COMPOSITE WING OPTIMALIZATION USING FEM ANALYSES SYSTEMS

Miroslav Spišák – Peter Malatin

This article describes the creation of a model wing unnamed air vehicle for the optimal design through the design wings that combine 2D orthotropic composite (Skins) and Isotropic Al materials (and all other structures) and compare them with the same wing perform a reorientation of composite layers of orientation in the skin . Optimal design for each wing with a different orientation layers can be obtained by comparing the stresses and displacements . Modeling structure is completed using 3D CAD system. Finite element modeling is completed MSc in Patran using IGS file as geometry , the element type is used to image the 2D shell elements with QUAD4 element topology and the different parts are connected RBE2 (rigid body element) connection . Static analysis performed using NASTRAN engineering . Obtained by the finite element model is analyzed using the aerodynamic (lift) force is used to simulate the load on the wing surface . The optimal design is found tabular stresses and displacements for each layer combinations.

K e y w o r d s: Composite Wing, Finite element Analysis, Composite Materials, Optimum ply orientation

1 INTRODUCTION

The critical element of aircraft is the design of the wings. Several factors influence the selection of material of which strength allied to lightness is the most important. Composite materials are well known for their excellent combination of high structural stiffness and low weight. Because of higher stiffness-to-weight or strength-to-weight ratios compared to isotropic materials, composite laminates are becoming more popular. Composite structures typically consist of laminates stacked from layers with different fiber orientation angles. The layer thickness is normally fixed, and fiber orientation angles are often limited to a discrete set such as 0°, ±30°, ±45°, ±75°, and 90°. This leads to different combinations of ply orientation and among that one will gives the better results , that is the optimized design for composite structures. A unidirectional laminate is a laminate in which all fibers are oriented in the same direction, cross-ply laminate is a laminate in which the layers of unidirectional lamina are oriented at right angles to each other and quasi-isotropic laminate behaves similarly to an isotropic material; that is, the elastic properties are same in all direction. Unidirectional composite structures are acceptable only for carrying simple loads such as uniaxial tension or pure bending. In structures with complex requirements of loading and stiffness, composite structures including angle plies will be necessary. Since each laminate in the composite material can have distinct fibre orientations which may vary from the adjoining laminates, the optimum ply orientation is also obtained as a result of the parametric study conducted using NASTRAN finite element package by varying the orientation sequence in the composite.

Figure 1: Unnamed air vehicle

2 GEOMETRICAL CONFIGURATIONS

The wing design is an iterative process and the selections or calculations are usually repeated several times. A variety of tools and software based on aerodynamics and numerical methods have been developed in the past decades, there by a reduction in the number of iterations is observed. Normally two spar construction is common in transport aircraft wing design. The spar near to the leading edge of the wing is called as front spar and the spar closer to the aft portion of the wing is called as rear spar of the wing. One end of the spar near the root of the wing is connected to the fuselage called root of wing, the other end towards the tip of the wing is a free end. This configuration is very similar to the cantilever beam arrangement in any engineering structure. Spars and Ribs are connected using L angle fittings. Figure 2 below shows the Location of Spar and Ribs from root of wing and Figure 3 shows the complete wing structure modelled in 3D CAD system.

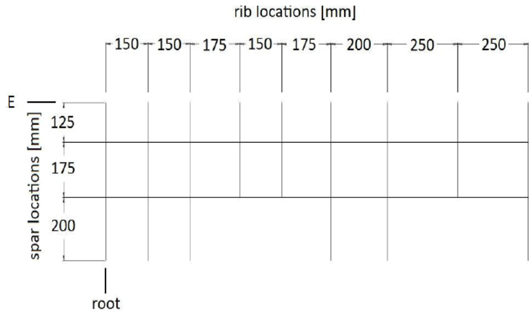


Figure 2: Location of Spar and Ribs from root of wing [mm]

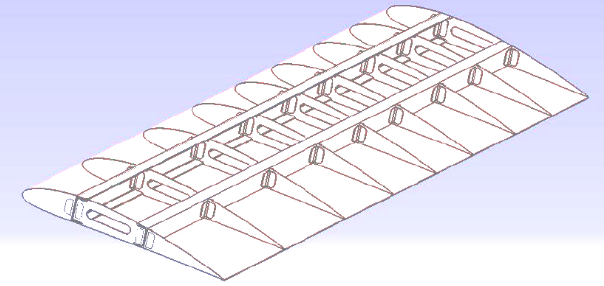


Figure 3: 3D model of Wing Structure

3 FINITE ELEMENT MODELING STRUCTURAL ANALYSIS OF WING STRUCTURE

FE model of the wing structure is as shown in Figure 4. Meshing is carried out by using CQUAD4 shell elements. Verification for the boundary, duplicates is carried out. Normal for each element is assigned. The material properties are assigned to every element in the model. The stress analysis of the wing structure is carried out using the finite element analysis approach. The skin and the ribs were connected by using the equivalence module; and the skin-spar connections were modelled by using RBE2 (Rigid Body Element-2) type multi point constraints. The connections between the members of the inner structure of a wing torque box in practice were generally done by using the fittings and fasteners. The fasteners for the connections were modelled by using RBE2 type multi point constraints.

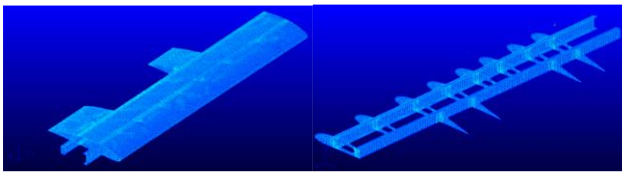


Figure 4: FEA model (meshing) of the wing structure

3.1 Material Property

Physical and Mechanical Properties of used **Isotropic** construction materials		
Materials	**Al 7075-T651**	**Al 2024-T3**
Apication	Spars	Ribs and Fittings
Density	2810 [kg/m3]	2780 [kg/m3]
Young"s Modulus, E	71.7 [GPa]	73.1 [GPa]
Shear Modulus, G	26.9 [GPa]	28 [GPa]
Poison"s Raito, ν	0.33	0.33
Ultimate Strength	572 [MPa]	483 [MPa]
Yield Strength	503 [MPa]	385 [MPa]
Shear Strength	331 [MPa]	283 [MPa]

Physical and Mechanical Properties of used **2D Orthotropic** construction materials		
Materials	**7781 E-Glass Fabric–Araldite LY5052 Resin–Aradur HY5052 Hardener**	**Average Graphite/Epoxy composite material**
Apication	Skin	Skin
Density	1772 [kg/m3]	1580 [kg/m3]
Young"s Modulus, E11	22.1 [GPa]	145[GPa]
Young"s Modulus, E22	22.4 [GPa]	10 [GPa]
Shear Modulus, G12	3.79 [GPa]	4.8 [GPa]
Shear Modulus, G23	2.96 [GPa]	4.8 [GPa]
Shear Modulus, G13	2.96 [GPa]	4.8 [GPa]
Ultimate Compression Strength	249 [MPa]	373 [MPa]
Ultimate Tensile Strength	369 [MPa]	560 [MPa]

3.2 Loads

It was found that, if the aerodynamic force is applied at a location 1/4 chord back from the leading edge on most low speed airfoils, the magnitude of the aerodynamic moment remains nearly constant with angle of attack.

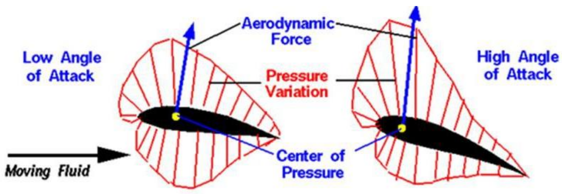


Figure 5: Pressure Distribution in Aerofoil

3.3 Boundary Conditions

The wing structure of an aircraft is connected to the fuselage through keel beam. So the wing structure is act as a cantilever beam connected with fuselage. One end of the wing structure can be fixed and taken as the boundary conditions of the model. This was satisfied by fixing all six degrees of freedom on the nodes corresponding to the fixing point.

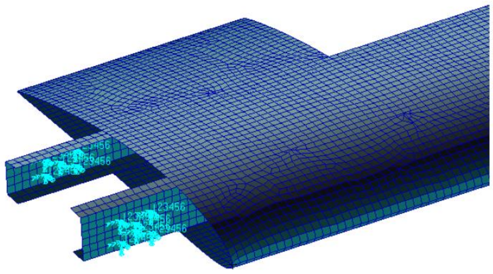


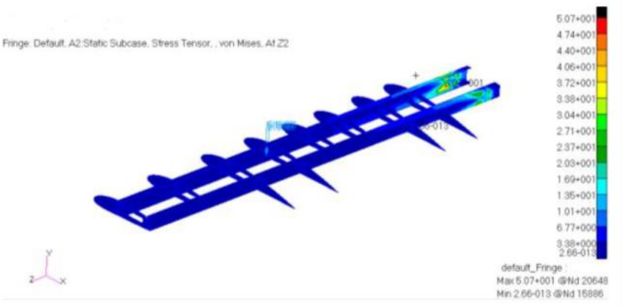
Figure 6: Boundary Conditions Applied on the Wing Structural Analyses

4 RESULTS OF OPTIMALIZATION SIMULATION

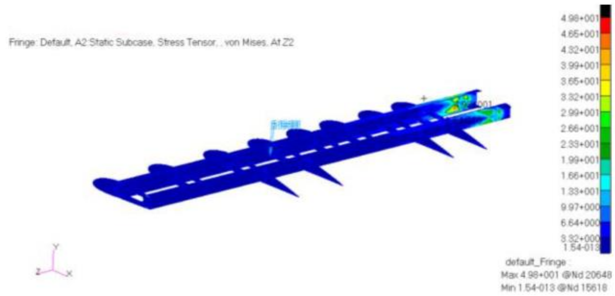
For the purpose of optimization simulation was selected load case: the aerodynamic loading under the cruise conditions. This conditions can simply be defined as $L = W$. The weight of the aircraft under design (unmanned aerial vehicle) is 500N (All-up weight of the aircraft). This load is based on the performance parameters considered for the aircraft. This load will be calculated by the aerodynamic load calculation. When the aircraft is flying at level flight the load factor is equal to „1‟. If the aircraft is flying at „1g‟ condition the load acting on the aircraft will be equivalent to the weight of the structure. Wing is known as lifting component in the aircraft structure. Majority of the lift load will be acting on the wing. The total lift load on the aircraft structure is normally distributed as 80% of the total load on the wings and remaining 20% of the total load on the fuselage. Therefore considering the 80% of lift load on wings, the total load acting on the wings will be equal to 500 X 0.8 = 400N. Therefore the load acting on each wing will be

400/2 = 200N. One end of the wing structure can be fixed and taken as the boundary conditions of the model. A lift load of 200N is applies on center of pressure of the wing for simulating the results. The Ply sequences selected for this study are:

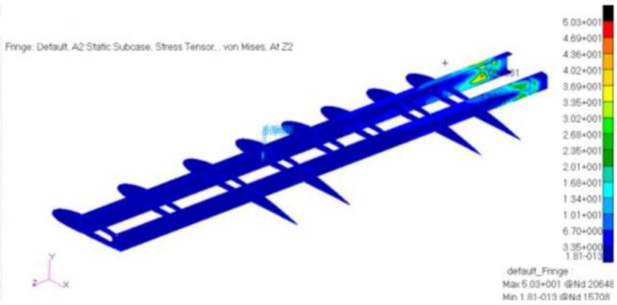
[0/90/+0/-0/90/0], [0/90/+45/-45/90/0], [0/90/+15/-15/90/0] and [0/90/+30/-30/90/0].



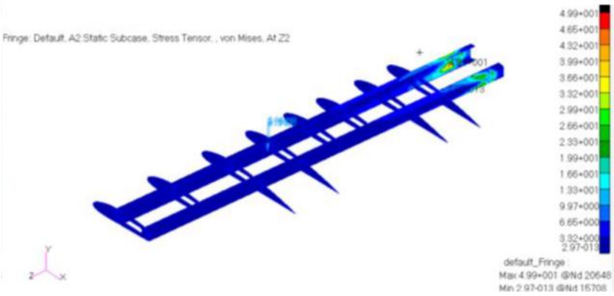
Stress field of the wing structure for ply sequence [0/90/+0/-0/90/0]



Stress field of the wing structure for ply sequence [0/90/+45/-45/90/0]



Stress field of the wing structure for ply sequence [0/90/+15/-15/90/0]



Stress field of the wing structure for ply sequence [0/90/+30/-30/90/0]

The result achieved here is tabulated in the Table 6, from table it clear that the ply orientation [0/90/+45/-45/90/0] gives the better result. So it is considered that the ply orientation [0/90/+45/-45/90/0] is the optimised one.

Table 1: Displacements and Von-Mises stresses obtained for the various ply layout sequences

Ply Sequences Gr/Epoxy	Displacement[mm]	Max Von Mises Stress[MPa]
[0/90/+0/-0/90/0]	4.63	50.7
[0/90/+45/-45/90/0]	4.13	49.8
[0/90/+15/-15/90/0]	4.47	50.3
[0/90/+30/-30/90/0]	4.29	49.9

5 CONCLUSION

The following conclusions are drawn from the studies conducted.

1. The Von – Mises stress distribution in the case of wing is less towards the wings leading and trailing edges and decreases towards the wing tip.
2. The variation in fiber orientation at the same skin thickness will produce the variation in the Von Mises stress (increase or decrease).
3. Maximum values of Von-Mises stress was observed at the support position of the combined wing.
4. The largest magnitude of displacement was obtained at the free end of the combined wing.
5. The replacement of Aluminium alloy by Gr/Epoxy reduces the total weight of the aircraft wing by 23.7%.

BIBLIOGRAPHY

[1] Datoo, M. H.: Mechanics of fibrous composites, London 1991, ISBN: 1-85166-600-1

[2] Chen, A. S. – Matthews, F. L.: A review of multiaxial/biaxial loading test for composite materials, Composites 24, 1993

[3] Juračka, J.: Návrh konstrukce křídla z kompozitního materiálu, *Teze k rigorózní zkoušce*, Brno, 1998

[4] Kábrt, M.: Kompozitní materiály v konstrukci malých sportovních a UL letounů, Zpráva CLKV, Litomyšl, 2000

[5] ESA PSS-03-203 Structural Materials Handbook, Volume 1 Polymer composites, ESA Publications Division, ESTEC, Noordwijk, The Netherlands, 1994, ISSN:0379-4059

[6] Tsai, S. W.: Composites design, 4th edition, 1988

[7] Zagainov, G. I. – Lozino-Lozinsky, G. E.: Composite Materials in Aerospace Design,London, Chapman &Hall 1996, ISBN 0-412-58470-0

AUTHORS´ ADDRESSES

Spišák Miroslav, Ing.
Department of Aviation Engineering
Faculty of Aeronautics
Technical University of Košice
Rampová 7, 041 21 Košice
e–mail:miroslav.spisak@tuke.sk

Malatin Peter, Ing.,
Department of Aviation Engineering
Faculty of Aeronautics
Technical University of Košice
Rampová 7, 041 21 Košice
e–mail:peter.malatin@tuke.sk