

3-D CAD MODELING AND MODAL ANALYSIS OF LIGHT AIRCRAFT WING USING SOLID WORKS AND ANSYS SOFTWARES

Assoc. Prof. M.Sc. Todorov M., PhD
Transport Faculty – Technical University of Sofia, Bulgaria
michael.todorov@tu-sofia.bg

Abstract: The aim of this work is to extract modal parameters of a light aircraft wing. Modal parameters like natural frequencies, and mode shapes characterise the dynamic response of a structure and can be used for determining of the wing divergence and flutter. The CAD (Computer-Aided Design) model plays a pivot role in the design and development phases of an aircraft. Creating drawings, preparing reports of assembly and part drawings, preparing bill of materials, the aircraft design becomes easier and faster with the use of CAD system. CAD model has to be imported in FEM (Finite Element Method) software, and so it can do FE model, which have to be solved. In this work a light aircraft wing is modelled by SolidWorks software. After that the CAD model is imported in ANSYS Workbench. The FE model is generated and solved by using ANSYS Workbench. The first six natural frequencies and mode shapes are shown for the proposed light aircraft wing.

Keywords: AIRCRAFT, WING, CAD, SOLID WORKS, FEM, ANSYS

1. Introduction

Computer-Aided Design (CAD) has wide applicability in the design and development process of an aircraft. CAD is used in creation of 2_D or 3_D virtual models. The benefits of CAD models are increasing rapidly, ranging from shape visualization to its analysis, machining, layout designing and considerable cost reduction [4].

The Finite Element Analysis (FEA) is a computer simulation technique for solving problems of engineering analysis. It uses a numerical technique called Finite Element Method (FEM). The FEM is useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained.

The extensive use of CAD software in the design, combined with the great features of the FEA provides a good opportunity for the study of aircraft structures, in particular of airplane wings [5].

Vibration problems in aircraft structures often involve the excitation of structural resonance or modes of vibration. An example of a severe resonance-related problem during aircraft operation is flutter. Before an airplane is realised, flight flutter tests have to be performed to detect possible onset of flutter. The classical flight flutter testing is to expand the flight envelop of an airplane by performing a vibration test at constant flight conditions, curve-fit the data to estimate the resonance frequencies and damping ratios, and then to plot these frequencies and damping estimates against flight speed or Mach number. The damping values are then extrapolated in order to determine whether it is safe to proceed to the next flight test point. Flutter will occur when one of the damping values tends to become negative. Before starting the flight tests, ground vibration tests as well as numerical simulations and wind tunnel tests are used to get some prior insight into the problem [3, 6]. The first step in such investigation of flutter is to obtain the natural frequencies and modes of the structure.

Moreover, the frequency range is important in the study of loss of static aeroelastic stability of aircraft wing. The smallest eigenvalue of wing determines the critical air flow rate at which the action of the stationary lift the wing deforms due to the elasticity to structural failure.

This research is based on the FEA of the light aircraft wing FEM modeled by CAD. The first six natural frequencies and mode shapes are obtained.

2. CAD Model of the Wing

Complete wing of a light aircraft is modeled in SolidWorks 2012 software consisting of spars, ribs, wing fuselage attachments, skin panels, and wing skin (lower and upper). Control surfaces are not modeled. CAD model of the wing is shown in Figure 1. In the

Figure 1, the canvas skin is not shown, since it provides only the aerodynamic shape of the wing, but does not have a role in the modal and structural analysis. The airfoil is Clark Y. The chord length is 0.940 m, and the wing length is 5.200 m.

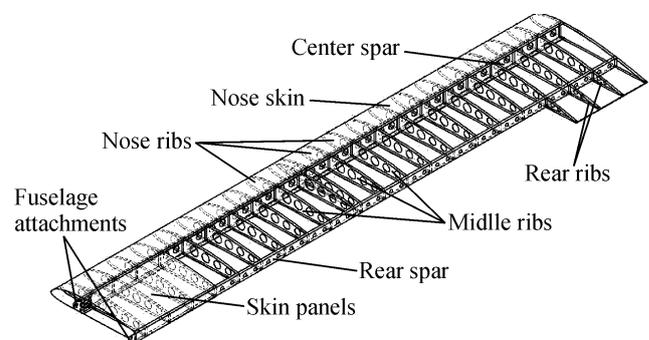


Fig.1 Solid Works model of the wing

2. FE Model of the Wing

The SolidWorks CAD model is imported in ANSYS Workbench 14. The FE wing model uses the patch conforming (tetrahedrons) mesh [2]. It has 196 610 nodes, and 94 986 elements. Size of the mesh is set manually to obtain the maximum thick mesh and taking into account the capabilities of the PC to solve the task. The option Advanced Size Function is used for shell models. The finite element mesh is shown in Figure 2.

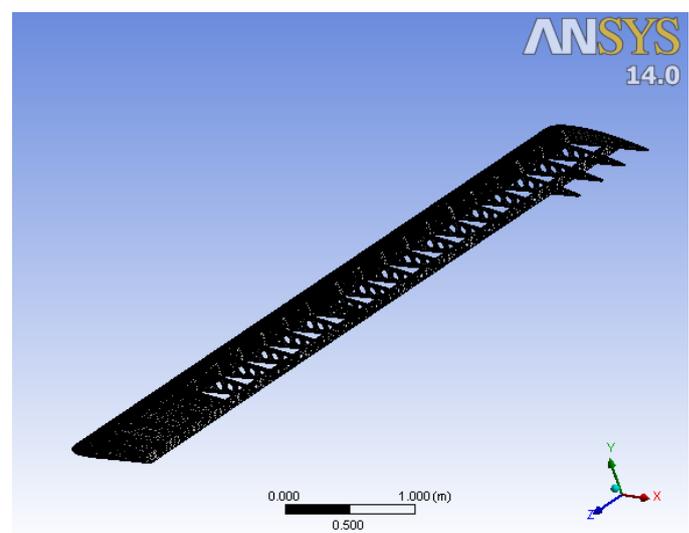


Fig.2 Finite element model of the wing

The wing is treated as a cantilevered beam, which is fixed at the fuselage attachment (all DOF), as it is shown in Figure 3.

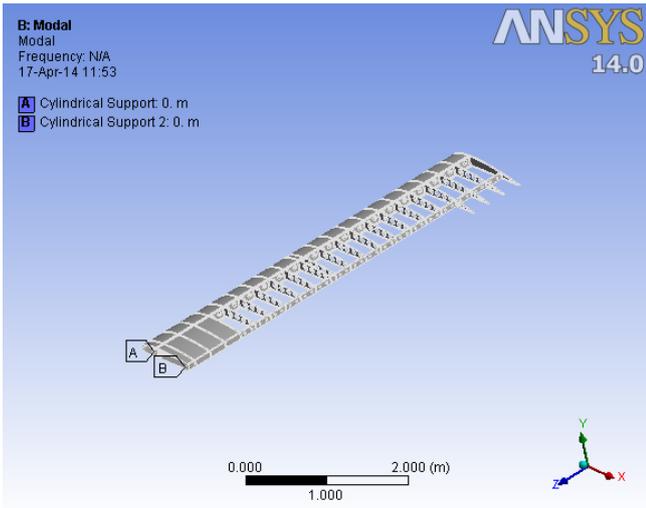


Fig.3 Finite element model applying boundary conditions

The material properties used in this study are:

Aluminum alloy with Young’s modulus 2×10^{11} Pa, and Poisson’s ratio 0.3.

To solve the problem the Block Lanczos method is used [1]. This method is very appropriate where there are complex models with a mixture of solids/shells/beams etc. Moreover, the modes in the frequency range can be easily extracted. The general equation of motion is

$$[M]\{\ddot{q}\} + [C]\{\dot{q}\} + [K]\{q\} = \{F(t)\}$$

where $[M]$, $[C]$, and $[K]$ are the mass, damping and stiffness matrixes respectively. It is assumed that the vibrations are free and the damping is ignored:

$$[M]\{\ddot{q}\} + [K]\{q\} = \{0\}$$

It is assumed that there is a harmonic motion, (i.e. $q = Q \sin(\omega t)$)

$$([K] - \omega^2 [M])\{q\} = \{0\}$$

The roots of this equation are ω_i^2 , the eigenvalues, where i ranges from 1 to number of DOF. Corresponding vectors are $\{q_i\}$, the eigenvectors. The square roots of the eigenvalues are ω_i , the structure’s natural circular frequencies. Natural frequencies Ω_i are then calculated as $\Omega_i = \omega_i / (2\pi)$. It is the natural frequencies Ω_i that are input by the user and output by ANSYS. The eigenvectors $\{q_i\}$ represent the mode shapes – the shape assumed by the structure when vibrating at frequency of Ω_i .

3. Results and Discussion

The analysis is done in ANSYS Workbench 14 software. The first six natural frequencies and mode shapes are shown in Figures 4 – 9, and Table 1.

The presented results show that four frequencies (3.22 Hz, 11.32 Hz, 23.35 Hz, and 68.83 Hz) are typical bending oscillations. The frequency 34.22 Hz is typical twisting oscillations. The bending and twisting oscillations are connected at the frequency of 59.60 Hz.

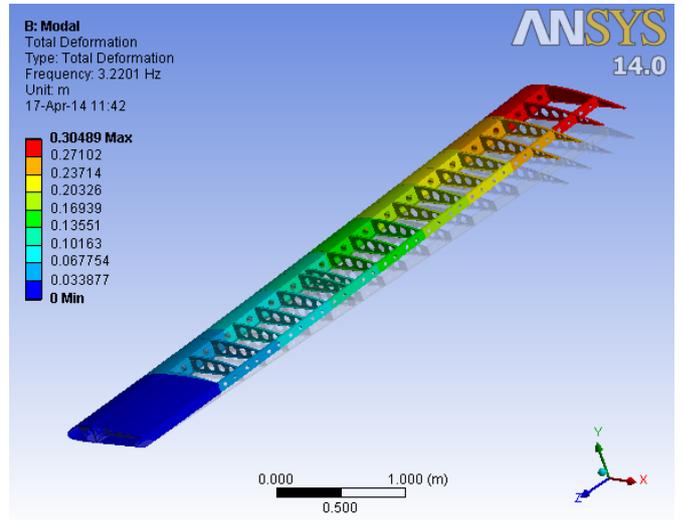


Fig.4 First vertical bending mode

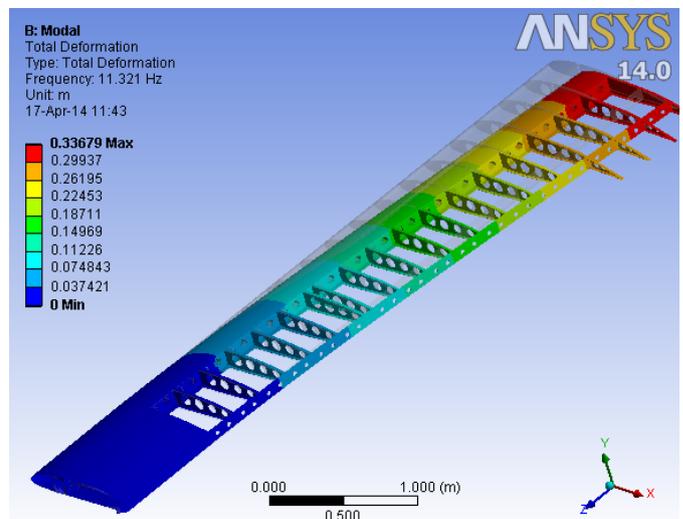


Fig.5 First horizontal bending mode

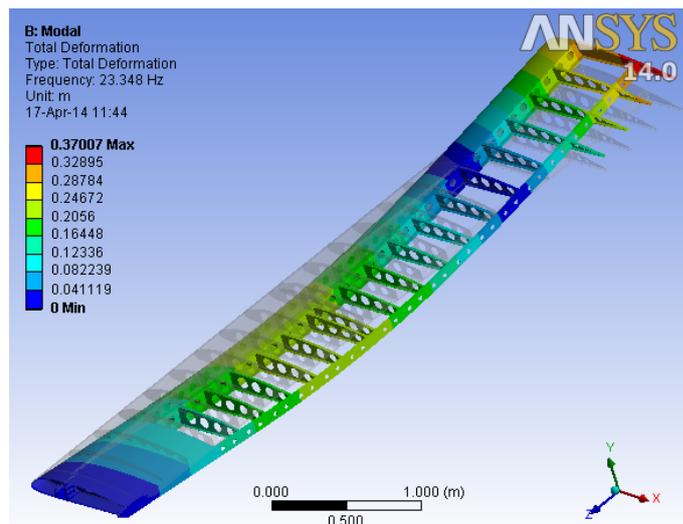


Fig.6 Second vertical bending mode

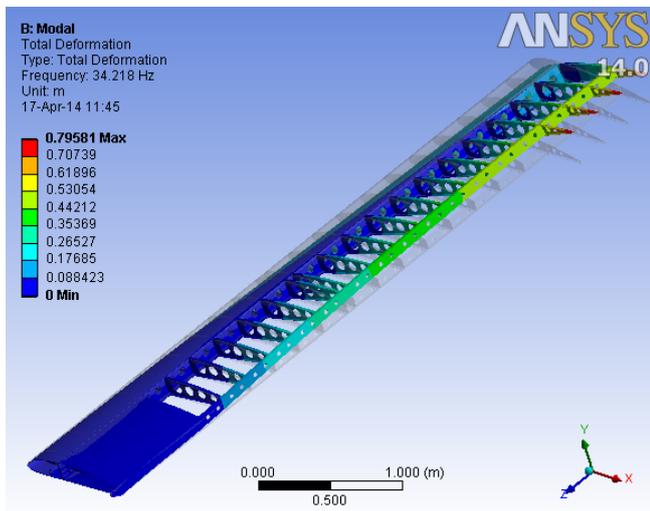


Fig.7 First twisting mode

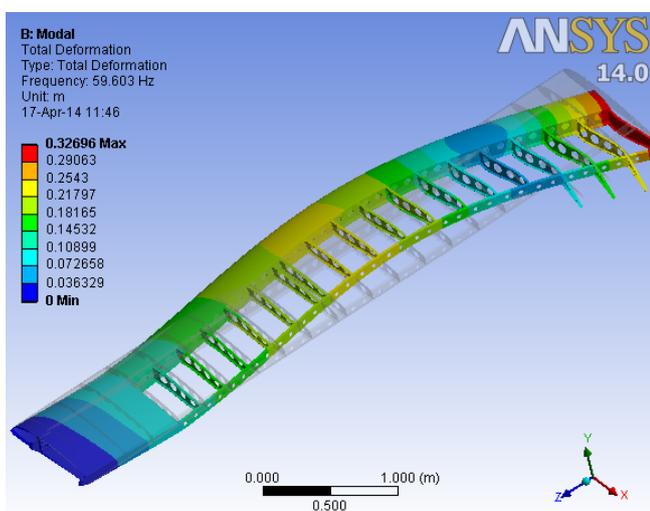


Fig.8 First vertical/horizontal bending mode

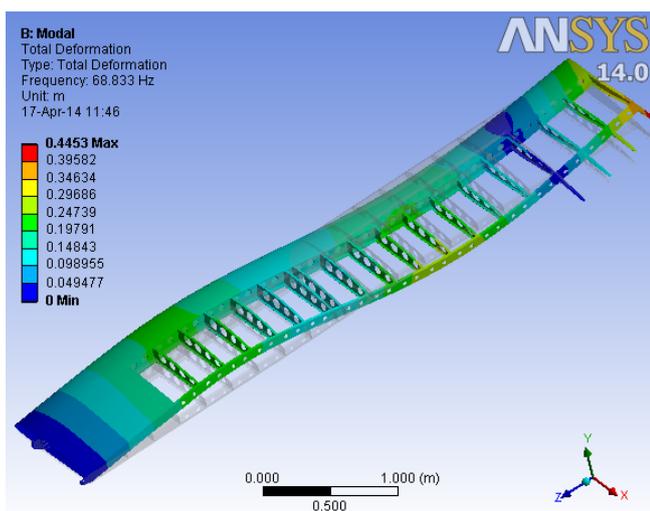


Fig.9 Third vertical bending mode

Table 1: Natural frequencies of light aircraft wing

	Natural frequencies, in [Hz]
First vertical bending mode	3.22
First horizontal bending mode	11.32
Second vertical bending mode	23.35
First twisting mode	34.22
First vertical/horizontal bending mode	59.60
Third vertical bending mode	68.83

In terms of the loss of static stability the lowest frequencies of 3.22 Hz (first vertical bending mode) and 34.22 Hz (first twisting mode) are of particular importance.

From the viewpoint of flutter the frequencies 3.22 Hz, 23.35 Hz, 59.60 Hz and 68.83 Hz (defining the vertical bending and vertical/horizontal bending modes) are very important.

3. Conclusion

CAD modeling of the light aircraft wing was done in SolidWorks. The model was imported in ANSYS, and modal analysis was made. The Block Lanczos method was used. The first six natural frequencies and corresponding modes were presented.

The future scope of work will be to perform the modal analysis of the same aircraft wing, but with a support structure. So we can see its influence on the modal parameters and how to avoid the loss of static stability and flutter because of support structure.

References

- [1] ANSYS Workbench User's Guide, Release 13.0, October 2010.
- [2] ANSYS Meshing User's Guide, Release 14.5, October 2012.
- [3] Agarwalla D., Parhi D.: Diagnosis of Modal Characteristics of Aircraft Wing Model Subjected to Irregularities, The International Journal of Engineering Science Invention (IJESI), 2013, pp.06-10.
- [4] Khan H., Usama M., Ahmad R., Rasool I.: 3-D Modeling and Analysis of Aircraft Wing Usin CATIA@Software and its Comparison with ANSYS@Software, Journal of Advances in Production, Automation and Transportation Systems, pp.19-22.
- [5] Rajappan R., Pugazhenth V: Finite Element Analysis of Aircraft Wing Using Composite Structure, The International Journal of Engineering and Science (IJES), Vol.2, Issue 2, 2013, pp.74-80.
- [6] Vulich Z.: Modal Parameters of Light Aircraft Wing, Proc. AIAC-11 Eleventh Australian International Aerospace Congress, March 13-17 2005, Melbourne, Australia.