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Finite Element Analysis of Wing Vibration Characteristics

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Abstract: Airflow disturbance is likely to cause bending deformation, torsional deformation and even damage of the wing. Each structure of the aircraft has its natural frequency. In order to prevent the aircraft from vibrating and causing the wing to deform, it is necessary to perform modal analysis on the aircraft wing. There are many advantages to modal analysis: it can provide guidance for structural design to avoid it. Resonance can either cause the structure to vibrate at a specific frequency. Modal analysis of the wing of the aircraft can obtain the mode of the wing at various frequencies, and obtain the relationship between the vibration frequency and the strain. In this paper, the modal analysis of the wing of an aircraft model using Mechanical APDL (ANSYS) is carried out to determine the modal frequency and mode shape of the wing, and the vibration characteristics of the wing are obtained through analysis to provide a basis for aircraft development.
Keywords: Wing vibration, modal analysis, ANSYS.

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1. INTRODUCTION

The wing is an important structure of the aircraft. Its main function is to generate lift and to make the aircraft have lateral stability and operability. In addition, the landing gear, fuel and other equipment can be installed on the wing. Using the Ansys finite element method for modal analysis, dynamic response analysis (modal, flutter, chattering, etc.), instability analysis, damage tolerance analysis, structural optimization design, Ansys finite element analysis for aircraft Wing design, manufacturing, use and maintenance, war damage assessment, etc. have a strong practical significance [1]. The correct analysis of the structural characteristics of the wing structure and the application of boundary conditions and loads are the basis and focus of the finite element analysis, which determines the correctness and effectiveness of the analysis results. The following is a case of a certain type of light aircraft. Modal analysis. The modal analysis response of the wing and the additional dynamic analysis response can reflect the stress, strain concentration, and concentrated areas where severe bending and torsion deformations are mapped. These locations map the weak areas of the stiffness or strength of the wing structure design. Through simulation, it is found that the structural area needs to be strengthened, and the occurrence of vibration accidents is fundamentally avoided.

2. WING STRUCTURE DYNAMICS MATHEMATICS

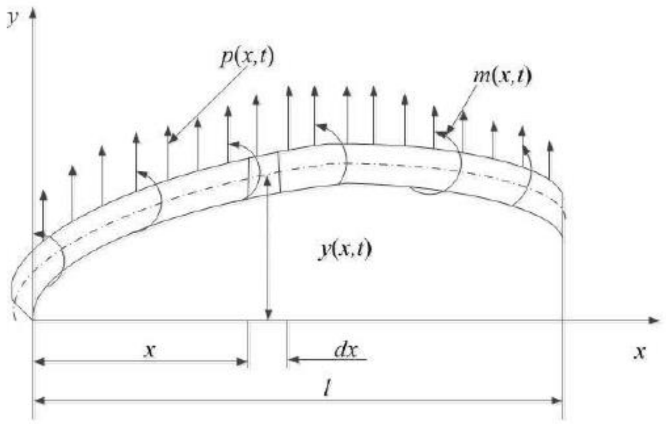

Figure 1. Force of lateral bending vibration of the wing structure

The natural frequency and mode shape analysis of the wing structure is a prerequisite for dynamics research. The key to solving the wing vibration problem is to determine the vibration characteristics of the system. The vibration theory of the wing model is similar to the cantilever beam [2]. Figure 1 shows the force applied when the equal-section wing is bent laterally. Assume that the central main inertia axis and the external force of each section of the wing (considered as an equal-section wing) are in the same plane, the wing vibrates laterally in this plane, and the bending deformation is dominant, then the wing is at low-order frequencies. The effect of shear deformation and the moment of inertia of the section around the neutral axis can be ignored. It is known that $y(x,t)$ is the longitudinal coordinate of the section of the wing structure from the origin x at time t, $p(x,t)$, $m(x,t)$ is the external load and external moment applied to the wing of unit length, ρ is the density of the material, and E is the elastic mode of the material. Volume, A is the airfoil area of the wing $J = \int_a y^2 dA$ Is the moment of inertia of the airfoil to the neutral axis?

3. THEORETICAL MODEL OF FINITE ELEMENT VIBRATION CHARACTERISTICS

3.1 modal analysis model

The free vibration of the linear system is decoupled into N orthogonal single-degree-of-freedom vibration structures, ie the N modes of the corresponding structure. The vibration mode refers to the relative value of the displacement generated by all points on the structure when the natural frequency of a certain order is excited. The vibration modes corresponding to different natural frequencies are different. Modal analysis [3] is to analyze the natural frequencies of each order of the system, and the natural modes corresponding to the frequencies of each order. It is generally divided into experimental analysis and computational analysis. The former uses the method of experiment combined with theory to obtain modal parameters, the latter is the finite element solution is used to obtain the modal parameters of the system. Modal analysis can be used as a way to study the vibration characteristics, mainly to determine the modal parameters of the structure, and provide reference for the study of vibration characteristics of the system, vibration fault identification and evaluation, and optimal design of system dynamic characteristics [2]. In fact, each system has an infinite number of natural frequencies. These natural frequencies are a series of discrete values. Since external excitations are more likely to approach lower-order frequencies, we usually focus on the first six orders of low-order frequencies and their corresponding modes. Response. The modal analysis of the structure is the premise of other vibration characteristics analysis. The various modes of the structure are analyzed to better analyze the vibration characteristics of the structure.

3.2 Analysi s of finite element dynamics model of wing

The profile of the aircraft wing parallel to the plane of symmetry of the aircraft or perpendicular to the leading edge is called the airfoil or wing profile [4]. With the continuous development of aviation technology, various airfoil series have gradually formed. In this paper, the airfoil model is used to model, and the modal response is compared with the theoretical calculation results of the wing to verify the reliability and accuracy of the Ansys Workbench finite element analysis.

3.2.1 Establishment of the wing model

First, select a wing data file found on the Internet, import the finite element modeling software, generate the airfoil, and stretch it into a solid wing model of equal section, as shown in Figure 2.

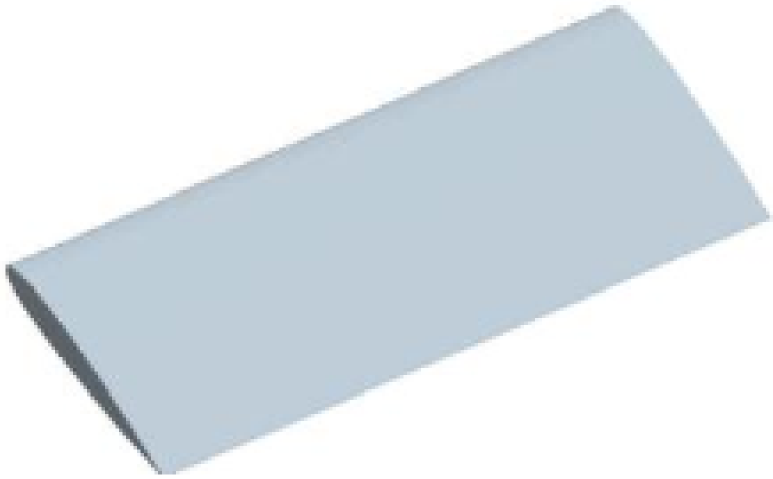

Figure 2. NACA0012 wing model

3.2.2 Modal analysis of the wing

When the wing performs its modal analysis under static conditions, only the gravity of the wing itself is considered, and the natural mode response and natural frequency of the wing under this condition are simulated.

First, modal simulation analysis

Add the wing skin material to low density polyethylene. The specific parameters are shown in Table 1. Reasonably divide the mesh, fix the wing root surface, and select Standard Earth Gravity as the steady-state external load. The AnsyWorkbench is used to analyze the natural mode and natural frequency of the wing model.

Table 1. LY12 alloy parameters

ElasticModulus(E, GPa)-	Poisson Ratio(ε)	ShearModulus(ν, GPa)	Density (ρ, kg/m3)
71	0.3	27	3800

Second, modal analysis of the wing

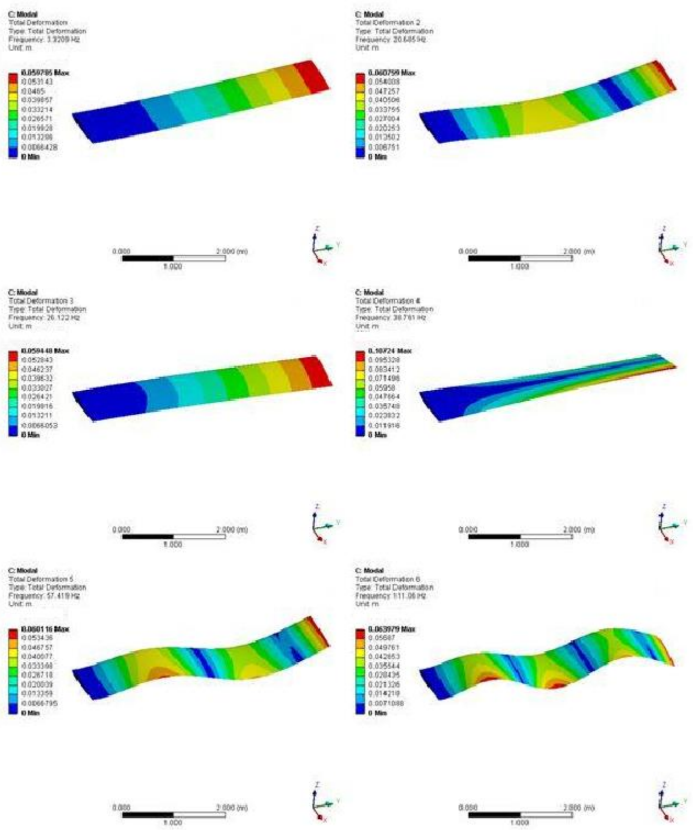

Figure 3. The first six modal modal responses under static conditions

Create a modal analysis module based on the static analysis and share the geometry data in the Static Structural module in Modal, which automatically creates a data connection. Table 2 shows the first six modal frequencies under static conditions, and Figure 3 shows the modal response of the wing under static conditions.

Table 2. Frequency of each order under static conditions

Modal order	1	2	3	4	5	6
frequency	3.2209	20.685	26.122	38.761	57.417	111.06
Mode shape	a bend	a bend	Twisted expansion	One twist	Two bends + one twist	Bending and torsion

Observing the first six modes of the wing, it is found that the shape of the wing becomes more complicated with the increase of frequency; the maximum deformation displacement of the first, second and third order vibrations is mainly concentrated in the 100% half-wing area. And the trend is increasing along the semi-span direction; the maximum deformation displacement of the fourth-order vibration is mainly concentrated in the rear edge position of the 60%-100% semi-wing region; the maximum deformation displacement of the fifth-order and sixth-order vibration displacement vibrations is concentrated in The rear edge position of the 22%, 60%, 70% half-wing area and the position of the 100% half-wing area.

4. CONCLUSION

There are often some uncertain factors in modeling. If the model is established reasonably, Ansys Workbench can give very close to the actual results. To analyze the dynamic characteristics of the wing structure, to accurately calculate the natural frequency theoretically, an accurate dynamic finite element model must be constructed, and the accuracy of modeling and analysis must be verified by experiments. Under the current data conditions, by analyzing the vibration characteristics of the finite element model of the wing, it can be seen that the vibration mechanism of the wing is burst-type vibration with the main wing twisted and the bending mode involved; under the basic design state The vibration characteristics of the wing meet the requirements of the vibration envelope. At different vibration frequencies, the modalities of the wings are different, the types of deformation are different, and the deformations are different. In actual design of the wing, it is necessary to consider the frequency of vibration in the flight environment of the aircraft to avoid excessive deformation of the wing and affect flight safety. For the airfoil in this paper, the flight environment under fourth- and fifth-order vibrations should be avoided. If the vibration frequency is within this range, the design of the airfoil needs to be changed and analyzed.

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