New Materials and Technology of Chinese Civil Aircraft

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Keywords: composite materials; hybrid structure; manufacture technology

Abstract. Criteria of next generation aircraft, "quieter, cleaner and greener", were dedicated by designers and stakeholders in the past decade years. New materials, different design philosophies and new manufacture technologies are used on civil aircraft in China. Gaps between China and abroad, in the fields of design, manufacture, materials, were mentioned. Chances and challenges China commercial aircraft company faced were pointed out. Finally, huge development potential and development trends of the domestic aircraft manufacturing were analyzed.

Introduction

Over the past few decades, global commercial aviation transport developed rapidly associated with world economic growth and globalization. The number of worldwide passengers increased from 1.5 to 3 billion from 2002 to 2013[1]. Air travel growth has undoubtedly an increasing effect on the environment. It is reported that air transport contributes about 12% of global Green House Gases[2]. Fortunately, more and more people get to realize environmental problems caused by airplane, such as, emissions, noise and deterioration of air quality[3]. European Union Emissions Trading Scheme decided that all airlines flying to and from EU airports will be charged for carbon emissions from January 1, 2012[4]. Increasingly, airlines concern about reducing overall cost including cost of purchasing and maintenance. "quieter, cleaner and greener" [5] is suitable for description of next generation aircraft.

World colossal aviation market is much gorgeous for all aircraft manufacturers. Industry experts forecast that aeronautics sector will experience substantial growth in coming years. For instance, Airbus evaluate that 5,000 new single-aisle aircraft in the United States during next 20 years, and Airbus seeks to gain a much larger portion of this future market[6]; in China, demand for aircraft added up to 8615 from 2011 to 2030, 7018 of which are to be purchased. The total size of aviation finance market will be up to 421.1billion dollars[7].People's Daily Overseas Edition reported that Boeing estimated 3770 new airplanes in China market in the future 20 years.

All this showed that opportunities and challenges which designers and manufacturers of airplane stand up to be considerable. Aiming at the huge market, Commercial Aircraft Corporation of China set up and decided to manufacture large commercial aircraft.

New materials in aircraft

Manufacturing Large Aircraft is one of most important aspects of country's industry. Large aircraft have 3 difficult questions : fuselage fabrication, avionics system and airplane engine. Fuselage incorporates new materials, fabrication process, structural cost and performance benefits of lighter-weight.

Principal "new" airframe materials include metallic alloys and polymer-matrix composites. New materials have been worked out in recent decades. Composite, especially, developed into research hot spot and have applied in various fields. All types of composite materials are used widely on new generation aircraft, even as important structural components on aircraft. Such as, horizontal stabilizer, vertical fin, fuselage floor beams, fuselage, Wings, the central wing, composite Fuel Tank and other primary load-bearing structures. Fig. 3 is a picture of a kind of composite which is used as structural materials on aircraft by the Cooperative Research Centre for Advanced Composite Structures (CRC-ACS). Fig. 4 shows materials usage of new generation Boeing 787 aircraft, it is easy to find that consumption of composite materials is more than 50%[8]. It reported that Boeing 787 aircraft will reduce fuel consumption by 20%, 8% of that contributes to use composite materials extensively on aircraft. Airbus used more than 50% composite on new airplanes, too[9].

On the other hand, aluminum alloys have been the primary material for the structural parts of aircraft for more than 80 years because of their well known performance. Using composite materials reduced the role of aluminum up to some extent, high strength aluminum alloys remain important in airframe construction. Lower manufacturing and maintenance costs of aluminum alloy are important advances can effectively compete with modern composite materials. New aluminum lithium alloy used on large aircraft of China was provided by Alcoa[10]. Aluminum alloy is estimated to contribute 61.4% of weight of Commercial aircraft C919, while composite 15%

Titanium and titanium alloys are widely used in aircraft applications because of their high strength-to-weight ratio and excellent corrosion resistance. Titanium is an ideal material for weight savings. Welding property of titanium alloys is generally much more than that of aluminum alloys. Titanium wielding can be produced with nearly 100 percent joint efficiency for strength and slight decreases in fracture and durability performance. Relatively low coefficients of thermal expansion and thermal conductivity of titanium alloys tend to minimize potential for distortion during welding operations. It is reported that volume of titanium alloy used on C919 is 9.3%， slightly higher than that of the Boeing 777 (7%～8%). Whereas mount of titanium alloy on A380 is 10%.

New processes in aircraft

Aircraft is complicated system, including 3～5 millions components. Every part must be designed and manufactured, then be assembled into an airplane with 415 thousands of fixtures. Each part was fabricated accurately by advancing manufacture technology.

High-speed and precision machining technology, such as high-speed CNC machining, ultra-precision machining, and multiple ultra-precision processing technology, has been researching in developed countries. Most of them have been used in aircraft production currently. For example, the surface roughness of a component machined by Advanced Technologies is up to 0.001μm. Abele[11] reported new technology for high speed cutting of Titanium alloy of aircraft in his research.

Computer technology, combined with manufacture industry, greatly improves technological level of the aviation industry. For example, additive manufacturing(AM) are widespread already. AM has been used to create complex aircraft parts in China[12]. All these progresses are playing increasing roles in simplifying aircraft process, stabilizing production, assuring quality, reducing cost.

Growth rate of titanium and aluminum-lithium alloy applied on the new generation of aircraft is ascribed to solve key processes, such as high-speed machining, chemical milling, forming, welding and other ones. Electron-beam, laser beam and ion beam have been rapidly developed, represented the high-energy processing technology in the past 10 years [13]. Electron beam welding has been used in main load-bearing frame, landing gear of aircraft, which has an extensive future development. So far, laser beam is preferred processing technology in the aircraft industry. Fig. 1 shows that the laser beam weld used in fuselage panel of Chinese aircraft.

Fig. 2 views an another welding technology: friction stir welding. Friction welding offers an extremely promising way to make joints with minimal requirements for extra mass and with extremely good final product properties showing very low distortion. All processes, to varying degree of course, are very reliable and repeatable, with few requirements in terms of nondestructive testing usually.

New aluminum lithium alloy used on large commercial aircraft of China was provided by Alcoa. Frontal fuselage section was fabricated with this aluminum alloy. Besides, new process was used to produce aluminum alloy. Alloy used on A380 is worked out with semisolid Processing using cooling slope [14]。

New design and conceptions

Techniques of civil aircraft design undergoes a dramatic shift to against air crash, because of fatigue and other mechanical damage. Design conceptions go through from static strength design, safe-life, fail-safe design for damage tolerant design in the past 50 years.

Fig. 1 Laser beam welding aircraft fuselage

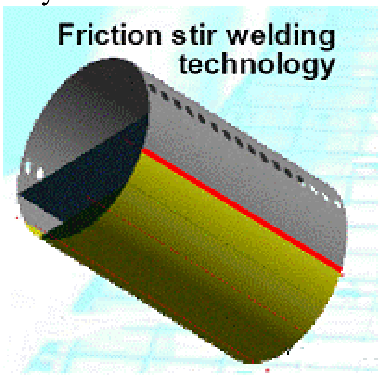

Fig. 2 Fuselage joined with friction stir welding

Innovative structural designs are adopted to meet people's demand for aircraft, namely more affordable, cleaner and quieter. It takes full advantage of new materials' potential benefits. New structural design concepts include selective reinforcement, hybrid structure, advanced joining method, and so on. Manifestations of such concepts in next-generation applications were found in metallic fuselage, composite wing, and composite fuselage components, as well as other applications.

Essence of new design method — "hybrid structures "and selective reinforcement is that a typical component structure in design is selected in term of fatigue crack propagation direction, rate and evolution rule in actual service loads and environmental conditions to make the crack propagation breaks, transforms or crack arrests when crack propagation approaches this local reinforcement structure, achieving the desired structure with low fatigue crack growth rate (FCG) and high residual strength. These structures include selective reinforcement, sandwich reinforced structure panel and hybrid tapered wing design.

Selective reinforcement is used as crack stoppers on the aircraft which the body is an integral structure in the modern aviation design with the purpose of significantly reducing the weight of the final assembly.

Mechanics of selective reinforcement is that reducing the crack driving force in the structure and hence the fatigue crack propagation rate is reduced by reinforcing some region of the structure to eliminate any premature failure of the structure. There are a few types of them as follows.

Fig. 3 and Fig. 4 show that it is six types of the selective reinforcement. In a word, the regions where could result in high stress concentrations or strength are weakened because of some reason will be added another panel which is bonded or riveted as crack stoppers to extend the life of structure.

The "hybrid structure" has been used on the airbus A380 aircraft, and its character is that composite, titanium alloy, steel and aluminum alloy are applied on a aircraft structure as a mixed integrated body. Main advantage of this structure is that it takes full advantages of features of various materials to reduce structural weight effectively, at the same time, to improve durability of the structure.

Fig. 5 show hybrid structures used on aircraft. In Fig. 5, structures of hybrid are obvious: different attribute materials are superimposed with adhesive. Different advantages of different materials play on the same structure. This property of the structure is better that any structures made by single materials.

Trend's direction of aircraft manufacture is creation of integral structures via of carbon fiber polymer composite materials and of manufacturing processes such as welding, casting and forging, high-speed machining. This is mainly driven by manufacturing cost savings in future aircraft. Integral structures also bring the benefits of weight savings and simplification in inspection. For example, 787 aircraft maintenance intervals are extended to 1000 hours, but at present, that of a Boeing 767 is 500 hours [15]. However, integral structures do not contain redundant structural members that could act as crack stoppers or retarders. In order to improve damage tolerance capabilities, it is an important design feature for single load path constructions. One of promising solutions is selective reinforcement.

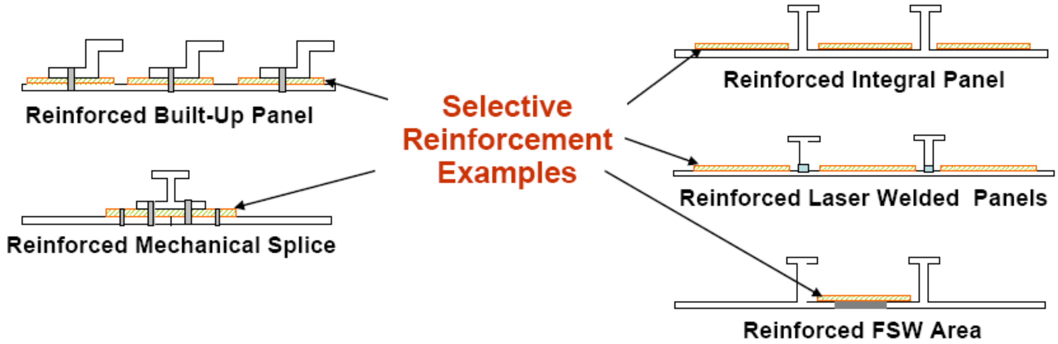

Fig.3 types of Selective reinforcement

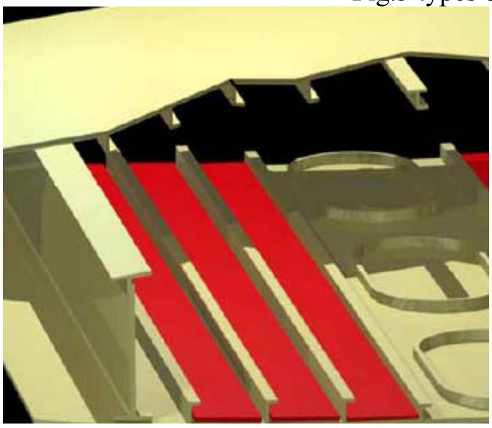

Fig. 4 Integral stiffened panels

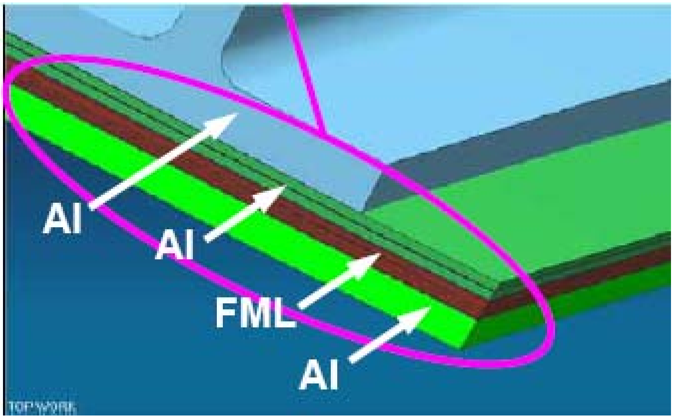

Fig. 5 Sandwich reinforced hybrid structure

New challenges and chances

Over the past few decades, manufacturing and design of civil aircraft have been subjected to multiple pressures of different stakeholders in order to decrease their footprint and improve their safety. Large commercial aircraft program of China has just started, while some subjects, such as the design, manufacture, organizational management, airworthiness certification, key technology research and so on are on the exploring way by ourselves. So all of our researchers should work hard and cooperation to accomplish Chinese dream.

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