UDC 629.7.002:621.762 (045)
DOI: 10.18372/2306-1472.81.14596

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PROSPECTS AND ASPECTS OF ADVANCED POLYMERIC COMPOSITE MATERIALS INTRODUCTION IN ANTONOV AIRCRAFT STRUCTURES

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Abstract

The study represents analysis of the status of PCM introduction in the locally produced aircraft, briefly describes certification processes to be followed during introduction of new materials. It also describes the results of ANTONOV Company specialists work in the area of introduction of new advanced polymeric composites

Keywords: material; design; composite; qualification; technology; process

1. Introduction

It is generally known that use of polymeric composite materials (PCM) in any branch of industry is a sign of high scientific, technical and qualitative level of its development.

Improvement of ergonomic qualities of leisure time items, medical equipment along with economic efficiency, reliability and structural life results in increasingly bigger volumes of PCM implementation especially in the aircraft and rocket manufacturing [1-2].

This is proven by the production output growth rate of the fiber glass products (including fiber glass plastics with thermoreactive and thermoplastic resins) which undergo permanent increase within the last five years (in accordance with JEC Magazine data[3]), and in 2017 has reached 1.118 million tons only in Europe (Fig.1). At the same time we can observe development and extension of implementation of out-of-autoclave production processes. For instance, use of RTM process for aircraft structures manufacturing has increased by 3.5% if compared with 2016 and amounted to 146,000 tons of structures manufactured by this method only in the European market segment, and the use of thermoplastic materials showed an increase of 3.6% (145,000 tons).

The North American market in terms of the volume of products made from polymer composites in 2017 changed little, if at all. Experts predict a change in the annual growth index in production for North America by only 2% until 2021, mainly due to the aviation industry. Within 2016–2021 the foreseeable redistribution of the global manufacturing of PCM products in favor of China by 5% will take place. Thus, the production volumes will be distributed as follows: China - 33% (5% increase), North America - 24% (2 % loss), Europe - 19% (2% loss), other Asian countries -19%, raw material production - 5% (1% loss) and will amount to 12.9 million tons by 2021 (2.1 million tons more than in 2016).

	2014 kilotons	2015 kilotons	2016 kilotons	2017 kilotons
United Kingdom/Ireland	146	150	152	153
Belgium/Holland/Luxembourg	43	44	45	46
Finland/Norway/Sweden/Denmark	42	39	40	40
Spain/Portugal	154	156	158	161
Italy	148	150	154	158
France	108	108	110	112
Germany	200	212	220	226
Austria/Switzerland	18	18	18	19
Eastern Europe*	184	192	199	203
Total	**1.043**	**1.069**	**1.096**	**1.118**

* - Poland, Czech Republic, Hungary, Romania, Serbia, Croatia, Macedonia, Latvia, Lithuania , Slovakia and Slovenia

Fig. 1. Volumes of fiberglass production in Europe by year

According to some expert assessments in Ukraine this factor runs at several hundred tons per year, mainly in the form of fiberglass products. This volume is represented mainly by small industrial enterprises which are involved in manufacture of light aircraft, construction, transport, as well as the leading enterprises of the industry: ANTONOV Company (Kyiv), Yuzhnoye SDO (Dnipro), Motor Sich JSC (Zaporizhia) etc.

2. Main part

It is commonly known that the Ukrainian aircraft industry, represented by the firm established in 1946, at present ANTONOV Company, has a generally recognized experience in development and

manufacturing of world-class competitive civil transport aircraft, which has been forming since the middle of the last century [4-5]. As a result of a tendency of intensive use of PCM, introduced way back when/as far back as O.K. Antonov was the general designer, ANTONOV Company has more than 70 years experience of use of these materials in transport and passenger aircraft structures, and until present time it has been actively working to increase the use of PCM in its aircraft.

These are mainly PCM based on melt bonding agents: epoxy, phenolic, polyimide. To a certain extent the use of these materials is driven by the heritage of the post-Soviet period, when enterprises had a closed cycle manufacturing: starting from the supply of initial components to the manufacturing of the finished product. This approach differs from the current world practice of aircraft serial production. Aircraft manufacturing corporations such as Boeing and Airbus develop extensive networks of logistics and cooperation in the supplies of aircraft parts and components within a strictly determined time periods, because more often than not maintaining and supporting of multipurpose production is not profitable. Current trends in use of bonding agents show that solution bonding materials are no longer as effective due to the formation of pores in plastics during the molding process (up to 2%), the complexity of the impregnation process, environmental issues and, as a result of this they are replaced by solution and thermoplastic bonding agents. The wide use of such new types of bonding agents in combination with more advanced reinforcing materials is due to the severization of customer's requirements to manufacturability, strength, reliability and service life of aircraft structures. The use of these materials in the aircraft results in the need of their certification in accordance with the requirements of the Aviation Regulations (AR).

It is known that in accordance with the AR requirements all materials used for aircraft structures manufacturing must undergo a general and special qualification based on different specific features of materials in order to determine if they may be used for aircraft structures in accordance with the requirements of Guidelines 23-29M "Procedure of aircraft materials qualification for compliance with the AR requirements", section E [6].

This qualification consists of three mandatory parts:

- qualification of materials-components;
- qualification of serial production processes for manufacturing structures from materials-components;
- determination of composites design performance.

The composites qualification is divided into two parts according to the type of structural elements (Fig. 2).

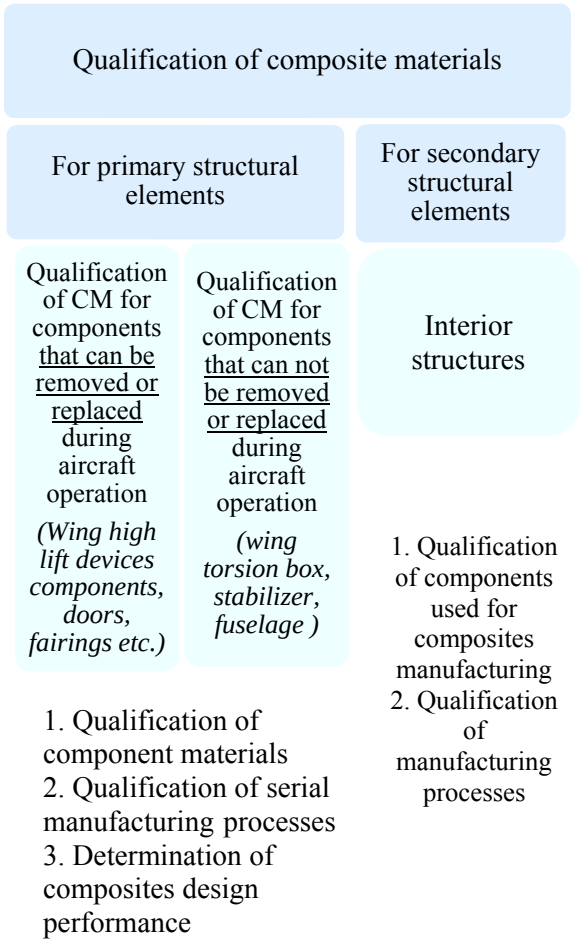

Fig. 2. Qualification of composite materials

In order to implement the qualification requirements, it is necessary to develop a number of research programs, determine the necessary types of tests in accordance with the certification basis requirements, the number of tests, their implementation, etc.

These activities involve the expenses for materials acquiring, instrumentation of production, manufacturing of samples, in other words, they require substantial equipment capability of the production facilities or the availability of specialized laboratories. These works also require a significant time interval to complete.

Many organizations and institutes in Europe and the United States specialize in performing this kind of work and offer their services in this area providing the customers with databases on the physicochemical and mechanical properties of materials under a separate contract. This approach somehow simplifies and speeds up the of material properties validation, however, this solution requires significant non-recurrent expenditures, which can be justified by the tight schedules of launching the production of the first aircraft.

In addition to that there is a number of associated problems that arise during certification of new materials instead of those used earlier:

- higher cost of imported materials if compared to locally produced materials and materials produced in the CIS countries, therefore this leads to an increase of the overall cost of the aircraft;

- most prepregs and film adhesives have a short pot life at room temperature and require storage at lower temperatures (up to -18 ° C), which imposes certain restrictions on their use (the need for aging after freezing, control over the condensate removal);

- to find an identical analogue to the material in use in terms of monolayer thickness, strength characteristics, draping quality is quite difficult and sometimes impossible. This results in the need to change the molding equipment and design documentation.

In order to improve the structures and manufacturing processes, ANTONOV Company is constantly working on the introduction of modern materials. The first materials implemented as a replacement for traditionally used auxiliary materials were materials produced by Airtech Europe S.A. They were used for manufacturing of the carbon fiber components of An-70 tail unit. Due to the specific design of the components, in the process of their manufacture, a very important stage was ensuring a high-quality assembly of the vacuum bag system for several stages of molding and for the final stage of the complete structure assembling. High elongation multilayer films got the things done. At the same time a lot of other materials were introduced, including the mould release agents that need no heat treatment after their application (the SK-5 mould release agent used earlier required drying in a furnace or autoclave for 5 hours before the beginning of the lay-up), drainage materials, “release fabrics” to name but a few.

Implementation of these materials resulted in not only improved physical and mechanical characteristics of the parts, but also in improved quality, as well as reduced power consumption during production of PCM products.

Having received a positive experience in introducing new auxiliary materials the “substitution with foreign materials” program was developed - i.e. introduction of foreign materials instead of previously used locally produced materials and those produced in the CIS countries. The program included the definition of types and brands of materials to be replaced, the search and identification of alternative suppliers, as well as the time periods of the program implementation (Table).

The results of many years of work of the ANTONOV Company specialists under the “substitution with foreign materials” program " can be considered as follows:

a) introduction of the resin film infusion (RFI) process for manufacturing of secondary structures, such as components of passenger and cargo cabin interiors, as well as flight compartment elements. Together with the said technology, modern phenolic and epoxy film resins were introduced, the use of which allowed to reduce production cycles, improve the quality and production standards of parts manufacturing [7];

b) introduction of carbon prepregs into primary structures allowed not only improving the quality of carbon fiber structures, but also increasing the factor of safety in structures due to the higher physical and mechanical characteristics of foreign carbon materials. Eventually, this will allow improving the existing and creating the new designs, taking into account the new level of physical and mechanical characteristics of plastic;

c) try-out, testing and approval of liquid structural adhesives - analogues of VK-type adhesives, which is widely used for manufacturing and repair of composite structures. A detailed description of the work in this direction is given in our article [8];

d) introduction of locally produced materials, in particular, glass fillers produced by RPA UKRPROMVNEDRENIE, allowed the use of materials designed in accordance with the technical specification of ANTONOV Company;

e) introduction of a number of auxiliary materials produced in Europe: films for vacuum bags, sealant tapes, drain and release fabrics enabled increase of reliability of expensive composite structures moulding in autoclaves with high pressure and temperature.

Table

A short list of basic materials to be replaced

Material	Country of origin	Alternative supplier
Carbon fabrics (UD and balanced)	Russia	Hexcel composites (France, Spain)
		Porcher Industries (France)
Glass fabrics	Ukraine	Porcher Industries (France)
High modulus glass fabric (S-Glass)	Belarus	Porcher Industries (France)
Aramid fabrics (Kevlar)	Russia	
Epoxy resins T -60˚C- +80˚C	Ukraine	5M (Czech Republic) 3M (USA) Gurit (Switzerland)
Epoxy resins T -60˚C - +150˚C	Russia	
Epoxy phenol flame resistant resins T -60˚C - +80˚C	Russia	
Polyimide resins T -60˚C - +250˚C	Russia	
Phenolic resins T -60˚C - +80˚C	Russia	
Epoxy films T -60˚C - +80˚C	Czech Republic	3M, Henkel (USA)
Honeycomb core	Russia	Hexcel (Spain, France)
Synthetic foams and pastes γ=51-110 kg/m^3	Russia	Evonik, Airex (Germany)

3. Conclusions

The study analyzes the development of fiberglass items production in different regions of the world. It notes the tendency of growth of non-autoclave technologies and increase in use of thermoplastic-matrix composites. The study describes some certification procedures faced by aircraft designer when new materials are used for aircraft manufacturing.

It is noted that, despite the long period of stagnation in the aviation industry development in Ukraine, which has been going on for more than 20 years, ANTONOV Company retained its scientific and technical potential in the area of development, implementation and application of new polymer composite materials and manufacturing processes for Antonov products with the purpose of their improvement, increase of economic and operational efficiency.

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О.В. Андрєєв

Перспективи та особливості впровадження сучасних полімерних композиційних матеріалів у конструкції літаків «Ан»

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Виконано аналіз стану впровадження полімерних композитів у вітчизняні літаки, надано короткий опис процесів сертифікації впровадження нових матеріалів. Описані результати робіт фахівців ДП «АНТОНОВ» у напрямку впровадження сучасних полімерних композитів.

Ключові слова: матеріал, конструкція, композит, кваліфікація, технологія, процес.

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Перспективы и особенности внедрения современных полимерных композиционных материалов в конструкции самолетов «Ан»

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В работе выполнен анализ состояния внедрения полимерных композитов в отечественные самолеты, кратко описаны процессы сертификации при внедрении новых материалов. Описаны результаты работы специалистов ГП «АНТОНОВ» в направлении внедрения современных полимерных композитов.

Ключевые слова: материал, конструкция, композит, квалификация, технология, процесс

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