Alpha Electro 167
Structural Substantiation for an Increased MTOM up to 570 kg

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List of issues and alterations

ISSUE	REASON FOR ALTERATION	PAGES AFFECTED	DATE OF ISSUE
A00	First issue	all	20.07.2020
A01	Correction of the SW121 comparison case and calculation	7,8	30.09.2020

Applicable certification standards

SOURCE	DOCUMENT
/1/	Certification Specifications and Acceptable Means of Compliance for Light Sport Aeroplanes CS-LSA, Amendment 1, 21 July 2013
/2/	ASTM F2245-12d, Standard Specification for Design and Performance of a Light Sport Airplane, ASTM International, West Conshohocken, PA, 2012, www.astm.org
/3/	Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes CS-25, Amendment 22, 5 November 2018

Affected paragraphs of the certification specification

This report deals with, or shows compliance with the following paragraphs of the certification specification:
CS LSA.10 Referenced Standards
CS LSA.15 Applicable Specifications

F2245 12d 5 Structure

AMC 25.307 Proof of Structure

Referenced documents

/1/ SR-164-01-10-001 A00 Alpha BCAR-S 164 Similarity Report
/2/ POH-167-00-40-050 A02 Pilots Operating Handbook
/3/ ST-121-57-00-002 A00 Virus SW 121 Static Test of Wing – Part 2
/4/ LA-121-03-00-001_A04 V-n Envelope

Contents

1 Preface

The intention of this report is to substantiate the structure of the Alpha Electro 167 in case of an increased MTOM to 570 kg from the initial 550 kg. This validates the aircraft structure also for the case of 560 kg MTOM. The report will compare the loads on the wing between the Alpha Electro 167 and the Virus SW 121, which was type certified under CS-LSA for MTOM of 600 kg.

For brevity, in the following text the aircraft names are abbreviated as follows:

- Virus SW 121 → SW121, VSW121
- Alpha Electro 167 → AE167
- Alpha BCAR-S 164 → AT164
- Alpha Trainer 161 → AT161

The wings of Pipistrel Virus and Alpha aircraft families are very similar in terms of geometry, structure and loading. A similar comparison exercise was already performed in the past on the AT164 for the British market. Incidentally, the structure of wings used on AT164 is the same as the one on AE167, except for the top shell of AE167 having no airbrake orifice. The latter is structurally detrimental, as it warrants reinforcements around the orifice, resulting in local stress concentrations. In other words, the AE167 wing, without an orifice is structurally better than the one used on AT164. Therefore, the document *SR-164-01-10-001 Alpha BCAR-S 164 Similarity Report* will be referenced to for the data pertaining to the comparison between the AE167 and SW121 wings.

Finally, the report will show compliance of the Alpha Electro 167 to CS-LSA requirements. In lack of a better officially accepted approach to show compliance for similar structures, the framework outlined in AMC 25.307 is used as a basis to facilitate the substantiation. The same approach was used to substantiate almost the entire structure of Velis Electro for its CS-LSA type certification and consists of five steps outlined below:

1. Classification of Structure
2. Justification of Structure
3. Need and Extent of Testing
4. Certification Approach
5. Interpretation of Data

2 Wing substantiation

2.1 Classification of Structure

As already explained in the preface, the AE167 wing may be considered identical to the AT164 wing, except for the lack of the airbrake on AE167, which is structurally better. Furthermore, the AT164 wing structure without control surfaces is identical to the AT161 wing, which is important, since the referenced report [1] for AT164 substantiation compares the AT161 and SW121 wings.

In summary, the AE167 wing structure is identical to the AT161 wing structure, except the lack of airbrake in AE167. This is important since the design differences referenced from [1] compare the AT161 and SW121.
The following texts are cited from *SR-164-01-10-001 A00 Alpha BCAR-S 164 Similarity Report* [1]:

"*The AT161 wing design is similar to the VSW121 wing design. In fact the spar shear web and the ribs are the same, while the spar caps and the skin have minor differences which are described below.*

…

Spar cap differences between the AT161 and the VSW121 are the different composite layer lengths and the slightly different layers utilized, implying a different total roving length for two aircraft's spar caps.
AT161 total roving length of the upper spar cap is 76.6 m, while for VSW121 is 85.1 m. Similarly, for the AT161 lower spar cap the total roving length is 71.8 m, while for VSW121 is 79.9 m.

The AT161 upper and lower spar caps have two roving strands less than the VSW121 spar caps. AT161 upper spar cap is composed of 38 strands while the VSW121 upper spar cap has 40 strands. AT161 lower spar cap is composed of 36 strands while the VSW121 lower spar cap has 38 strands. So, the AT164 spar cap is roughly 5% weaker than the VSW121 spar cap.

…

The AT161 wing skin has basically the same composite layer layout as the VSW121 wing, but the C200 layers used in VSW121 wing are replaced with C160 in AT161 wing. So, AT164 has some carbon layers with lower areal weight therefore a lower wing torsional stiffness. Anyway, the wing section inertia has a prevalent effect over the lower wing torsional stiffness, with the result that AT161 wing eigenfrequencies are slightly higher than VSW121 wing eigenfrequencies.

…

Also, the AT161 wing tips have straight horizontal and rounded tips, while the SW 121 wing tips get an additional downward bending that can be noticed in Figure 1 (see in [1]). *This different wing tips shape results in a different span for the two aircrafts: 10.5 m for the AT161 and 10.7 m for VSW121, implying a small load reduction for the AT161.*"

As shown above, the structure of the AE167 wing uses the same structural design concepts such as details, geometry, structural arrangements, load paths and materials as the SW121 wing structure with minor differences in terms of amount of material. On this basis, the wing structure is classified as a *Derivative/Similar Structure*.

2.2 Justification of Structure

As the AE167 wing is classified as a *Derivative/Similar Structure*, justifications for the structure are required. Since differences exist only in the skin and spar caps, only those will be considered in this chapter.

As may be derived from the citations in chapter 2.1, the wing skin on AE167 has a slightly lower torsional stiffness when compared to SW121 due to a much lower V_{NE} of 135 KEAS on AE167, compared to 163 KTAS on the SW121. Torsional stiffness is required at high speeds where the pitching moments are greater and flutter could occur. As the topic of this report is the substantiation of the mass increase, not the speed increase, no further investigation is required as the mass increase consequences on the torsional loads are neglectable.

However the spar needs further consideration. The bottom and top spar caps used in AT161 and AT167 are roughly 5% weaker than the ones in SW121, as may be derived from citations in section 2.1.

The most critical loading condition on the wing is positive bending and shear stress. This condition is also affected by the mass increase and will therefore be investigated further. According to CS-LSA the structure must withstand the maneuvering load factor of 4.0 g and the gust load factors at V_C and V_D. The design speeds may be derived from the POH airspeed limitations [2] as follows:

- V_C is equal to V_{NO}, which is: 106 CAS
- V_D my be derived from V_{NE}; according to CS-LSA as $V_D = V_{NE}/0.9 = 150$ CAS

For these two speed conditions, the gust load factor is checked at 570 kg in accordance with CS-LSA:

- Gust load factor at V_C: 3.99 g
- Gust load factor at V_D: 3.11 g

This means, that the critical load condition is the positive maneuver with a 4g acceleration at MTOM of 570 kg.

Since Alpha Electro has no fuel in the wings, the MTOM mass configuration is the most critical and would be comparable to a maximum zero wing fuel weight mass configuration of the SW121. Since the final static test of the dominant design load on SW121 wing was done at the *maxF* mass configuration, which includes fuel in the wings, this needs to be considered in the comparison which follows.

Since the *maxF* mass configuration has a mass of 600kg total, with 22.5 kg of fuel per wing as seen from Figure 1, we must for the comparison subtract 45 kg of the wing fuel mass, which acts as a load relief. The wing mass need not be subtracted, because masses in both cases are almost the same.

	config. .	fuel litre	mass kg	1/2 w.f.F kg
	maxF	62,6	**600,1**	22,5

Figure 1: SW121 *maxF* mass configuration with m=600 kg, 22.5 kg fuel per wing [4].

The conditions of the case which was statically tested for are shown in Figure 2, taken from *ST-121-57-00-002 A00 Virus SW 121 Static Test of Wing – Part 2* [3].

1.1.2 Flight load case - final

		D0001	Dominant sym.pos. B/S		
Nr.	.	11027	11026	11037	.
Name	.	Positive gust g2 - 00.maxF.h1	AB manouevre m2AB - 00.maxF.h1	Positive gust g2 - n1.maxF.h1	.
flight case	.	+gust Vc	+ man.Va	+gust Vc	.
.	.	g2	m2.AB	g2	.
.	.	C	-1,088	C	.
V	km/h	222	185	222	.
n	.	4,48	3,00	4,48	.
q	Pa	2.329	1.616	2.329	.
$C_{L\,a/c}$	.	1,189	1,149	1,189	.
$C_{m\,ac}$	.	-0,120	-0,120	-0,069	.
n_w	.	4,58	3,05	4,54	.
$C_{L\,w}$	.	1,217	1,170	1,206	.
$C_{L\,w}$ (α)	.	1,201	1,156	1,368	.
α	deg.	9,5	8,9	12,3	.
wing	.	.	.	.	.
FE efficiency	%	.	.	.	.
FE	deg.	.	.	.	.
ang.acceler.	s^{-2}	.	.	.	.

Figure 2: SW121 final dominant bending case with m=600 kg, 22.5 kg fuel per wing, positive gust case n=4.48 [3].

Since the SW121 V-n envelope allows for higher airspeeds, the gust loads are considerably higher than the maneuvering loads, therefore this loading condition will be assumed for the comparison.

Assuming that the lift distribution of both wings is the same due to the geometry, the relative difference between the critical bending moment at the root may be quantified based on conditions discussed above as follows:

$M_{Root\ 167} = m_{164} * n_{164} *$Lift arm = 570*4.00*Lift arm
$M_{Root\ 121} = m_{121} * n_{121} *$Lift arm = (600-45)*4.48*Lift arm

Load reduction = (1- $M_{Root\ 167}/M_{Root\ 121}$)*100 = 8.3%

Meaning, that the AE167 will experience a 8.3% lower bending moment at the root compared to SW121. Now since the geometry is the same, the critical internal stress relative difference between the SW121 and AE167 may also be approximated simply as follows:

Internal stress relative change = load relative difference / structural relative difference
Internal stress change = 0.917 / 0.95 * 100 = 0.965 -> 96.5 %

Showing, that the internal stresses on the AE167 with 570 kg MTOM will be 3.5 % lower when compared to SW121.

2.3 Need and Extent of Testing

The AE167 wing structure is a *Derivative/Similar Structure* to the SW121 wing structure and the AE167 wing external loads, internal loads and internal stresses have been proven to be smaller than the ones calculated, tested and approved for the SW121 wing.

Therefore, the wing structure of the AE167 MTOM=570kg needs not to be statically tested.

2.4 Certification Approach

It has been shown and reasoned that the AE167 wing external loads, internal loads and internal stresses are smaller than the ones calculated and tested on the SW121 wing structure. Thus, the certification approach for the wing structure is *Analysis, supported by previous test evidence*.

2.5 Interpretation of data

Based on the discussion shown in previous subsections of this section, the wing structure need not be tested. The proof of structure is instead substantiated by analysis, supported by previous test evidence. Figure 3 shows the bending moment and shear force diagrams of the identified dominant initial case shown with green and the statically tested internal loads of the dominant symmetric positive bending/shear case on SW121:

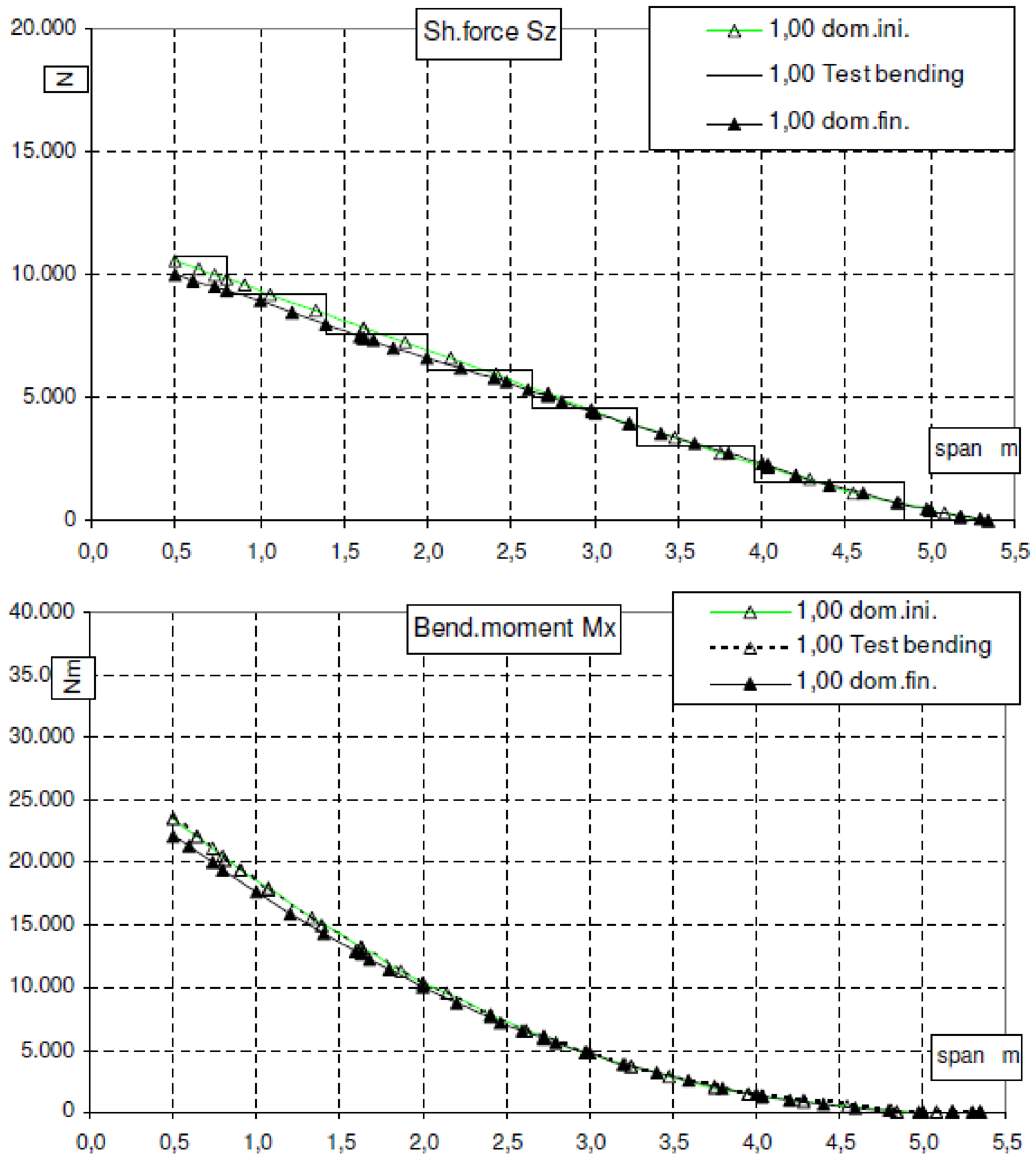

Figure 3: Calculated and tested internal loads on SW121 from *ST-121-57-00-002 A00 Static Test of Wing-Part 2* [3].

Figure 4 shows the conclusion of the test report *ST-121-57-00-002 A00 Static Test of Wing-Part 2* [3] for the test of the dominant symmetric positive bending/shear case on SW121:

5. Pass/fail status	per initial loads	per final loads
Limit test	passed, FSi=1,20	passed, FSf=1,15
FE functionality at limit load	passed	passed
Ultimate test	passed, FSi=1,80	passed, FSf=1,725

Figure 4: Static test results from *ST-121-57-00-002 A00 Static Test of Wing-Part 2* [19].

Therefore, the wing structure on the AE167 with MTOM=570 kg, considering the flight, has been substantiated to applicable certification requirements by analysis, supported by previous test evidence.