Fourthly, of relevance to powered sailplanes, cushions should be resistant to combustion.

The cushions used with the harness have a large influence on the safety performance of the harness. The cushions and the harness are best thought of one integral system, the cushion-harness system, if you like. A well designed harness installation performs badly when coupled with a poorly designed or installed cushion and vice versa. Performance of the cushion under load is an important physical characteristic for optimum safety outcomes. Excessively soft cushions are compressed under acceleration. As the foam is compressed the webbing restraining the occupant loosens and the occupant’s body moves under the harness in a motion called “submarining”. When in-flight load is removed, the cushion rebounds and there is potential for injury to the pilot’s body, particularly the spine. This scenario is shown in Figure 1.

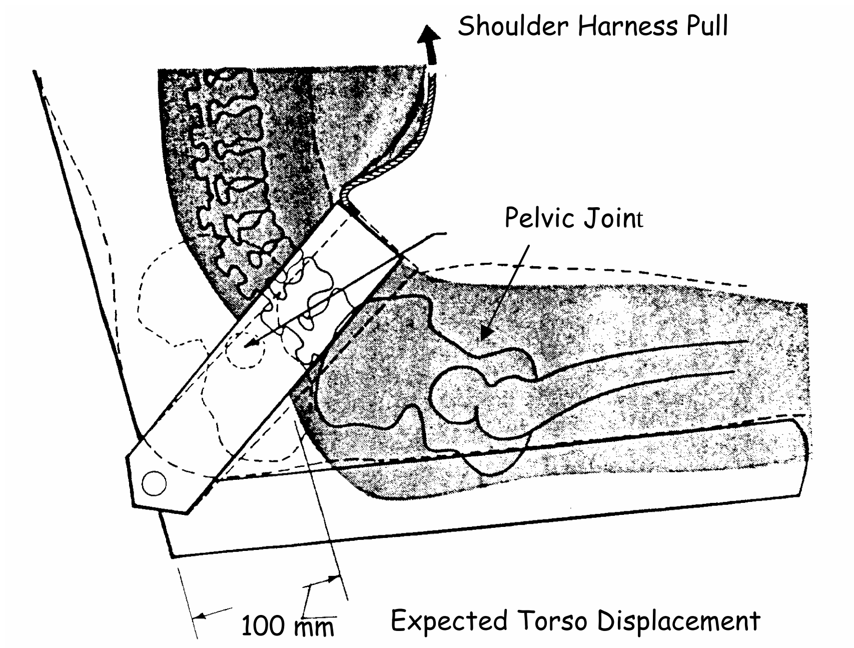

FIGURE 1. SUBMARINING MOTION CUASED BY INAPPROPRIATE CUSHION CONSTRUCTION, (FIGURE 1.8.1 FROM BASIC SAILPLANE ENGINEERING)

Submarining can be minimised by using energy absorbing, non re-bounding foams in seat cushions. Research in association with the BGA, OSTIV and others indicates that significant reductions in spinal g- loading to the seat occupant's spine, one of the more vulnerable and critically affected parts of the body in crash scenarios, result from use of hard grade, low-resilience foam. The spine is subjected to increased g exposure when soft foam is used, even when compared to a bare seat scenario. The optimal cushion construction was found to be 25 mm of hard grade, low resilience foam with 12 mm of medium grade low resilience foam for comfort. The medium foam is placed above the hard foam and the sandwich is upholstered UV light protection and wear and tear. The total uncompressed thickness of the cushion should not exceed 40 mm to minimise the slack in the harness induced by in-flight loads to prevent submarining. The renowned aviation medico and glider pilot, Dr Tony Segal, has published many excellent articles and papers on crashworthiness which are well worth reading for any pilot (refer to Gliding and Motorgliding International).

A dark foam, brand-named Dynafoam, was in the past extensively available for aviation cushion construction, particularly for pilots over a hot-seat. Another more modern product called Confor™ Foam has been available for some years now. Confor™ Foam is manufactured by AeroE-A-R Specialty Composites. It is available from a number of sources. One source in Australia is Phil Gorman of Specialty Foams Australia at 12 Nicolas Dr Casuarina, WA 6167.

phone (08) 9419 4004, fax 08) 9419 7317, or email: phillipgorman@bigpond.com.au). Specialty Foams Australia will either cut foam to length from supplied measurements or will measure a seat cushion supplied to the factory and cut the foam to fit. Beverly Soaring Club in WA has already used the services of Specialty Foams to supply Confor™ Foam.

Another source of is Hi-Tech Foams of 3710 Air Park Rd., Lincoln, NE 68524 402/470-2346 United States of America (phone: 0011 1 402-470-2346, email : seatfoam@inetnebr.com website: http://www.seatfoam.com/prod01.htm).

Confor™ Foam can be used to construct cushions with the desirable characteristics referred to at the beginning of this article; namely, comfort (pressure point reduction), it will absorb impact not rebound it ("impact safety", or low-resilience) and it resists combustions. The physical characteristics of a typical foam are listed in Table 1.

Confor™ Foam meets FAR 25.853 and FAR 24.855 burn specifications (refer to Table 1) and can be installed in certified aircraft, such as all sailplanes and powered sailplanes with a normal Certificate of Airworthiness as well those operating under a special Certificate of Airworthiness (otherwise known as an experimental certificate).

CONFOR FOAM -TYPICAL PROPERTIES						
Property	**Test Method**	**CF-47 Green**	**CF-45 Blue**	**CF-42 Pink**	**CF-40 Yellow**	**CF-38 Yellow**
PHYSICAL PROPERTIES						
Density Nominal (LB/ft)	ASTM D3574	5.8	6.0	5.7	5.8	6.4
Flammability	FMVSS 302	Meets	Meets	Meets	Meets	Meets
	FAR 25.855	Meets	Meets	Meets	Meets	Meets
		Meets	Meets	Meets	Meets	Meets

	FAR 25.853(b)					
	UL 94 Rating (@min 0.25 in)	Listed HBF	Listed HBF	Listed HBF	Listed HBF	Listed HBF
Dielectric Strength	ASTM D149 (V/mil)	27	27	27	27	27
Ball Rebound	ASTM D3574 (% Rebound)	2.8	2.4	1.0	0.9	
Thermal Conductivity, K	ASTM C177 BTU-in/hr-ft^2 -deg. F	0.28	0.28	0.28	0.28	0.28
Volume Resistively	ASTM D257, (Ohms-cm)	1.6×10^{13}	1.6×10^{13}	1.6×10^{13}	1.6×10^{13}	1.6×10^{13}
Impact Absorption	ASTM F355 Modified 11 lb.missile, 3.4 m/sec., 24" drop, "G"Max	70	58	58	75	165
Hardness	ASTM D2240, Shore 00 15 sec impact:					
	4C	91	86	83	79	74
	10C	88	80	77	70	60
	16C	71	46	21		
	21C	20	8	4		
	27C	12	5	2		
	32C	10	4			
	38C	8	4			

Table 1. AeroE-A-R Specialty Composites Technical Data Sheet TDS-13, FAR 25.853 and FAR 25.855 specifications for burn testing. NOTE: The data listed in this data sheet are typical or average values based on tests conducted by independent laboratories or by the manufacturer. They are indicative only of the results obtained in such tests and should not be considered as guaranteed maximums or minimums. Materials must be tested under actual service to determine their suitability for a particular purpose.

Now for a few words about the harness itself.

Part 108 of the Civil Aviation Orders (CAO's) specifies a number of processes, procedures and specifications for the manufacture, inspection and maintenance of aeronautical equipment used in aircraft, including gliders. Interestingly, Part 108 is actually a collection of "grandfathered" Air Navigation Orders (referred to as ANO's). The ANO's are being progressively phased out and are being updated and replaced by the CAO's or, alternatively, their content is being merged into the various amendments to the Civil Aviation Regulations of 1988 (called the CAR's) or the evolving Parts of Civil Aviation Safety Regulations called, you guessed it, the CASR's). Eventually, the CAR's, the remaining ANO's and the CAO's will be replaced by the CASR's. The CASR's are aligned with international regulations and standards so the goal in all this aviation law reform is that, one day, all aircraft all over the world will be operated and maintained to the same standard, for better or worse (but let's not go there now!). You're no doubt aware of at least a very small part of this process in action, particularly with media coverage of the changes to Airspace Regulation and, if you own or operate a glider, by your involvement in the transition of your glider's registration to comply with the CASR Part 47 (we'll go their in a future article).

To get back to the point, CAO 108.42 deals with specifications for harness installations. It's the law and it must be obeyed, and yes, that means you, the glider pilot, maintainer and operator. CAO 108.42 states that harnesses certified by many foreign authorities (these are called "Contracting States" and include the LBA, FAA, BGA etc) as complying with one of the following specifications are permitted for use in Australia:
(a) Safety Belt — U.S.A. Federal Aviation Administration Technical Standard Order TSO-C22;
(b) Safety Belts — British ARB/CAA Specification No. 1 (Issue 3);
(c) Safety Harness — British ARB/CAA Specification No. 4 (Issue 2);
(d) Three Point Lap-sash Safety Harness — Applicable parts of (a) or (b) above; or
(e) Inertia Reels — U.S.A. Military Specification MIL-R-8236.
The law makes provision for approval of harnesses not complying with any of these specifications if it can be shown that they provide an equivalent standard of protection for specific installations. Such approval would require compliance with CAR's 21A, 35, 36, 36A to mention a few (so let's not go there either, particularly since fines are $5,000 per transgression apply)

The additional requirements of CAO 108.42 are as follows:
- Each harness fitted must be for only one person and must be independent of any other harness fitted.
- The harness must not appreciably restrict the movement of the wearer's limbs.

- four (or five) point harnesses must not have straps permanently connected to the thigh straps, or straps which do not immediately disconnect from the thigh straps when the harness is released.
- Three point lap-sash harnesses with a freely sliding buckle (i.e., similar to automotive seat belts) are not acceptable.
- release mechanisms must not lock onto webbing using serrated or knurled metal parts
- only one release mechanism is acceptable and **two** independent safety belt assemblies are prohibited.
- webbing material must be made from an approved continuous filament synthetic fibre.

In addition to the CAR's and CAO's, the GFA's airworthiness documentation makes a number of requirements regarding harnesses. For all sailplanes to have a valid Certificate of Airworthiness issued after 30th August 1980, GFA's Mandatory Airworthiness Requirement (MAR) No. 1 requires harness systems to be fitted with an approved quick release mechanism unaffected by acceleration forces and with lap-strap adjusters operated by an upward pull action. The MAR also calls for all webbing to be resistant to degradation by ultra violet light.

The European Aviation Safety Agency (EASA) publishes certification specifications for sailplane designers and manufacturers. These specifications are beyond what the pilot or inspector needs to worry about, but for completeness, here is what the EASA has to say about seats, safety harnesses and headrests from AMC 22.785(f) and AMC 22.788 of CS-22, a derivative of the old JAR 22:

"(1)The arrangement of the safety harness installation should minimise the probability of the occupant's body from either sliding underneath the belts or sliding laterally when subjected to inertia loads acting in the forward or sideward direction, respectively.
(2) For semi-reclined seating positions the anchorage points of the lap belt should be located well below and behind the H-Point at an angle between 80 ± 10 degrees to the datum line through the H-Point parallel to the longitudinal axis of the sailplane.
The H-Point (Hip-point) is the pivot between the torso centre line and the thigh centre line of the occupant. The determination of the H-Point, or the anchorage point of the lap belt, should be made by a rational method. An acceptable means is contained in CS-22, Book 1, Appendix J.
(3) The anchorage points of the shoulder belts should be located below and behind the pilots shoulders at an angle of 15° +2°/-0° to a line parallel to the longitudinal axis of the sailplane for a 50 percentile male. The lateral separation should be not more than 200 mm.
a) If possible, the structure of the headrest should be integrated into the backrest of each seat.
b) Each headrest should be so designed that protection from injuries referred to in paragraph CS 22.788(a) is ensured for each occupant irrespective of whether or not a parachute is worn."

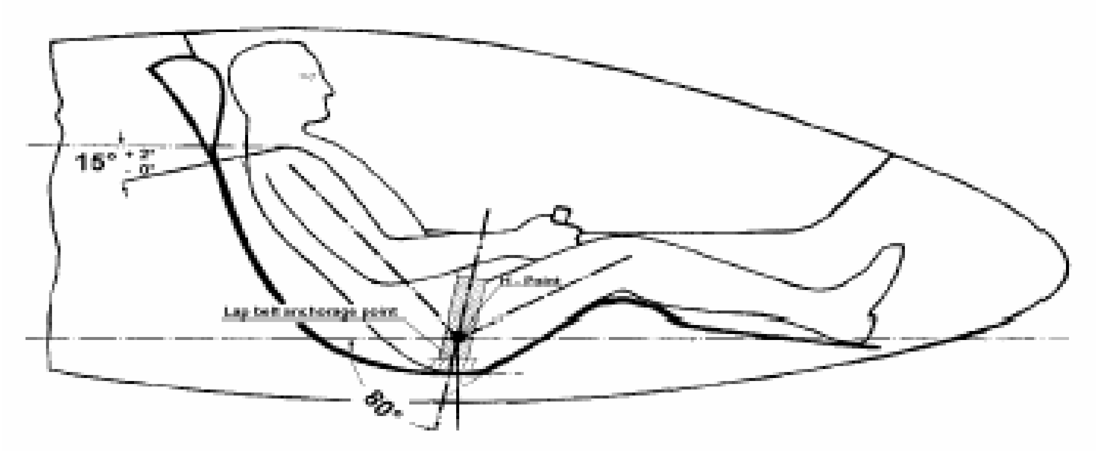

FIGURE 2, FROM CS-22 (REFER TO EXTRACT ABOVE)

Len Diekman
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