29th International Conference
ENGINEERING MECHANICS 2023
Milovy, Czech Republic, May 9 – 11, 2023

SAILPLANE WING SECTIONING BASED ON STRUCTURAL WEIGHT

Dubnický L.[*], Šplíchal J.[**], Juračka J.[***]

Abstract: *High-performance sailplanes use large wingspans, and the wings are split into sections to allow ground transport, storing and maintenance. Sometimes more section variants are available, resulting in different overall sailplane wingspans. Regular wing sectioning nowadays consists of 4 sections, with considerable weight differences between the inner and the outer sections. The option to use 3-piece sectioning is reviewed and combined with 2 wingspan variants. The splitting location, based on the equal weight distribution among the sections, is calculated according to the wing weight distribution model. The following structural design provided a more accurate wing mass value and the weight distribution model. The original and the calculated weight distributions are compared and an improvement is suggested for later application.*

Keywords: Sailplane, Glider, Wing, Sectioning, Weight.

1. Introduction

Current high-performance sailplanes are highly optimized and performance gains between the generations are rather marginal. Manufacturers, therefore, focus on implementing other features that enhance comfort, safety, variability etc. Regarding structural material, sailplanes use exclusively GFRP (glass fiber-reinforced polymer) and CFRP (carbon fiber-reinforced polymer) for the wing and fuselage. Metals are used in landing gear and flight control assemblies. The cantilever monoplane is a dominant concept. Wingspan is typically adapted to FAI (Fédération Aéronautique Internationale) competition categories – for single seaters those are e.g., 15 m, 18 m, or open class with no limit for wingspan. In open class, there is always a strive to bring the highest aspect ratio possible with a wingspan close to 30 m, e.g., Eta and Concordia gliders. A wingspan, that exceeds 18 m but is too short to make a viable open class choice, can still be used to bring a good compromise in performance and handling qualities for non-competition “pleasure” flying.

Sailplanes are always designed for the simple wing and horizontal tail removal from the fuselage. This is necessary for storage and ground transport inside the narrow trailer compartment. The wing is usually split at the fuselage into the left and the right half, those are interconnected with each other and with the fuselage using spar extensions and pins. A higher wingspan can necessitate another split and interconnection between the inner and the outer wing section, to produce reasonably sized parts for storing and transport. This solution, which can be considered a standard, is depicted in Fig. 1. Different variants of the outer wings may be available, to offer variability of the final wingspan. Because the structural weight is determined by the design loads, the inner parts of the wing can become impractically heavy, while the outer ones are significantly lighter (1:5 ratio). Moreover, the inner wing section dimensioning must account for the longer outer sections, resulting in unnecessary mass in configuration with shorter outer sections.

[*] Ing. Lukáš Dubnický: Institute of Aerospace Engineering, Brno University of Technology, Faculty of Mechanical Engineering; Technicka 2896/2; 61669, Brno; CZ, Lukas.Dubnicky@vutbr.cz

[**] Ing. Jan Šplíchal, PhD.: Institute of Aerospace Engineering, Brno University of Technology, Faculty of Mechanical Engineering; Technicka 2896/2; 61669, Brno; CZ, Jan.Splichal@vutbr.cz

[***] Assoc. Prof. Jaroslav Juračka, PhD.: Institute of Aerospace Engineering, Brno University of Technology, Faculty of Mechanical Engineering; Technicka 2896/2; 61669, Brno; CZ, juracka@fme.vutbr.cz

ISSN: 1805-8256, doi: 10.21495/em2023-59

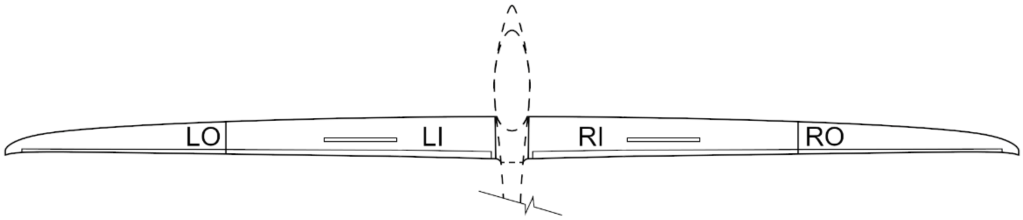

Fig. 1: Regular wing sectioning, 4 sections.

Greiner (2021) on the other hand offers a solution that achieves a different wingspan using the optional inner wing parts. This allows to choose a wingspan either 18 m or 26 m. It is emphasized that such a solution avoids the increased mass in a small wingspan configuration.

Another solution for sailplane wing sectioning is the use of 3 sections: 2 outer sections (left and right) and a middle section. The middle section is continuous through the fuselage, symmetrical to each side and can be fitted on top of a fuselage. The continuous middle section eliminates the interconnection of the wing sections near the maximal bending moment; therefore, it offers weight savings. A similar solution was used on the Nimbus Sailplane (Holighaus, 1969).

2. Method

For sailplane user is beneficial to keep the wing section weights low and rather equalized to allow a single-person rigging of the sailplane (with the use of supporting stands and wheels). Based on the review of the options the wing consisting of 3 parts is designed. Unlike the Nimbus Sailplane, the middle section is designed in 2 span variants – bringing the 18 m or 21 m final sailplane wingspan. See Fig. 2. It can be considered not as effective as the Greiner solution because the middle part is manufactured for each wingspan variant. On the other hand, the use of the middle section eliminates the transfer of the maximum bending moment through the interconnecting elements near the axis of symmetry. The outer sections are joined outwards at the lower bending moment. This solution offers weight savings. It is especially beneficial for thin airfoils, which are going to be used for their high velocity performance. The spoilers are to be designed in the outer sections to avoid airflow disturbance on the tailplane with spoiler extension.

The MTOW (maximum take of weight) for the 18 m variant is set to 600 kg. The 21 m variant MTOW is based on the requirement, to equally use the structural limits of the outer sections in both 18 m and 21 m use. The equal bending moment progression is at 760 kg MTOW for 21 m. Because the lift coefficient and the local chord length distribution are similar, this value results in the same wing loading [kg/m2] between the versions.

To assure the equalized weight distribution, the location of the split and therefore sizing of the sections is to be calculated according to the expected weight distribution of the structure. The intention is to produce similar weighing sections in the 18 m variant. It can be expected the middle section must be shorter than the outer sections because the inner part of the wing distributes higher bending moments, therefore the thicker spar layup is necessary resulting in higher linear weight density.

The weight distribution is prepared prior to wing calculation in order to include self-weight loads. The expected wing mass based on the current designs is expected to be 120 kg for the 18 m version, this means 3x 40 kg sections, 60 kg per side. The preliminary weight distribution is based on the local chord length squared (Dostál, 1962). A local increase in weight density is used for wing sections connection (main spar extension and the opposing pocket), neighboring spoiler installation and wing-fuselage connection. Integration from the wing root and from the wing tip is then used to find the required location for equal section weight. Water ballast is not included, because the ballast water in the wing lowers the bending moments.

After the structural design of the wing, weight distribution based on the internal structure sizing was calculated and it can be compared with the original estimated distribution.

3. Results

The equal weight of the outer sections and the middle section for the 18 m variant is found for the 7/4/7 [m] scheme, 40/40/40 [kg] sections. The middle section of the 21 m wingspan is wider by 3 m from its shorter counterpart giving the 7/7/7 [m] scheme. See the comparison in Fig. 2. The weight of this wider middle section and corresponding MTOW are based on the 18 m weight distribution and the increased bending moment loading of the higher wingspan. The expected mass of the middle section for the 21 m is 64 kg, resulting in 40/64/40 [kg] sections.

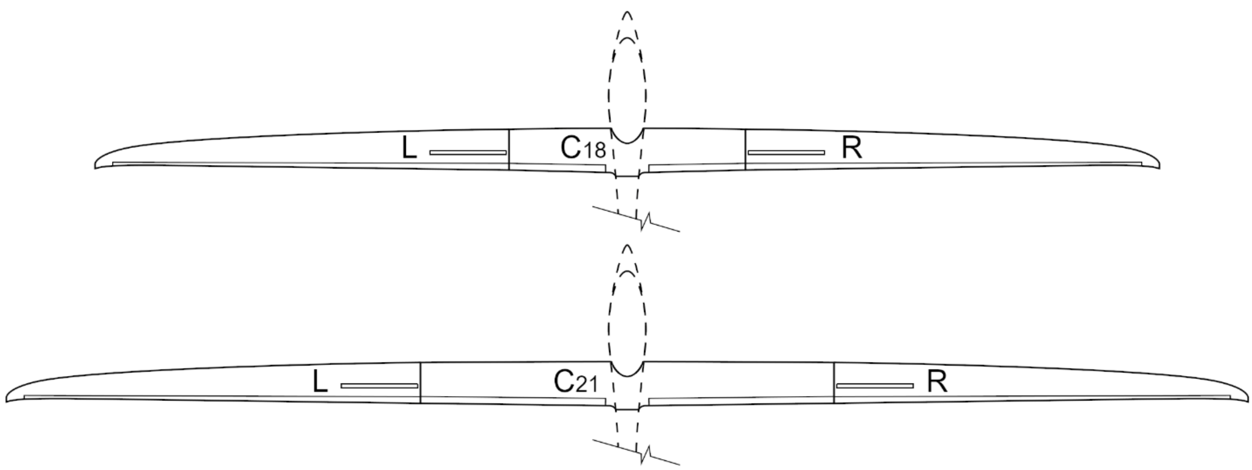

Fig. 2: Resulting three-piece sectioning: Common 7 m span left and right sections, 4 m span middle section for total wingspan of 18 m (above), 7 m span middle section for total wingspan of 21 m (below).

The structural model of each section consisted of complete internal geometry, laminate layups, foams and the estimate of the flight control system weights. The weight of the epoxy adhesive for the final assembly was not included. The resulting weights are 28/36/28 [kg] and 28/62/28 [kg] for 18 and 21 m variants respectively. The weight distributions are compared in Fig. 3.

4. Discussion

The calculated structural mass of the outer sections is lower than the one assumed initially. The final production weight can be expected to be higher than the calculated value. Also, the manufacturing deviations increase the final mass. On contrary, the calculated structural mass of the inner sections is well comparable with the assumed values, but in spite of the lower mass of the outer sections, it can be a coincidence in the distribution model. According to the calculated weight distribution, the section split should be closer to the fuselage by 0,4 m.

The weight distribution model based on the local chord length would be more accurate with higher exponent. In the Fig. 3, the adjusted estimate uses the exponent of 4. The optimum for the equal section weight splitting is rather shallow because the considerable portion of the weight is connected with the splitting. Therefore, the splitting location can be chosen in the certain range according to other design criteria.

It is also possible to alter the conditions and search the equal weight distribution for 21 m variant. This option was also verified, but the 18 m middle section span is too short in that case, which diminishes the gains of lower bending moments in the section connections. This solution can be marked impractical.

To assure the continuous wing planform contour, the middle section must be close to rectangular planform for both variants. Other design decisions including fuselage length, tailplane sizing etc. are not included in this phase of the design. Continuous middle section bending deformation will necessitate a proper solution for fuselage hinges design, which must allow the change in mutual distance and axis orientation.

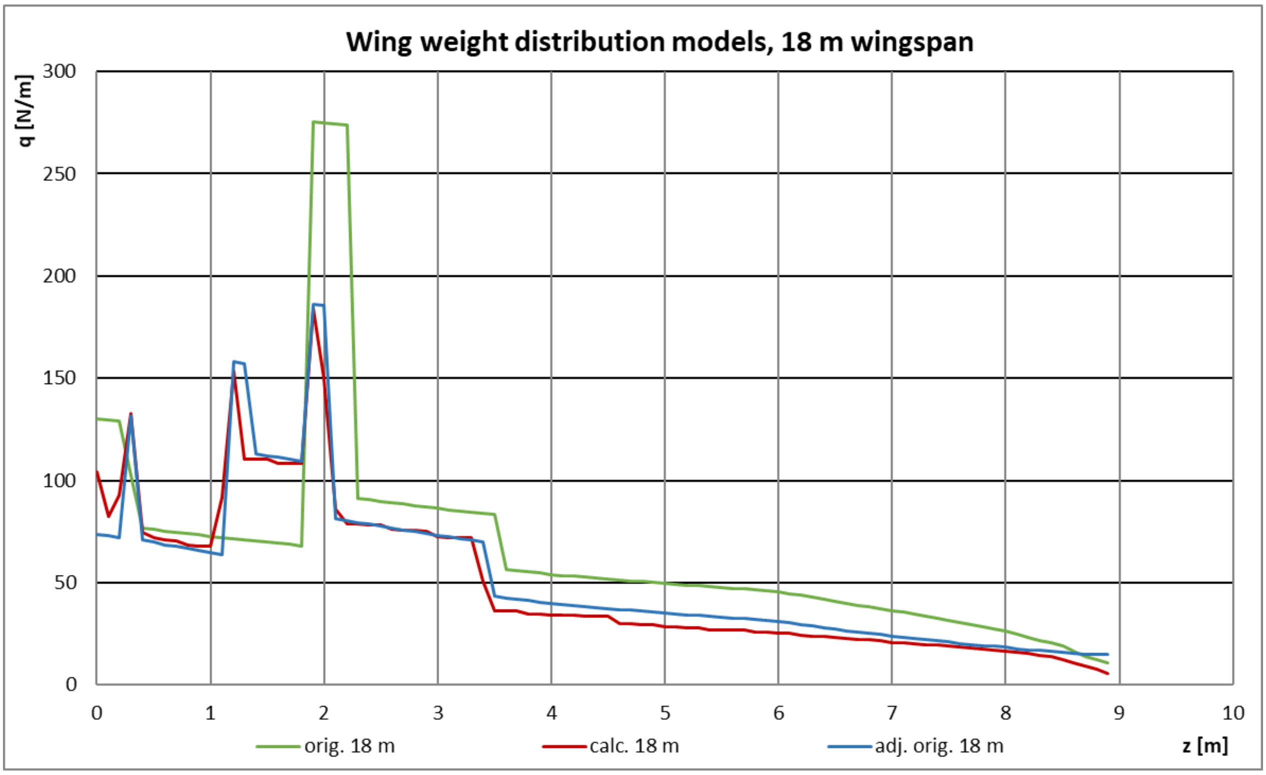

Fig. 3: Weight distribution models showed on the one half of the 18 m wingspan variant, distributions: original 18 m – estimate used for section splitting, based on the (local chord length) squared; calculation 18 m – calculated from the structural design geometry, laminate layups etc.; adjusted original 18 m – improved estimate for later applications, based on the (local chord length) to the power of 4.

5. Conclusion

The sailplane wing design with 3-piece sectioning was presented. The estimated weight distribution was used to identify the splitting location, that ensures the equal section masses. Afterwards, the weight was calculated according to structural design and it was compared with the initial estimate. For similar structure, when using the local chord length for the weight distribution, the exponent of 4, is suitable. In later design phases especially in aeroelastic tailoring this design can lead to conflicting requirements for optimal shape of 18 m and 21 m versions.

Acknowledgement

This work has been supported by the project No. FSI-S-23-8163 funded by The Ministry of Education, Youth and Sport (MEYS, MŠMT in Czech) institutional support.

References

Dostál, J. (1962) Konstrukce a projektování letounu. pp.3. (in Czech)

Greiner, M. (2021) Two birds with one stone (and one trailer), in: Proc. 35th OSTIV Congress, pp. 103-106.

Holighaus, K. (1969) Nimbus: A Sailplane unique in Construction and Performance. Sailplane & Gliding, Vol. 20, No. 2, pp. 100-106

Thomas, F. and Milgram J. (1999) Fundamentals of Sailplane Design. College Park Press