DESIGN OF AN ALL-COMPOSITE WING FROM CARBON FIBERS FOR SMALL TRANSPORT AIRCRAFT WITH MAXIMUM TAKEOFF WEIGHT UP TO 2000 KG

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Objective of this thesis is design of an all-composite wing from carbon fibers for small transport aircraft with maximum takeoff weight up to 2000 kg. The basic building formula is a certification specification CS 23. The thesis carries calculation of basic aerodynamic analysis of wing and its load. Furthermore is a read-in engineering design and FEM calculation.

K e y w o r d s: Profile, wing, load, sandwich, beam, wing skin.

1 INTRODUCTION

During the development of aviation structures, there has always been added an emphasis on effective material using. Trying to find the right balance of safety, working-life, ecological balance and economic efficiency, there is an ambition to develop new materials which are close to these opposite requirements. The introduction of new progressive composite materials has started the out crowding of aluminium alloys, which had been the most used materials in aviation till then. Those materials had found its use in aviation constructions, thanks to the properties, like low specific weight, high fracture toughness, better chemical and atmospheric resistance and high specific strength.

The application of composite materials in aviation constructions for light airplanes or airliners (according to the CS/FAR 23 and 25 rules) is continually raising. Actual requirements on production and potential of decreasing the absolute activity expenses for airliners production are the main reasons for widespread application of composite materials.

2 DEFINITION OF COMPOSITE MATERIAL

A composite material is a combination of two or more materials which form the stiffen elements which ensure the strength and connecting matrices which are used as an adhesive.

Because the composite material is – by contrast to metal materials – anisotropic (especially fiber composites), there is a way to increase the material strength and other characteristics by the right fiber direction orientation and so increase the total material effectivity and efficiency.

Elastic properties of the orthotropic layer for the 3D model are fully characterized by 9 elastic constants:

Young's modulus E_1, E_2, E_3
Poisson's constant ν_{12} ν_{23} ν_{13}
Young's shear modulus G_{12}, G_{23}, G_{13}

2.1 Laminate

It is made from more one – direction oriented same or different material layers, which are variously oriented between each other and stored in matrical material. The orientation is written by a code, in which are the relations between angles of each layers and the main material direction (for example balanced laminate [0/+45//90/-45/90/0]). There is used balanced and unbalanced laminating which can be assigned for foreground deformation if it is right used.

2.2 Sandwich construction

Sandwich constructions consist of light and rigid construction panels, which consist of the core (honeycomb) in the middle and the skin (cover) on the part surface. These three-layer panels are used in wing constructions, control surfaces and fuselage.

3 MAXIMUM FAILURE STRESS CRITERIO

This criterion doesn't expect any interaction between each types of failure. That means that the critical stress for one mode doesn't affects on other modes by its stress. The failure happens when one of these critical merits σ_{1u}, σ_{2u} and τ_{12u} reaches the critical mode. These values are concerned on the main laminate axes

4 DESING AND LOADING CALCULATION OF A COMPOSITE WING

In accordance to the thesis assignment, for wing calculation it is chosen the maximum take-off weight.

$$m_{MTOW} = 2000\ kg = 4409\ lb$$

For this weight, there was designed a flight envelope with accordance to the CS 23.333 regulation, where has been chosen the most unfavourable condition in which the airplane recovers from dive flight. This maneuver is critical for the wing strength in accordance to the force from the lift.

$$n = \frac{L}{G}$$

$$L_D = L_{vod}\ .n$$

In agreement with the constitution equation, the lift force acting during the maneuver is equal to the lift force acting on horizontal flight multiplied with the load factor ratio.

4.1 Pressure distribution on the wing

From the constitution equation has been counted the maximum angle of attack α during a dive flight, which has a value of α=3,68 °. For this point was calculated the distribution of the lift coefficient on the wing in the XFLR5 software.

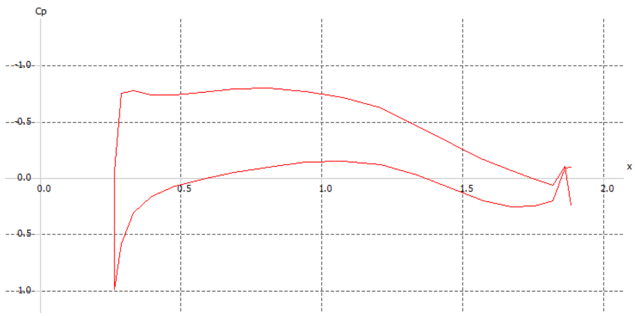

Figure 1. Pressure coefficient cp for α=3.68° (SAT)

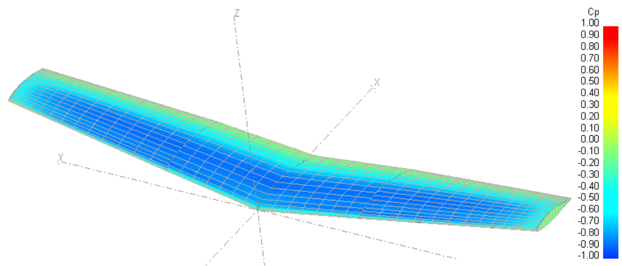

Figure 2. Dissolution cp for α=3.68 Wing - the upper side

5 DESING OF WING CONSTRUCTION

The wing consists of the upper and lower sandwich panel, two main beams and one support beam, tables and seven ribs. The wing is attached by eight 20 mm pins which are mounted in bronze housing glued right in the web.

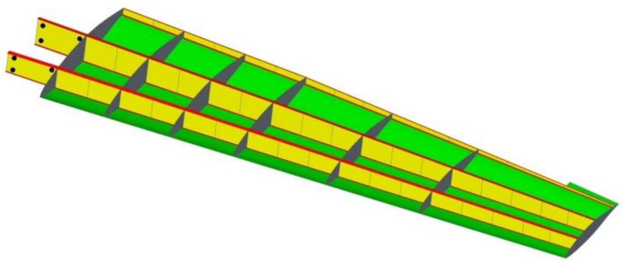

Figure 3. Upper side of the wing

5.1 Wing components material constants

For the calculation were chosen predefined material properties like Transversely Isotropic for the maximum stress criterion using.

5.2 Material orientation definition

Composite materials, as it has been referred in the last chapters, are characterized by different material properties in each direction. That’s the reason why is so important to choose the right material orientation for optimal composite properties applications. The coordinated system has been chosen for each construction part personally (in data position 1, 2, 3).

5.3 FEM calculation

The strength calculations in module Pro / mechanica STRUCTURE are based on the geometric element method (GEM). The principle of this method consist, similar to the finite element method, is based on dividing the analyzed volume to elements. For the required accuracy achieving, there is used the P – adaptive technology.

5.4 Definition of model loading

The model has been loaded with the functional pressure value by each segment which has been taken from the output XFLR5 data, next it has been counted on pressures and imported in a table form (.pts files) defined on a geometric skin area.

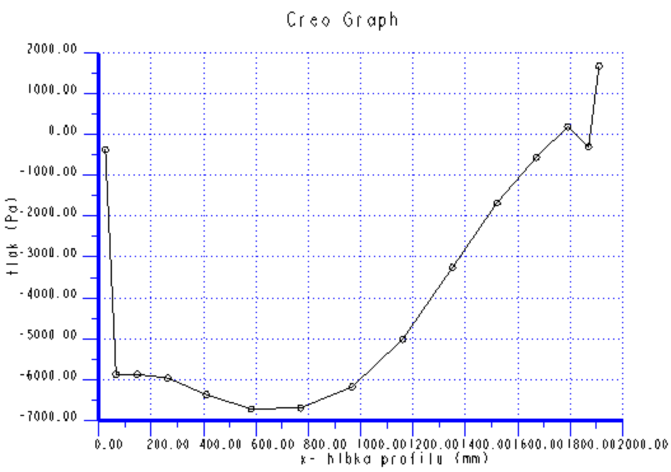

Figure 4. Example of pressure distribution on the vacuum side for root of the wing

For the model analysis was used the static analysis method Multi-Pass Adaptive which is using the P-Adaptive technology, which concludes the calculations with those the user can achieve values like stress, deformation, etc.

5.5 Laminates structure – Analysis of Shell elements

For each area element there has been assigned a material compound. After choose of the beginning compound design of each layer in the laminate and after the optimization, there has been achieved the final state of each layer constitution.

6 RESULTS INTERPRETATION

6.1 Evaluation with the maximum stress criterion

By the FEM analysis there was necessary to take into account the non-uniformity of each laminates and superficial dividing on the model.

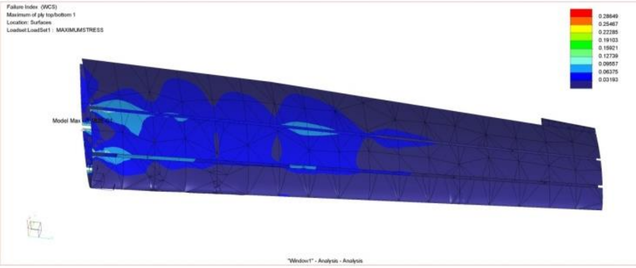

Figure 5. Shell-wing skin, layer 1, the upper side of the wings

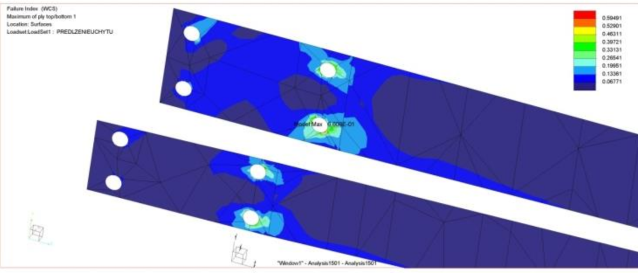

Figure 6. Shell – web, layer 1

6.2 Appreciation

From the past analyses ensures, that the Shell-skin elements don’t exceed the allowed values on any layer on all laminate zones. Critical become the Shell-skin elements in the foam layer.

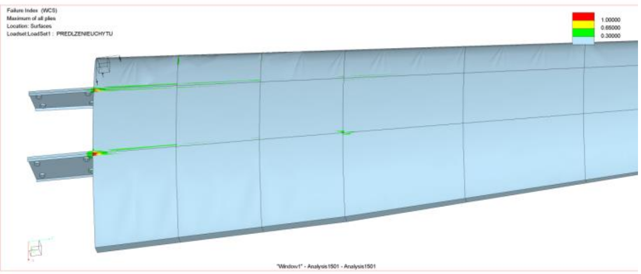

Figure 7. Shell-structure of wing

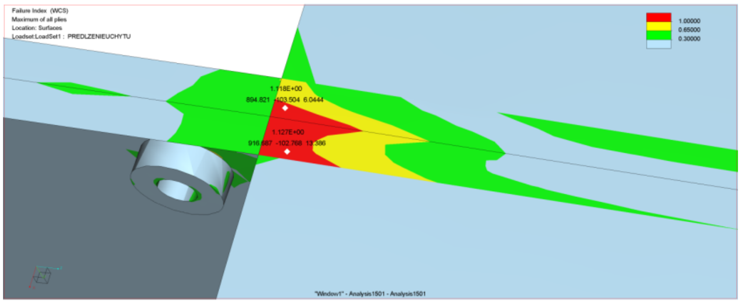

Figure 8. Critical area of the wing skin

A gradual analysis has shown the development of critical stress by the wing length in the table – wing connection for the pulled side of the wing in the foam layer of the sandwich composite.
The deformation of the foam core is in this case ignored, because even if the foam get damaged, it isn’t a suspension element, it only creates a suspension for increasing the effective high of the skin – the skin is bending solid. There is also a question, how is the simulation result real (in reality, 5% high stress is out of consideration).
For the next real implementation of the wing, there is necessary to make static strength tests (which simulates the real loading), further there are requirements on fatigue strength, dynamical stress tests and aeroelastic effects incidence.

7 CONCLUSION

In this thesis is presented a proposal of basic geometric characteristics of wings, design loads according to CS 23 specification for maximum maneuver of flight and optimization design procedure laminate structural wings.

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