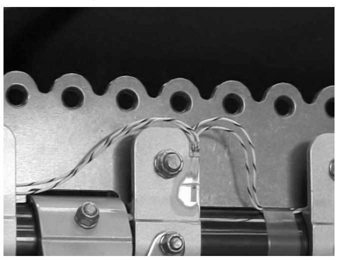
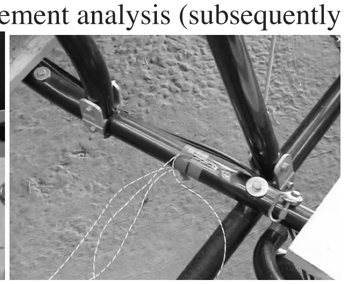
Report on the Airwolf 912S Airframe Load Test of 06/27/2006

By Carl Tharme, Issue 1

Introduction:
The airframe was prepared for test with three pairs of strain gauges in the three critical areas G1, G2 and G3, as detailed in Ref.1 and Figs. 1&2 below.

Stage 1
Prior to loading, all the gauges were balanced to zero and datum measurements taken of the datum values of two chosen key airframe dimensions for comparison of test deflections with the finite element analysis (subsequently referred to as FEA).


Stage 2
The previously specified weights, totaling 1215 kg, were then added to the airframe on the ground, i.e. supported only on its wheels. NB. no nose balance weights were added at this stage. A new set of readings/measurements were then taken.

Stage 3
The loaded airframe was then hoisted gently using a mobile crane, at the same time adding nose weight (as anticipated), to keep the airframe approximately level. The latter was found to require 103 kg (see Fig. 1). It is believed that this was greater than the previously estimated 73 kg because the lifting load on the riser plate front holes was greater than that on the rear holes as a result of the lifting strops being of slightly different lengths . Thus, the total weight added was 1318 kg, resulting in an all up test weight of about 1518 kg (equivalent to 3.46G based on the max. take off weight of 438 kg).
Following a visual inspection, which showed no signs of overstress or excessive deformation, a new set of readings were taken.

Stage 4
The airframe was then lowered to the ground for another set of on-ground, fully loaded readings.

Stage 5
The airframe was unloaded on the ground to obtain a final set of datum readings.

Discussion of the Results

All the readings and measurements taken above are summarized in Table 1. These are shown together with results from representative FEA's of the airframe under the same load conditions for comparison. It should be noted that the unloaded airframe during the datumn or "zero" readings during stage 1 of the test is actually subject to the bare airframe self-weight and so there is actually some initial stress in certain airframe parts, e.g. area G2 in Figs. 1 and 2. Thus the strain values shown for the FEA Stage 1 comparison should be subtracted from subsequent FEA stage readings for comparison with the already-zeroed strain gauge readings. Furthermore, it should be noted that the +/-20~E shown for the datum readings is intended to give an idea of the accuracy/resolution of these readings bearing in mind the resistance variations due to temperature changes etc.

Stage 2 (Ground Loading Case)
With the airframe supported only on its wheels, it is noted that the cables and hang brackets (positions 01 and 03 in Figs. 1 and 2) are essentially unloaded.

However, there is good correlation between the FEA and measured strains on the significant loaded frame rails at position 02. i.e. the "zeroed" FEA estimated strains of - 496 and 537 compare well with the average of the measured strains at this position before and after the lift, of -498 and +512 respectively. This is considered to be within experimental tolerance.
With regard to deflections, for dimension A in Fig 1, the FEA estimated deflection was -12mm (a shortening) compared with -18mm for the measured deflection using the datum value of 1879mm taken before loading. However, if the datum value taken after unloading of 1876mm is used, then the measured deflection for A becomes -15rnm. It is suggested that the variation of *3mm* in these datum values could be due to the taking up of joint clearances and general "lost-motion" in the structure acting as a mechanism under these relatively high loads. Bearing this in mind, the comparison of the 15mm minimum measured deflection against the 12mm predicted by the linear, perfectly elastic FEA would seem reasonable. As can be seen from table 1, the FEA estimated deflection for dimension B of -3mm compares very closely with measured values.

Stage 3 (Main, Lifting Case)
Table 1 shows close correlation between the average strain measured on the inner and outer surfaces of the lift cable tang and that estimated from the cable load predicted by the representative FEA. NB. the difference in the measured values on the tang surfaces clearly shows the inevitable bending of the tang caused by offset of the tang section neutral axis relative to the line of action of the cable tension.

For the critical main rail tubes, correlation between FEA and test is again considered good, with the tensile strain measured on the upper surface of the tube of 724ue comparing with the "zeroed" FEA value of 803ue. For the lower, compressive surface the comparison is -866JlE for the test and -874/1E for the FEA. This is considered satisfactory with regard to experimental error.

Correlation for the bracket strains at gauges G3, however, is not so obvious, with the PEA predicting approximately twice the measured values. On further scrutiny of the model it was realised that the extruded brackets were modeled as simple, constant section beam elements, whereas the actual brackets are of a relatively complex cross section, in which the section thickness changes suddenly near the strain gauge position. Furthermore, the model shows a rapidly varying bending moment at this position. Here, the FEA predicted moment is much less than the bracket leg maximum bending moment reflected in the FEA strains of 2029ue and -1648ue shown in table 1. However, a more comparable result is obtained by averaging the inner and outer surface strains, which is the net axial strain in the bracket's thinnest section of 5.lmm.

Subtracting the stage 5 datum figures (rather than the initial stage 1 zero datum values) for these gauges, the measured axial tensile strain is then calculated at + 185ue, which compares with the average FEA value of + 191ue, i.e. good agreement.

With regard to the deflection measurements for this case, it has become clear following the test that the value of 1312mm measured at dimension B is clearly incorrect. i.e. suggesting an impossible deflection of 51mm at this point. It is now believed that the measurement was actually taken at the lower bracket bolt rather than the correct upper bolt position. Since these bolts are 50mm apart it is inferred that the true measurement would have been 1262mm implying a true deflection of 0. This agrees with the FEA result. However, this is of course, conjecture and must not be relied upon.

Another anomaly is indicated by the measurement at A for this case, i.e. 1871mm, which implies a test deflection of -5mm (shortening) relative to the datum value of 1876mm measured after unloading the airframe. This compares with the FEA prediction of -4mm. Logical consideration of the structure and loading for this case would suggest that this dimension should increase if anything, rather than reduce. Thus it is inferred that this measurement was also incorrect and should be ignored. On the other hand, this anomaly might be explained by some kind of non-linear, lost motion type of deflection in the airframe acting as a mechanism, as previously mentioned for the ground loading stage.

Note on the Effect of the Cable Modification

For interest, the last row of table 1 shows FEA results for the airframe in this test configuration without the lift cables added to the original structure. This shows greatly increased strains in the main rails (as expected). Indeed at the critical bolt hole section just forward of the gauge position G3, the FEA indicated that the peak bending stress would just exceed the material elastic limit during the test.

Conclusion

Apart from two suspect deflection measurements, good correlation is shown between the test results and the FEA. Certainly there was no sign of damage or permanent deformation of the airframe following these tests.

It would therefore seem reasonable to conclude that the analysis in Ref. 2 is representative and accurate and also that the airframe comfortably meets Section S strength requirements.

Drop Test Report
For futher interest positive landing load drop test was completed.
The airframe was loaded with 80 kg in each seating position, and 36 kg in the fuel tank position thus giving the loaded airframe the max gross weight of 438 kg.
The loaded airframe was hoisted using a mobile crane keeping the airframe approximately level to 610 mm.
The airframe was then drop tested, upon visual inspection the airframe showed no signs of overstress or excessive deformation and a new set of readings were taken verifying no structural compromise to the airframe was recorded.

References

1. Airwolf 912ULS Airframe Test Schedule for 06/27/06 By Carl Tharme
2. Powrachute Airwolf 912ULS Section S Compliance Report, Airframe Structural

Analysis by Carl Tharme

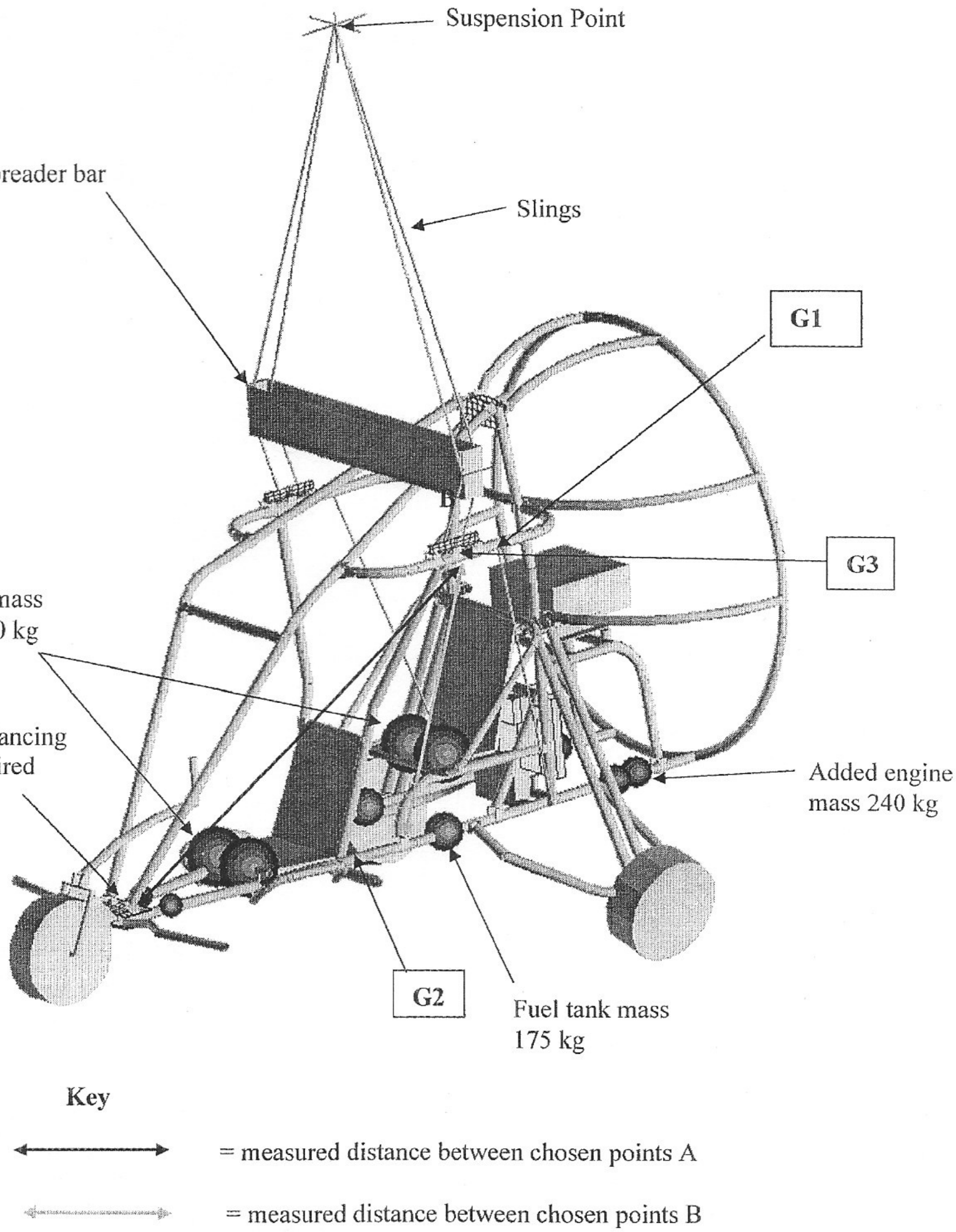
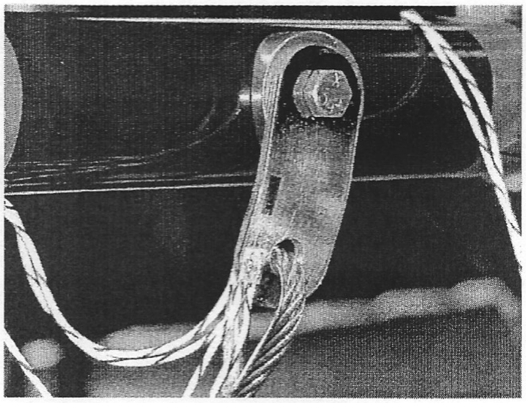


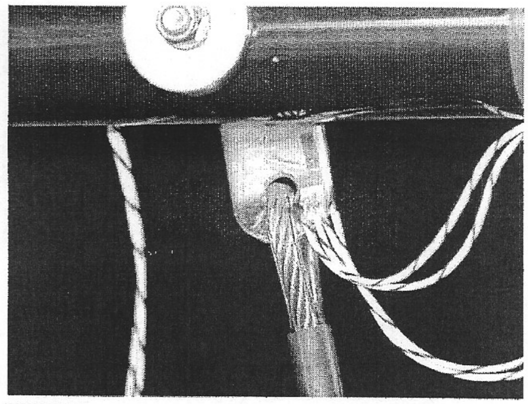
Figure 1 Load Test Configuration

Table 1: Measurements Taken

Test Stage	Gauge Position or distance measured	G1 inner	G1 outer	G2 Upper	G2 Lower	G3 Inner	G3 Outer	Dist A	Dist B
	Units	με	με	με	με	με	με	mm	mm
1	Unloaded on Ground	+/-20	+/-20	+/-20	+/-20	+/-20	+/-20	1879	1261
1	FEA Comparison	0	0	-42	+37	0	0	1879	1261
2	Loaded on Ground	+/-20	+/-20	-505	+525	+80	+/-20	1861	1259
2	FEA Comparison	0	0	-538	+574	0	0	1867	1258
3	Loaded off ground	+322	+93	+724	-866	+1113	-813	1871	1312
3	FEA Comparison	196	196	+761	-837	2029	-1648	1883	1261
4	Loaded on Ground	0	-28	-490	+498	+40	-110	1861	1258
5	Unloaded on Ground	0	-26	0	0	+40	-110	1876	1262
3 Ref.	FEA (no lift cables)	_	_	1862	1960	2029	-1648	1889	1268

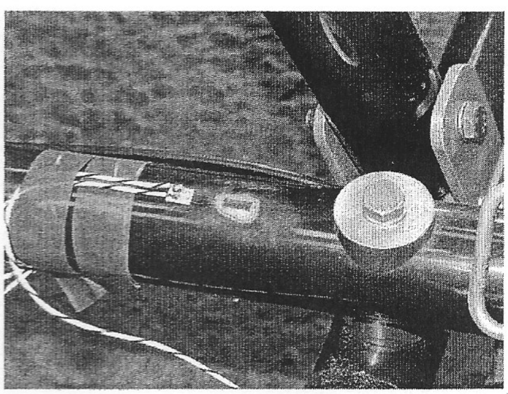


G1 (Cable tang outer surface)

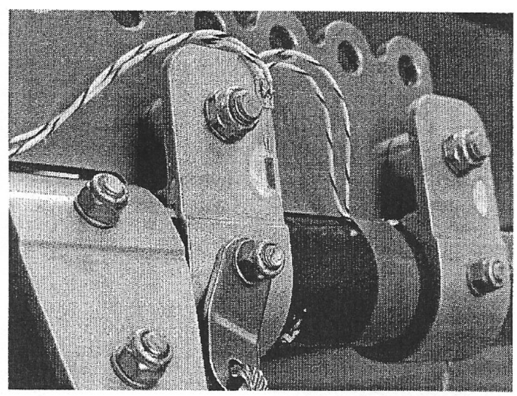


G1 (Cable tang inner surface)

Figure 2 Strain Gauges (total of 6)



G2 (Frame rail upper surface, lower gauge not shown)



G3 (Centre hang bracket inner surface, opposite gauge not visible)