Study on Integrated Optimum Design System of Composite Aircraft Structures

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Abstract: With the development of aircraft manufacturing industry, transportation, national defense and other aspects, the requirement for the overall performance of aircraft is getting higher and higher, and the research of composite aircraft structural integrated optimization design has attracted more and more attention. In this paper, the application of composite materials in aircraft structure is described firstly. Secondly, the current research situation of composite aircraft structure comprehensive optimization design is analyzed. Finally, the existing problems are described. Thus, under the constant attempts and efforts of more experts and scholars, the comprehensive optimization design of aircraft composite structures in the aircraft manufacturing industry can be continuously innovated and reformed, so as to improve the overall performance of aircraft and create greater value for the country.

1. Application Status of Composite Materials in Aircraft Structures

In the aerospace industry, the structural efficiency of aerospace structure has always been a very important index for its consideration. The improvement of structural efficiency can not only greatly reduce the overall weight of the structure, but also improve the utilization of structural materials, so that the aircraft can improve its maneuverability and continuity in the course of running. Navigation performance, in turn, can save fuel consumption. The application of composite materials in aircraft structural comprehensive optimization design has been the main direction of aerospace industry in recent years. In the decades of aerospace industry development, the application of composite materials is more and more extensive. It belongs to the new research results in the development of material science and technology. At present, composite materials are used in aircraft. The application of structural design has expanded from non-stressed structural parts, sub-stressed structural parts to the design of the main bearing parts, and its application scope is more and more widespread, which is also recognized and valued by many scientific workers.

As we all know, weight has always been an important parameter of aircraft performance. For a long time, designers have been working on manufacturing materials that can reduce the weight of aircraft structure. From the wood structure materials in the early 20th century to the alloy materials in the 1930s, even though the metal materials of light alloys have greatly reduced the weight coefficient of aircraft structure, the requirements for aircraft weight reduction are far from being met, so the emergence of composite materials has received great praise from aircraft designers[1]. Composite materials are mainly composed of continuous fibers with high elasticity and strength. Their fatigue resistance, specific strength and specific stiffness have great advantages over traditional metal materials. Since the 1960s, composite materials have been widely used in aircraft manufacturing, and their proportion has increased year by year, as shown in Table 1. Moreover, due to the directional designability and coupling of the stiffness of the composite material, the elastic deformation of the wing surface under the action of aerodynamic load pressure is beneficial to the aerodynamic force, structure and maneuverability of the aircraft, so as to make the aircraft operational efficiency and some core techniques in the process of maneuvering. The operation has been improved accordingly. For example, the aeroelastic torsion of aircraft is enlarged by the design of composite materials. At present, the use of composite materials is one of the important indicators to measure the quality of aircraft design and manufacturing. Moreover, with the continuous development and optimization of composite materials, more and more advanced fighter aircraft are designed and manufactured using composite materials to improve their performance and use.

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Various parameters.

Table 1 Proportion of Composite Material Amount to Total Weight of Aircraft Structures of Different Types

Aircraft model	F14	F15	F16	F18	AV-8B	F-22	JSF37	S37
Composite utilization ratio	0.8%	1.6%	2.5%	9.5%	16%	21%	23%	25%

2. Research on Comprehensive Optimum Design of Composite Aircraft Structures

Aircraft composite structure design is different from the traditional metal structure design. In the design process, it can complete the solidification forming technology very well. At the same time, its tailoring characteristics also make the design possibility more abundant. For some operations in the process of conforming to the comprehensive design of material structure, continuous optimization design method is needed to fully realize, so mature and guaranteed design scheme is also a key factor for the success of conforming to material structure design. As early as the 1970s, the structural finite element analysis method introduced by mathematical programming marked the emergence of modern structural optimization design methods, and solved many problems of complex structures that could not be solved in early design. Therefore, the theory of structural method design has been widely used in aircraft structural design process, but its actual effect is not ideal because of the need for computer aids and the small speed and capacity of early computers.

Since the 1970s, with the widespread use of composite materials, structural design methods of composite materials have been studied and valued by more and more people. A series of design ideas which can improve the computational efficiency of structural optimization algorithms have been studied successively, such as the use of model regionalization technology, mobile boundary optimization technology, variable connection technology, etc., making the structural optimization design optimized continuously. On this basis, the structural and aerodynamic performances of aircraft can be significantly improved by utilizing the design and coupling characteristics of composite material stiffness course, and the aerodynamic and structural coupling design. A new optimization design method, composite material aerodynamic tailoring optimization design method, is more widely used. People know and use it. This method needs to rely on computer technology and use the corresponding system to complete, such as TSO system or FASTOP system [2]. The TOS program system mainly compares the wing part of an aircraft to a Ritz plate structure, which reduces the degree of freedom of finite element analysis and improves the calculation efficiency of the system. Furthermore, the comprehensive optimization design of weight, deformation, strength, divergence speed and lift line slope can be realized by the optimization calculation method of non-linear programming. FASTOP system program is also used in the use of finite element analysis technology, so that the accuracy of structural analysis is greatly improved. At the same time, the criterion optimization method and two-stage optimization model are used to optimize the design of wing flutter and strength. Moreover, besides TOS and FASTOP system programs, there are many program systems supporting the optimization design of composite materials. With the cooperation and support of these programs, the aeroelastic tailoring design methods of composite materials become more flexible and diverse. With the strong support of the state, this design method is gradually applied to fighter aircraft. In the design process, and also achieved good results.

In the late 1980s, with the expansion of composite aeroelastic tailoring design methods and the accumulation of experience, a structural automation design software including composite aeroelastic tailoring design content, ASTROS, was successfully developed by the White Laboratory of the US Air Force [3]. The structure of the system is shown in Figure 1. On the basis of synthesizing the knowledge systems of various disciplines, it provides the auxiliary design function for the preliminary design of aircraft structure, thus realizing the optimization of the overall mechanism design of aircraft.

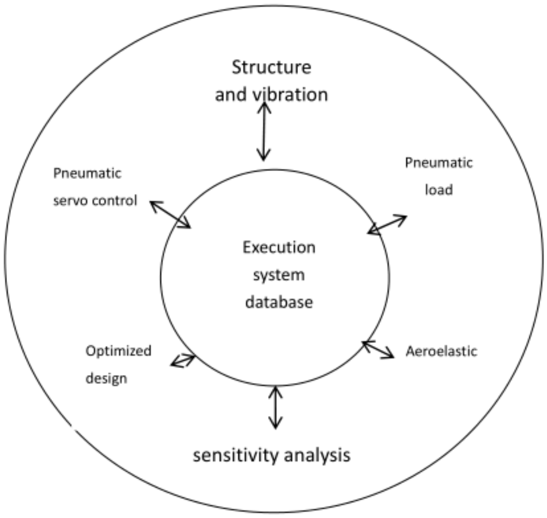

Fig. 1 Architecture of ASTROS System

In the mid-1990s, with the proposal of Active Aeroelastic design method, the class handling performance and overall quality of aircraft can be fully improved by using the Active Aeroelastic control method, which accords with the flexible characteristics of material structure. But the traditional optimization design method cannot satisfy this new design principle, so the multi-disciplinary and multi-system optimization design idea became the most important optimization design demand at that time. Researchers divide the system rationally according to the domain knowledge and main function manifestation involved in each part of the system. On the basis of the sub-system, they give full play to the role of computer network and the knowledge of various disciplines, such as heredity, statistics, Non-linear Numerical Optimization and so on, so that the whole system can be obtained. Optimal design [4]. And this design method is fully applied to the aircraft manufacturing process, and the results are remarkable.

3. Existing Problems in Comprehensive Optimum Design of Aircraft Composite Materials

With the continuous development and progress of aircraft structural integrated optimization design and the accumulation of many years of experience by scholars, structural optimization design has become more and more mature in the field of Aeronautics and astronautics. But there are still many shortcomings, especially in the practical application of aircraft manufacturing and the overall development trend.

3.1 The accuracy of Aerodynamic Numerical calculation needs to be improved.

With the development of aircraft manufacturing industry, the requirement of numerical aerodynamic calculation accuracy in aircraft design process is getting higher and higher, so the aerodynamic numerical analysis method needs to be optimized step by step. At present, the aerodynamic model is mainly based on linearization equation, which is more suitable for the traditional attachment fashion, but can not reflect the impact of angle of attack. At the same time, this theory is more suitable for the subsonic supersonic phase, but not for the transonic phase.

3.2 Automation design technology of aircraft structure layout is not perfect

With the in-depth study of aircraft structural design technology, aircraft structural automation has become an inevitable trend. With the support of difficult technology, aircraft structural integrated optimization design must meet the requirements of automation design. Of course, the premise of realizing this requirement is that the layout design of aircraft structure is reasonable, especially under the premise of combining multi-disciplinary fields. However, due to the fact that many layout problems are difficult to deal with rationally and pertinently by some mathematical methods under the influence of computer science, it is difficult to realize automation in many layout structure designs. It requires human participation, using the experience of the designer to complete.

3.3 The calculation method of system program needs to be improved.

Nonlinear mathematical programming algorithm with continuous variables is widely used and recognized as the main optimization program of general structural integrated optimization design method because of its high computational efficiency and fast convergence speed. But this method has a necessary premise that the requirements of mathematical models are very high. The variables of the mathematical model must be continuous, and the design space must be combined. If the mathematical model can not meet the above conditions, then the error of the design will be greater. Therefore, the optimization calculation method for complex systems needs to be further improved.

4. Conclusion

Composite materials, as a new type of material in the field of aircraft manufacturing, have been widely used in the global aircraft manufacturing industry. Because of its design characteristics, composite materials can not only improve the performance of aircraft, but also reduce the structural weight of aircraft itself. However, with the increasing requirements for aircraft performance in military, transportation and other aspects, more and more experts and scholars pay attention to the optimization of composite aircraft structural integrated design. Therefore, this paper focuses on the study of composite aircraft structural optimization and comprehensive design. From the initial structural finite element analysis method to composite aerodynamic tailoring optimization design method, to the emergence of ASTROS design system and Active Aeroelastic design method, the aircraft composite structure synthesis has been established step by step. The growth of optimization design. But even though many years of research theory and practical experience, there are still some deficiencies in the comprehensive optimization design of aircraft composite materials, such as the comprehensive optimization design of aircraft composite materials, the calculation method of system program, the accuracy of Aerodynamic Numerical Calculation and so on, which need to be improved. Therefore, the comprehensive optimization design of composite aircraft structure needs more people and more time to try and work hard.

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