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Application of Resin Matrix Composites in Aircraft and Development of Its Manufacturing Technology

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ABSTRACT. *This paper summarizes a series of development plans to promote the application of composite materials in aircraft at home and abroad in the past 35 years, as well as the composite consumption of representative military and civil aircraft in each stage. The development status of domestic aviation composite materials and the amount of composite materials used in military and civil aircraft in different periods are compared and analyzed. The development trend of composite molding technology is summarized The automatic manufacturing technology of composite materials and the low-cost manufacturing technology of liquid forming of composite materials are introduced. The opportunities and challenges in the field of advanced composite manufacturing in China in the new period are put forward.*

KEYWORDS: *Resin based, Compound material, Aviation, Manufacturing technology*

1. Introduction

Resin matrix composites are widely used in aerospace because of their advantages of light weight, high specific strength, designability, excellent fatigue resistance, good corrosion resistance and high comprehensive cost-effectiveness ratio. The application of advanced composite materials in aircraft has caused great changes in aircraft design and aviation manufacturing industry. The application of resin matrix composites in aircraft structures has become a world-wide one The trend of aviation equipment development is that the amount of advanced composite materials on aircraft has become an important index to measure the advanced nature of aviation equipment. By the end of 2019, the consumption of composite materials for international advanced civil aircraft has exceeded 50%, the fuel efficiency has increased by more than 20%, the weight has been reduced by 20%~30%, and the maintenance cost has been reduced by 30%.

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2. Development of Aircraft Resin Matrix Composites Abroad

2.1 Development of Advanced Composite Manufacturing Technology in the United States

In the late 1970s, NASA implemented a series of medium and long-term development programs to promote the development of advanced composite manufacturing technology. ACEE (aircraft energy efficiency) was launched from 1976 to 1986 The aim of this project is to apply composite materials to the secondary load-bearing structure of aircraft to reduce the fuel consumption of the aircraft. The program can reduce the weight of the aircraft by 25% ~ 30%, and save fuel consumption by more than 15%. The Act (advanced composite technology program) program, which was launched from 1987 to 1997, focuses on the development of low-cost manufacturing technology for composite materials, and adopts RTM (resin transfer) Combined with advanced structural design concepts such as weaving and stitching, low-cost processes such as molding, resin transfer molding (RTM) and resin film infiltration (RFI) have been manufactured with a length of 12.8% The results show that the failure load of the composite wing box is 1.5 times of the design load. The weight loss of the aircraft can reach 30%~50% and the production cost can be reduced by 20% ~ 30%. The main application of this plan is the central wing box of C130 large transport aircraft, and the ast (Advanced subsonic) was launched in 1992 Technology (Advanced subsonic speed) program, aiming at the integrated manufacturing of composite wing box, has carried out corresponding ground test and verification, and accumulated rich basic technical experience.

2.2 Development of Composite Manufacturing Technology in Europe

In 2000, the EU launched the Tango (technology application to the near term business goals and objectives, based on short-term and long-term business application goals) program, which aims to achieve 20% weight reduction of structure weight %A series of advanced automatic manufacturing technologies for composite materials (prepreg/prepreg tape automatic placement, automatic dry fiber placement, etc.) and low-cost manufacturing technologies (LRI, RFI, etc.) are adopted, In 2005, the European Union launched the al-cas program, which improved the airframe efficiency of aircraft, especially commercial aircraft. The research results were applied to A350 aircraft, reducing the structural weight by 20%The cost involved is equivalent to that of metal materials.

In 2019, Airbus launched the wing of Tomorrow program, which aims to develop an efficient and low-cost composite wing manufacturing technology for single channel aircraft, such as modular manufacturing, efficient resin injection and autoclave rapid curing, so as to significantly improve the production cycle of composite wings, and enable them to adapt to the production capacity of about 60 A320 series aircraft per month. Airbus has started the assembly of the first structural part for verification in June 2019, and plans to complete three full-scale

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demonstration verification pieces and carry out corresponding structural and strength tests in 2020[1]. It is expected to complete the “tomorrow wing” program in early 2022[2], which will enable the new generation of aircraft to use longer and thinner wings to improve its aerodynamic efficiency.

Table 1 Consumption of Composite Materials for Military and Civil Aircraft At Home and Abroad

Type	First flight time	Developing country / manufacturer	Amount of composite material /%
A300	1985	France / Airbus	5
A310	1986	France / Airbus	10
V-22	1989	U.S.A	59
A340	1992	France / Airbus	14
A330	1993	France / Airbus	13
EF2000	1994	UK	40
F/A-18-E/F	1995	U.S.A	23
F22	1997	U.S.A	26
RQ-4	2001	U.S.A	59
A380	2005	France / Airbus	25
A400M	2009	European Union	40
A350	2013	France / Airbus	52
F35	2015	American	31
C919	2015	China	12
Xin zhou700	2016	China	12
CR929	2018	China	55

Table 1 lists the consumption of composite materials for some military and civil aircraft at home and abroad. It can be seen that the application of advanced composite materials in aircraft presents a trend of increasing year by year. The application parts have experienced the development of secondary load-bearing components such as radome and hatch cover at the beginning, and then to the development of large-scale main load-bearing components such as fuselage and wing The technology is becoming more and more mature, and the development of automatic manufacturing and low-cost manufacturing technology of composite materials has been paid more and more attention[3-5].

3. Development Status of Aircraft Composite Technology At the Domestic

In the 1980s, the amount of composite materials used in China's aviation equipment was basically maintained at 1%, and the application parts mainly included radome, cover, equipment cabin, engine fairing and other non load-bearing structures; from the 1990s to the beginning of the 21st century, the application of

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composite materials on fighter aircraft was as high as 6%, and the application parts of composite materials began to be vertical tail, rudder, aileron and horizontal tail wing The development of equal load-bearing components, such as the vertical tail of J-7 and J-8; after more than 40 years of research and development, the technical level of advanced composite materials in China has been continuously improved, composite materials have been widely used in various types of aircraft, and gradually began to explore the application of composite materials in aircraft main bearing structure, such as the central wing box of large aircraft. In recent 10 years, with the large aircraft listed as the national medium and long-term science and technology development plan[6], the application of advanced composite technology has been significantly improved[7], and the composite material consumption of civil aircraft can reach up to 20%. Although China has made some progress in the manufacturing technology of aviation composite materials, due to the weak basic research, backward material technology, immature process technology and lack of engineering application verification, the application scope and proportion of advanced composite materials are far from the international level, and the comprehensive cost-effectiveness is still low.

4. Development Trend of Advanced Composite Manufacturing Technology

4.1 The Composite Parts Tend to Be Large-Scale and Integrated, and the Manufacturing Technology Tends to Be Automatic

The application of automatic manufacturing technology of composite materials in China has made certain development. At present, the aircraft R& D and manufacturing units have basically realized the basic automatic production technologies, such as CNC blanking, laser projection paving, CNC milling and automatic ultrasonic flaw detection. However, due to the weak foundation and lack of technology accumulation, the automation level is still low compared with the European and American countries. Especially in the aspect of large-scale composite parts, automatic placement, hot diaphragm forming, automatic assembly of components and other technologies are still in the experimental research stage, and can not be applied in engineering. Therefore, the application technology research of automatic manufacturing technology is still the work that needs to be actively carried out in China's composite manufacturing industry. In order to further improve the automation level of composite manufacturing, major main engine plants and scientific research institutes have successively purchased automatic tape laying machine, hot diaphragm forming machine and other automation equipment, and actively carried out relevant process technology research.

4.2 Development of Composite Manufacturing Technology to Low Cost Manufacturing

Compared with the traditional aluminum alloy components, the manufacturing cost of composite parts is much higher, so reducing the manufacturing cost has

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always been the goal of composite manufacturing field. LCM (liquid composite moudling) technology is a potential low-cost manufacturing technology. Different from the traditional prepreg/autoclave molding technology, the liquid molding adopts the process of dry fiber curing at room temperature or temperature rising, which can greatly save a lot of energy consumption in the low-temperature storage of prepreg and the working process of autoclave. RTM, as a closed die forming process, can form complex composite components at one time through the assembly of multiple core molds, and the surface quality of finished products is better than that of autoclave molding, and the production efficiency is also higher. Vari does not need a special mold, and the resin is sucked into the dry fiber preform by vacuum. The manufacturing cost is low. By optimizing the process, the composite parts equivalent to the autoclave curing process can be manufactured, which is also a potential technology.

Domestic researchers have actively explored liquid forming technology, especially RTM technology. Zhao Wenbin et al. Prepared high-rise shear strength and ablation resistant expansion section by using needle punched preform as reinforcement material and distributed injection method; Through PAM simulation, Li Yanping and others analyzed the whole RTM molding process of double skin variable curvature multi cavity box end, optimized the injection scheme and channel layout by simulating the pressure distribution and injection time in the process of glue injection, and verified the simulation results through experiments. At present, although the domestic RTM technology has made some progress, there is still a certain distance from the engineering application. For example, there is a large technical gap in the prefabrication preparation, especially in 3D braiding. In addition, the corresponding technology accumulation is needed in mold design and runner layout.

5. Conclusion

After nearly 35 years of development, foreign advanced composite manufacturing technology has been at a high level. Composite parts have gradually realized integration and large-scale, and have been applied to large-scale main load-bearing structural parts such as aircraft fuselage and wing, which greatly improves the composite material consumption level of aircraft. At present, the composite material consumption of more advanced civil aircraft such as A350 has exceeded 50% And its manufacturing technology is also developing rapidly. Advanced automatic manufacturing technologies such as automatic placement of prepreg, hot diaphragm molding, automatic assembly of skin analysis are widely used, and low-cost manufacturing technologies such as liquid forming are developing rapidly. In comparison, although the domestic composite manufacturing technology has made a certain degree of development, compared with foreign countries, it is still in a relatively backward level, lack of research on integrated automatic forming technology of large-scale parts, lack of technology accumulation and corresponding technology verification platform. Although a certain system has been formed in low-cost manufacturing technologies such as RTM, vari and RFI, a

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large number of process technology verification and basic technology accumulation are needed to realize engineering application.

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