Analysis of UAV wing load calculation

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Abstract. According to the existing wing structure design cases, design a simple model of the UAV wing according to the engineering needs, and use the flow-solid coupling function of the ansys finite element analysis software to calculate the working load of the wing structure.

1 Introduction

Unmanned aerial vehicle (UAV, UAV; colloquially also “drone” or “drone”, from English drone) is an aircraft without a crew on board.

UAVs can have varying degrees of autonomy, from remotely controlled to fully automated, and also differ in design, purpose, and various other parameters. Drones can be controlled by issuing periodic or continuous commands; in the latter case, they are known as remotely operated vehicles (ROVs). UAVs can perform reconnaissance missions (currently their main task), strike at ground and sea targets, intercept air targets, carry out jamming, fire control and target designation, transmit information and data, and deliver cargo.

Drones have two outstanding advantages over manned aircraft.

The first is that drones can replace manned aircraft and get closer to targets.

perform various combat missions in the depth of the affected area, reducing the risk to the pilot's life to zero.

Secondly, UAVs offer a high cost-benefit ratio in carrying out their missions.

In order to meet the increasingly high demands placed on aircraft structures, composite materials are increasingly being used in the design of aircraft structures. With the rapid development of aviation technology, the application of composite materials in unmanned aerial vehicles has gradually evolved from secondary load-bearing structures to main load-bearing structures. As a typical main load-bearing structure, the design and optimization of the composite wing structure has become a research hotspot in the aviation field due to its large size and complex forces.

This dissertation takes a certain type of unmanned aircraft as an example and uses finite element analysis software to analyze and calculate the workload of a composite wing structure according to engineering needs and existing wing design options. First, according to the existing wing structure design cases, the UAV wing structure is designed according to engineering needs, then the lift coefficient and drag coefficient of the wing structure are calculated by the Fluent finite element analysis program, and finally the finite element

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analysis program used to calculate the wing workload using the fluid-solid analysis function.

2 The use of composite materials in UAV structures

2.1 Characteristics of composite materials

With advantages such as light weight, design stiffness, fatigue strength and corrosion resistance, composite materials can significantly reduce the weight of structures and effectively improve aircraft performance. composite materials can be cut to meet different load-bearing capacity requirements to increase structural efficiency and reduce structural weight. the most important design feature of composite structures is the large design space. in addition to traditional geometries, design parameters include paving sequence, paving ratio, and laminate paving angle. to solve the problem of optimizing the design of various parameters of composite structures, the method of structural finite element analysis and optimal design is usually used.

2.2 Current state of research in the field of optimal design of composite structures

Composite structure design optimization research for a wing mainly includes two aspects, first, for a typical composite laminated structure, mainly considering various constraints and target functions, creating various optimization models, and conducting research on related optimization algorithms; second, for specific engineering problems, optimization of the design of the composite structure.

For composite layered structures: Zehnder N, Omprakash Seresta conducted a study on the optimization of composite materials using genetic algorithms for the structure of layered plates; Abouhamze M applied genetic algorithms and neural network algorithms to optimize the number of layers and the sequence of layers of composite plates; Lin C C, MucA, Park J H investigated the optimization of composite structures by combining genetic algorithms and finite element methods; Omprakash Seresta created an optimization model with a minimum mass objective function and a collapse stability constraint. Park J H explored the optimization of composite structures by combining genetic algorithm and finite element method; Omprakash Seresta created an optimization model with mass minimization as the objective function and post-collapse stability as the constraint, and optimized the layer design of the composite structure; Wen Liu combined the finite element method to optimize the collapse stability of composite structures; Jose H The design of the composite structure was optimized using the finite element method; Jose Humberto S. Almeida Jr. et al. used genetic algorithms to optimize the sequence of laying composite pipes under internal pressure; Amir Ehsani et al. used genetic algorithms to optimize the stacking sequence of laminates to improve the maximum bending load of laminates; R. H. Lopez et al. have considered various failure options. R. H. Lopez et al. have optimized the laminate for various failure criteria; Wei Wang et al. used the ant colony algorithm to optimize the flexural design of composite reinforced panels; P. Emmanuel Nicholas et al. optimized the maximum laminate safety factor using a genetic algorithm and several failure criteria.

To solve engineering problems: computational analysis of composite structures can be achieved by computational methods of the theory of mechanics or finite element tools, for simple structures of the corresponding material can be achieved by computational methods of the theory of mechanics, but for complex composite structures it is difficult to calculate and analyze by methods of structural mechanics, therefore, in Most of the research and design of composite structures uses finite element tools. That is why most of the research and design of composite structures is carried out using finite element tools. The use of finite element tools for the design of composite structures in practical engineering is of great importance in improving the quality and efficiency of structural design and reducing costs.

3 Design requirements

3.1 Basic design requirements

The wing is mainly used to generate lift and control the roll of the aircraft with aerodynamic forces, so it must be designed with aerodynamic parameters in mind, so that the appearance is as smooth as possible, and the strength and rigidity of the structure meet the requirements; provided that the shape, load and connections are defined, the structure should be designed to be as light as possible while maintaining the integrity of the structure; the design must achieve the requirements of the aerodynamic form in terms of strength, rigidity and other aspects; it should be easy to disassemble and assemble, and also be interchangeable. interchangeability and ease of inspection, maintenance and repair. In general, the main objective of the wing design is to provide a lightweight and highly rigid wing structure while providing structural safety and functional reliability.

Insufficient strength of the wing structure will result in structural damage, so strength is a design factor that must be considered when designing the wing structure. Insufficient rigidity of the wing structure will lead to excessive deformation of the wing structure, which does not guarantee an effective aerodynamic shape and will reduce the aerodynamic characteristics of the aircraft; insufficient stiffness will also cause serious problems such as wing flapping. The wing not only provides lift to the aircraft, but also has many functional components such as landing gear, ailerons, and fuel tanks. Therefore, the structural design of the wing must meet the functional requirements and not affect the operation of the functional components after deformation under the action of the load. Weight is the main requirement for wing design, subject to the requirements of aerodynamics, strength and stiffness, as well as various functional structures. The extremely lightweight wing design means that the UAV has a longer range, a larger payload and greater maneuverability. In particular, this means designing a structure that is as light as possible within the overall design requirements.

4 Requirements for designing a finite element model

In finite element analysis, complex actual structures cannot be directly solved by the finite element method, but the continuous medium must be discretized and converted into a mathematical model that can be used for finite element analysis. This is one of the most basic and important tasks of finite element analysis, tedious, but important, but determining the rationality and reliability of the finite element model, which ultimately affects the reliability of the analysis results. Therefore, in order to use finite elements to accurately solve practical engineering problems, it is necessary to create a reasonable and efficient finite element model that can truly reflect the real working conditions of the physical structure. However, in a real finite element analysis, a simplified model cannot fully reflect the real working conditions, but only real engineering problems simplified for various degrees of deflation, and can only reflect the most important contradictions in engineering problems. This shows that the error of the actual engineering simplified model is too large compared to the calculation error of the FEA itself. It can be seen that the accuracy of the

FEA method is mainly determined by the realism of the simulation analysis model and the scientific simplification of the structural model. The finite element model must meet the following fundamental design requirements.
1) The principle of balance: In the nodes, each unit and its entirety must maintain a state of uniform force and stable balance. Deformation coordination principle: if elements converge at the same node after being subjected to external forces, these elements can remain converging at the node after deformation.
2) In this case, in the entire structure, each node must satisfy the principle of deformation matching.
3)Principle of boundary conditions: for a unique mode in finite element analysis, the boundary of its structure must strictly satisfy the specified displacement constraints.
4) Stiffness equivalence principle: the rigidity of torsional resistance, bending resistance and shear resistance in the finite element model should be considered as equivalent as possible.
5) The principle of selecting nodes: when choosing nodes, it is necessary to ensure the correct and complete route of transmission of the force of the entire structure, focus on the characteristics of the transmission of force of the structure and select them carefully, without distortion.
6) The principle of meshing: meshing is one of the key tasks in simulation analysis, which is related to the convergence of solution values. Therefore, in order to accurately subdivide the mesh, the level of accuracy, structural layout, force situation, element type, and workload must be considered.
7) Principle of processing: principles of processing: in order to obtain a finite element model that is as similar as possible to a real structural body, it is necessary to carefully approach the approximation of surfaces and curves and select elements that represent the true stress state of the structural parts of the model.
8) Load principle: when loading the drive, the load model must be carefully adjusted to accurately generate the nodal force. And a simplified load cannot ignore the main load-bearing components.

5 Composite wing model

5.1 Basic structural forms of the wing

The main wing structures of modern UAVs are skeletal skin structure, integral structure and sandwich structure. Different structural shapes have different characteristics, and understanding the forces acting on the wing structure and choosing the correct wing structure shape is critical to the subsequent detailed design of the structure.

Skeleton cladding design

The structure is mainly divided into single-beam, multi-beam and single-beam. This type of structure has the characteristics of high strength, rigidity and light weight, and its force transmission path is clear, and the division of labor of each component is clear, which is convenient for designers to design and widely used in various aircraft. This design mainly consists of skin, spars, ribs, stringers and longitudinal walls.
1. Envelope: to form a streamlined aerodynamic shape, the aerodynamic load acts directly on the skin, and the load is transferred to the longitudinal and transverse power frame, and together with the wing spar or longitudinal spar forms a closed box-shaped thin-walled structure. wall to carry the airfoil and form a wall together with the stringer to bear part of the axial force caused by the bending moment of the airfoil.

2. Wing ribs: form and support the airfoil airfoil, and transfer part of the aerodynamic load on the skin to the spar; some ribs are stiffeners, which mainly play the role of transferring additional concentrated loads, such as: engines, ailerons, concentrated loads created by fuel tanks and steering gear, etc.
3. Wing spar: This is the main longitudinal power element of the wing spar type; loads taken by the skin, stringers and ribs are eventually transferred to the spar and then to the fuselage via the spar.
Stringer: Supports the skin and is supported by a rib to withstand the axial force caused by the bending moment of the airfoil and the lateral force caused by the local aerodynamic force.
4. Longitudinal wall: the structure is similar to a beam, which, together with the spar, receives and transmits the lateral force of the airfoil and the tangential force generated by the torque. The beam wing skin is thinner, the spars are strong, and the stringers are weak. The spars are located along the line of maximum thickness of the wing surface. With this arrangement, the spars have the highest section height, which can increase the moment of inertia of the beam section. Improve the strength and rigidity of the spar.
5. The one-piece airfoil has a thicker skin and, together with stringers and spars, forms a wall that can be subjected to axial load and absorbs most of the bending moments. Stringers are denser, and their cross-sectional area is close to beams. The beams are weaker and together with the panels form closed box segments to increase the torsional rigidity of the airfoil structure. 6. Due to the thicker skin and denser stringers, the bending moment of the wing is transmitted through the wall plate, consisting of the skin, beams and stringers, the transverse force of the wing is transmitted by the wall of the longitudinal wall, the torque is mainly passed through the closed skin. The advantages of the monolithic wing are good bending and torsional resistance, high material utilization, and better safety and reliability than the beam type.

Integral structure and sandwich structure.

With an increase in the speed of the aircraft, the aerodynamic drag and pressure in the airfoil of the aircraft increase. To reduce drag and improve the carrying capacity of the wing structure, it is necessary to reduce the height of the airfoil and increase the thickness of the skin. If the skin frame structure is still in use, it is often difficult to meet the requirements. strength and stiffness requirements A new type of airfoil sandwich structure. The characteristics of the overall structure of the airfoil are that the skin and frame are integrated, there are few connecting parts between the parts, the thickness of the airfoil skin can be easily changed, the stiffeners can be reasonably arranged, the strength and rigidity are good, the load capacity is large, and the aerodynamics are good in appearance. and simple structure. As the airspeed continues to increase, severe aerodynamic heating will occur and the airfoil of the sandwich structure will emerge as time requires. Commonly used sandwich structures include honeycomb structure, lightweight packing structure, corrugated sandwich structure, etc. All of them consist of top and bottom panels and sandwich core, which can be honeycomb, lightweight core or corrugated frame, which can accommodate spars and nervures. In general, several movable airfoils such as leading edge flaps, ailerons, trailing edge flaps and spoilers, etc. are often placed on the wing to realize control of the aircraft. The function of the leading edge flap is to increase the camber of the wing profile due to its deflection, increase the angle of attack of the stall and improve the aerodynamic characteristics, the aileron is used to increase the lift and realize the roll of the aircraft; the spoiler can prevent the aircraft from rolling. Turn control plays a role and can also be used to slow down. The wing is often the basis for the installation of important parts of the aircraft, and other parts are often installed, such as landing gear, engine, flight control surface drive, etc. The interior space of the wing can be used to store the main landing gear and integral fuel tank, as well as control systems and some small equipment and accessories.

5.2 Initial structural design of the wing

According to engineering needs, in combination with the existing design cases of the wing structure, an airfoil type NACA2415 was created, as shown in the figure, the wing chord length is 900 mm and the wingspan length is 12000 mm. The cruising speed is 0.5 Ma. The finite element model of the wing in this work should be simplified as much as possible in accordance with the above principles. Based on the symmetry of the wing, a one-sided wing of the UAV was chosen here for finite element analysis. The components of the model are cemented to each other and, provided there is good bonding, the adhesive layer and the part are treated as the same continuum. Characteristics of the chamfer structure model, holes to reduce weight, etc. are not modeled based on the premise of ensuring the accuracy of the finite element calculation. There are bolts, rivets and other forms of connection between the skin and spars and ribs of the wing, and the connection between bolts and rivets is non-linear, which is difficult to establish with an accurate model, so this is not considered in this paper.

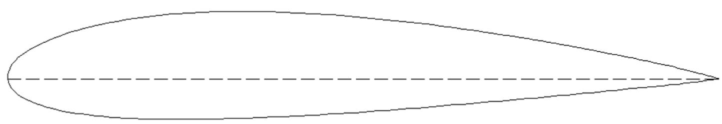

Fig. 1. NACA2415

5.3 Initial structural design of the wing

Wing loads are distributed aerodynamic loads. The environment for aerodynamic calculations is different from the environment for structural mechanics analysis, and the location and size of the structural mesh cannot be the same. In order to ensure the accuracy of external wing loads during structural analysis, aerodynamic field loads must be converted to structural field loads using a suitable calculation method. First, the Fluent finite element software is used to calculate the aerodynamic field load on an operational wing of an aircraft. As shown in Figure 2.

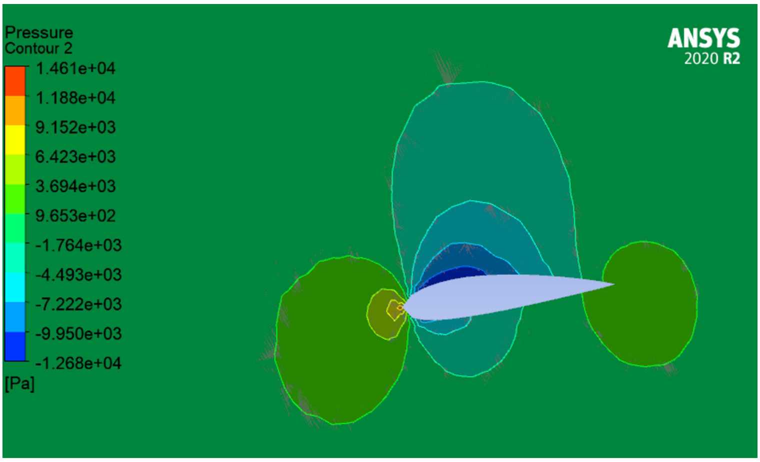

Fig. 2. Aerodynamic field load

The fluid-structure interaction function of the finite element software is used to convert aerodynamic field loads into structural field loads. Figure 3

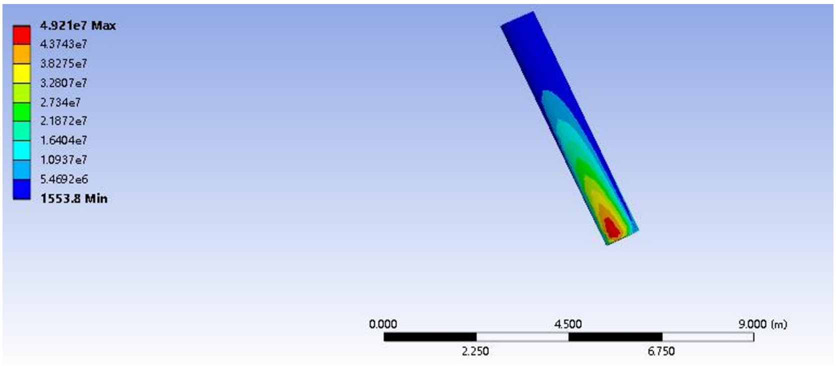

Fig. 3. Aerodynamic field load

The aerodynamic loading of the field is calculated by the finite element analysis software and the analysis and calculation of the structural field load transformation is carried out, the form of the load distribution necessary for the design analysis is obtained, the boundary conditions of the wing structure analysis are refined. It provides an initial physical model for optimal design and analysis of the next step wing design.

6 Conclusion

An unmanned aerial vehicle (UAV; commonly known as a drone or UAV) is an unmanned aerial vehicle. Compared to manned aircraft, UAVs offer a high cost-benefit ratio for missions. UAVs play an increasingly important role in today's society.

The wing is one of the important structural components of the UAV and the main supporting structure of the UAV. The wing accounts for approximately 30-50% of the aircraft's total structural weight, but carries approximately 70% of the total aerodynamic load, and its main function is to generate lift. The design of the wing structure must be based on the correct choice of materials, reasonable overall structural layout and optimum design. The main basis for the design of the wing structure is the overall three-sided view of the UAV, the layout, the theoretical scheme of the wing, and the main operational parameters and external loads that provide the strength analysis of the wing. The main elements of wing structure design are: familiarization with the basic principles of wing structure design, performance requirements and design specifications; determination of the general layout plan of the wing structure; prototype design, i.e. determination of the location, structural shape and dimensions of the main structural elements, etc., as well as the forms of connections of the main elements and assessment of the main characteristics of the structure; and detailed design, i.e. execution of drawings of all wing structures.

In Aerodynamic load field is calculated by the finite element analysis software and analysis and calculation of the structural field load transformation is carried out, the form of load distribution necessary for the design calculation is obtained, the boundary conditions of the wing structure analysis are specified. Wing workload analysis is an important basis for optimizing the design of wing structures. It provides an initial physical model for optimal design and analysis of the next step wing design.

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