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THERMOPLASTIC MATERIALS - A NEW STAGE IN THE LIFE OF AIRCRAFT CONSTRUCTION

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Abstract

Purpose: *The main purpose of this article is to update the processes of using thermoplastic materials in modern aircraft structures of aircraft.* ***Results:*** *The result of the analysis of the modern market for aviation technologies and aviation materials is the active use of thermoplastic materials in the structures of aircraft of leading manufacturers in the field of aircraft construction.* ***Discussion:*** *The introduction of technologies for using composite thermoplastic materials in aerospace structures by foreign aviation enterprises is characterized.*

Keywords: tapas technology, thermoplastics, automatic welding, orthoset.

1. Introduction

Thermoplastic composite materials have shown great promise as materials for existing and future aircraft components. It is likely that in the near future, components made of thermoplastic composites will enter RAAF service as replacement components that were previously made of metals or plastics. thermosetting composites such as graphite/epoxy.

Thermoplastic resins have a number of advantages over conventional thermosetting resins, such as epoxy resins. Thermoplastics have chemical resistance and impact resistance and can be used in a wide temperature range. They have a very low level of moisture absorption, which means that their mechanical properties deteriorate less in hot / humid conditions.

Thermoplastic composite materials have a number of advantages, but may also require different manufacturing and repair technologies.In particular, it is often necessary to use significantly higher processing temperatures and pressures than for typical thermosetting composite materials.

Repair methods for thermoplastic composite materials include the use of bolted joints and repairs with an adhesive joint in accordance with conventional thermosetting composites and metal components. However, unlike thermosetting resins, thermoplastics can be melted after their formation. They can also be joined using a process called fusion welding, which produces high-strength welds.

Fusion bonding allows you to join thermoplastic composites by heating them to a temperature close to their melting point, and then applying enough pressure to secure the weld. In General, thermoplastic composites are currently more difficult to repair than conventional thermosetting composites. Given the range of possible structural forms and types of damage, it is likely that a number of different repair methods will be required, and there is no single method that is optimal for all cases [1].

2. Analysis of research and publications

Composite construction has several advantages over metal, wood or fabric reducing weightais one of the main differences from traditional materials in the aircraft industry. It should be remembered that creating a composite aircraft design does not guarantee that it will be lighter; this depends on the design, as well as on the type of composite used. A more important advantage is that the very smooth curved aerodynamic design of composite materials reduces drag. This is the main reason why glider designers switched from metal and wood to composites. In aircraft construction, the use of composites reduces drag, which ensures their high characteristics.

Today, composites can be found in designs ranging from small gliders to most new passenger and commercial aircraft. Lack of corrosion is the third advantage of composites. Engineers are no longer concerned about corrosion due to condensation of moisture on hidden areas of the fuselage skin, for example, behind insulation coverings. This should lead to lower long-term maintenance costs for airlines.

Analyzing the above information from various scientific and design sources, we can safely conclude about the relevance of the use of thermoplastic materials in the modern world of aircraft construction [2].

3. Setting up a problem and task

Over the past decade, the global commercial aerospace industry has experienced a period of significant growth, during which увеличился passenger traffic has increased. In order to meet the demand for air transportation and replace the aging fleet of aircraft, the world's leaders in modern aircraft manufacturing have come to the conclusion that stagnation in production has led to an increase in the number of incomplete aircraft orders, as aircraft manufacturers themselves struggle to keep up with demand, thereby staying in constant competition. These two significant factors have pushed manufacturers to introduce unique technologies into their aircraft. Создатели Aircraft designers are already using technical solutions for the introduction of thermoplasticized composites in small airframe design details, as well as exploring the possibility of using them in larger structures, such as torsion bars of the wing, fuselage panels, and components of power plants. In order to meet the global market demand, manufacturers of aviation and space technology are striving to increase production rates and volumes so that existing and future types of aircraft do not face production stasis and obsolete production technologies. One of the promising directions is to reduce the time of the production cycle, due to the use of composite materials in their structures [3].

The main task of applying the above-mentioned technologies is to displace metal components from airframe structures, reduce labor intensity in manufacturing, increase reliability, as well as speed up the processes of Assembly and production of products.

4. Materials and research methods

4.1. Thermoplastic materials in euro-construction

Thermoplastics represent an alternative to thermosetting polymers in composites and promise to increase productivity. Unlike composites that include thermosetting polymers, thermoplastic composites do not require a curing stage in which the composite is formed by applying heat and pressure to multiple layers of pre-preg to form a solid laminate. Thermoplastic composites simply need to be heated to a temperature above the melting point of the thermoplastic matrix, compacted and cooled, in contrast to thermosetting composites, which require a curing time to form polymer crosslinks in the molecular structure. Thermoplastic composites are usually packaged as rolls of tape consisting of unidirectionally oriented carbon fiber pre-impregnated with a thermoplastic resin. Thermoplastic composites are also available in the form of woven tapes or reinforced thermoplastic laminates. In thermoplastic composites for the aerospace industry are used a thermoplastic resin with high performance characteristics, including polyetheretherketone. Thermoplastic composites used in aircraft construction usually contain about 50-60% carbon fiber by volume. The ratio of carbon fiber to thermoplastic resin is selected to achieve the desired mechanical properties and compatibility with the manufacturing process [4].

The advantages of thermoplastic composites, such as their impact strength, relatively high out-of-plane strength, and resistance to recycling, have long attracted aircraft-designers the concept of primary structures made of thermoplastic composites. But aircraft engineers were hesitant to find a cost-effective way to transition from modeling systems to computer aided design (CAD) to the production process using new materials, however, did not stop. In conventional designs, the fuselage frames contain holes through which longitudinal stringers pass. Under pressure, these holes serve as homogeneous objects that are subject to strong flaking, which is a serious problem for a non-fastener design, given the low strength of composites out of plane compared to metal [5].

4.2. TAPAS 2 technology

The TAPAS 2 (Thermoplastic Affordable Primary Aircraft Structure 2) technology was launched in the Netherlands in 2009 with the aim of developing new thermoplastic composites and processes for use in the Airbus aircraft industry (Toulouse, France). The consortium is embarking on a second phase of applications and materials development, and its members hope to bring a thermoplastic composite fuselage and torsion box concept to market by 2020 that will prove the viability of thermoplastics in commercial aircraft designs. In addition to Airbus, the TAPAS consortium includes a number of composite suppliers, composite parts manufacturers and research institutes based in the Netherlands. These include Project Manager Fokker Aerostructures (Hoogeveen), Airborne Technology Center and Kok & Van Engelen (both based in The Hague), Dutch Thermoplastic Components (Alkmaar), Technobis Fiber Technologies (Uitgeest), TenCate Advanced Composites (Nijverdal), KE- operates, CoDeT and Technische Universiteit Delft (all based in Delft), the University of Twente (Enschede) and the National Aerospace Laboratory in Amsterdam. As part of the first phase of the program, called TAPAS 1, the consortium investigated the use of thermoplastic composites in aircraft fuselage structures. Added torsion boxes as another application. The material used was a new TenCate unidirectional carbon fiber prepreg with Hexcel AS4 fibers and Arkema PEEK matrix. Processes used included automatic fiber placement, stamping and welding [6].

The thermoplastic composite fuselage panel conforms to the complex fuselage geometry with fiber-guided AFP skinning and joint orthogrid consolidation. Successfully handling high cockpit pressure and impact forces and other performance requirements, the new concept developed with TAPAS and TAPAS2 technologies and now used in aircraft construction is what is described as a “butt joint with orthogonal stiffness. leather with welded frames ". Unpacking this description highlights three key design features and manufacturing developments required to implement them: orthogrid, butt joint, and welding technology [7].

4.2.1. Orthoset

The panel strength requirements are partially met by a fully interconnected orthogonal stiffening lattice. This orthogrid eliminates the peak loads associated with stringer holes, eliminating points where delamination increases. The orthosis consists of continuous longitudinal stringers and frames made up of two separate components: intermittent but connected longitudinal blade stringers and frames welded on top of them [8].

GKN Fokker, in conjunction with the TAPAS 2 program concept, has developed and patented a butt joint that connects the orthogrid and orthosis to the sheathing using cost-effective injection molded short fiber elements and flat continuous fiber laminates for stringer and lid (here T-stringer has been replaced by L-stringer). Thus, this is a new generation of fuselage stiffeners that have evolved over the years of orthosis development. Specifically, GKN Fokker has applied its patented butt joint technology to the Gulfstream panel (also to the previous TAPAS panels) (Fig. 1).

The blade and cover of the T - or L-stringer components, as well as the components of the stringer with blades, are made from blanks cut using waterjet cutting from a flat carbon fiber laminate. The connecting elements (the shell to the web and the web to the cap) are made by injection molding, the P-shaped filler of short-fiber carbon material, the resin, and the type of carbon fiber correspond to the type of mesh elements [8].

4.2.2. Built in L-stringers.

The fuselage, designed by GKN Fokker of carbon fiber designed and manufactured for Gulfstream, includes curved longitudinal L-shaped stringers with a slightly blunt angle to detach the tool. The skin and the orthogonal grid are consolidated together in the Inar Internal Mold Line (IML) tool. In the tool there are grooves, in which the components are loaded artashatci and sets of. The AFP-formed shell is then placed on the IML, and the entire Assembly is bagged and sealed in an autoclave [9].

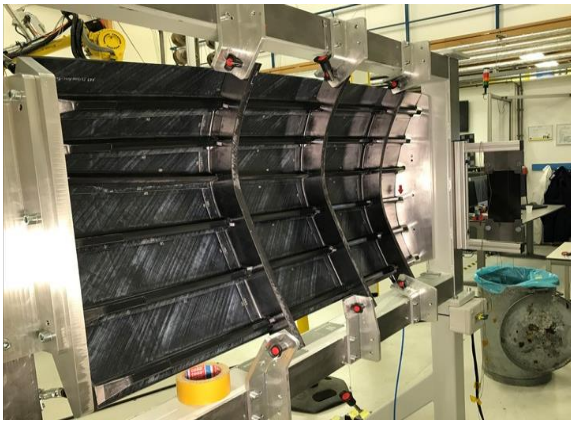

Fig. 1. Gulfstream fuselage panel

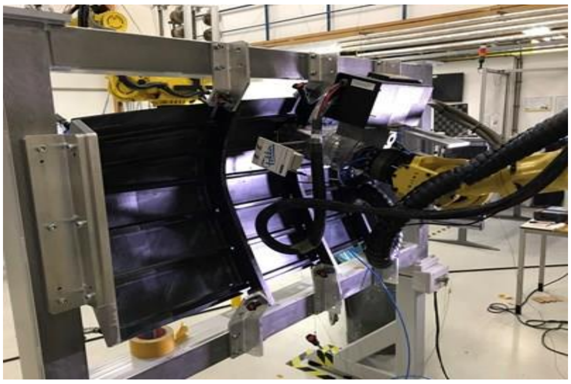

Fig. 2. Automatic welding for joining parts with thermoplastics

4.2.3. Automatic welding

GKN Fokker has developed and applied robotic welding technology to promote the economic feasibility of creating a thermoplastic composite fuselage panel (Fig. 2).

The combination of the orthoset and the butt joint design ensures orthogridse that the orthoset and the frame are joined together without fasteners by welding. Several welding technologies were developed by TAPAS team members at TAPAS2, including induction, conductive and ultrasonic welding technologies The Gulfstream panel used conductive welding to connect the frame wall to the longitudinal stringer of the blade. This task is performed using a welding. head mounted on the robot - another development that contributes to the profitability of production [10].

5. The results of the research

The biggest advantage of thermoplastic composites may be a faster production cycle. Thus, at present, when developing competitive functional polymer materials for aviation use, it is not enough to ensure that they perform the main functions in the aircraft design. It is necessary to create materials taking into account multilateral fundamental research - including aging and climatic resistance. It is necessary to take into account the issues of environmental friendliness of manufacturing technologies and the use of new materials, use modern methodologies for computer modeling of properties and the main approaches of digital production. Since the beginning of the active research and application of thermoplastic materials, in the world of aircraft construction it has been designated as a "new generation" material.

6. Discussion of research results

Given the wide range of thermoplastic components used in the aerospace industry today, it is clear that much progress has already been made. Based on existing applications alone, tonnage of these materials is expected to grow by 200–300 percent over the next decade, encroaching on market share now held by metals and thermoset composites. Advances in thermoforming, welding and bonding are opening up new possibilities for thermoplastic products in secondary and primary structures as well as high volume interior components. In five years, this could significantly increase our estimates of this material and our market share.

Thermoplastic composites will certainly challenge thermoset composites for a place of honor. Heat and pressure processing methods are more similar to those used for metal processing than thermosetting polymerization processes. This fact is driving the rapid expansion of the use of modern thermoplastic instead of aluminum and titanium in clamps, staples, trays and other simple parts. Over the next few years, continued research could expand the practical range of sizes and shapes of parts - soon enough to potentially influence material selection processes for the Airbus A320neo and Boeing 737 MAX.

7. Conclusions

This article demonstrates that scientific and technical progress in the field of aircraft construction does not stand still. Manufacturers and designers, in pursuit of innovation and profit, are developing more and more new technologies that are being introduced into modern passenger and transport aircraft.

The innovative material that has been researched and presented in this article, not only in words, but also in deeds, has proven its purpose. Developments in the field of thermoplastic and thermosetting composites have made great strides forward. This is perfectly demonstrated by the leading modern aviation manufacturers Airbus and Boeing. In their products, they actively began to use more and more composites than metals. In turn, this shows that modern materials are not inferior to metals in strength and technological characteristics, but, on the contrary, are in many ways superior to metal or aluminum materials. Weight reduction is the main criterion by which composites currently hold the first place when choosing components in modern aircraft designs.

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Термопластичні матеріали - новий етап в житті літакобудівництва

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Мета: Основна мета цієї статті - оновити процеси використання термопластичних матеріалів у сучасних конструкціях літальних апаратів. **Результати:** Результатом аналізу сучасного ринку авіаційних технологій та авіаційних матеріалів є активне використання термопластичних матеріалів у конструкціях літаків провідних виробників у галузі авіабудування. **Обговорення:** Характеризується впровадженням технологій використання композитних термопластів в аерокосмічних конструкціях іноземними авіаційними підприємствами.

Ключові слова: технологія тапас, термопластик, автоматичне зварювання, ортосет.

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Термопластические материалы - новый этап в жизни самолетостроения

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Цель: Основная цель данной статьи - актуализировать процессы использования термопластов в конструкциях современных самолетов. **Результаты:** Результатом анализа современного рынка авиационных технологий и авиационных материалов является активное использование термопластичных материалов в конструкциях самолетов ведущих производителей в области авиастроения. **Обсуждение:** Охарактеризовано внедрение технологий использования композитных термопластов в аэрокосмических конструкциях зарубежными авиационными предприятиями.

Ключевые слова: тапас-технология, термопласты, автоматическая сварка, ортосет.

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