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Creation of ultra-light spacecraft constructions made of composite materials

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Abstract

The problem of creating ultra-light composite structures is considered. An overview of the main modern methods of manufacturing composite materials and methods of increasing the weight efficiency of constructions in view of the structure destination, its force work and operating conditions are given. The main design and technological solutions to reduce the weight of a regular construction zone, connection zone and transition zone are offered. The importance of taking into account the anisotropy of mechanical and thermo-elastic properties of composite materials for structures with special requirements for dimensional stability is noted. Guidelines for choice of materials components and manufacturing technology depending on the design application, operating conditions and the nature of load distribution are given. Examples create ultralight structures and their properties are given.

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Keywords: composite materials; integral constructions; design and technology concept; technology; mass efficiency

1. Introduction

One of the main problems in the design of aerospace structures is the choice of material that satisfies requirements of the exploitation of the future product. This material should have the necessary strength, be sufficiently stiff, be plastic and resist environmental influences [1]. Composite materials have these properties. Moreover, due to the clearly expressed anisotropy of mechanical properties, they can create structures with specific characteristics.

Reinforced plastics have a unique combination of properties such as high strength and stiffness, high resistance to wear, low density, and good humidity, chemical and corrosion resistance. [2]

Table 1 shows the strength properties of traditional structural materials, and of composite materials.

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Table 1. Strength properties of traditional structural materials and of composite materials

Material	Mechanical properties		Density	Structural efficiency				
	$\sigma_{\max}(MPa)$	$E\ (GPa)$	ρ (g/sm^3)	$\frac{\sigma_{\max}}{\rho}\left(\frac{MPa}{g/sm^3}\right)$	$\frac{\sigma_{\max}}{\rho g}(km)$	$\frac{E}{\rho g}(km)$	$\frac{\sqrt{E}}{\rho}$	$\frac{\sqrt[3]{E}}{\rho}$
Aluminum	440	72	2.8	157.1	16	2600	3.03	1.49
Titanium	1080	110	4.4	245.5	24	2500	2.38	1.09
Alloy steel	1930	200	7.8	247.4	25	2560	1.81	0.75
Glass/Epoxy	550	34	1.8	305.6	30	1890	3.24	1.80
Kevlar/Epoxy	1100	83	1.4	785.7	79	5930	6.51	3.12
Graphite/Epoxy	1200	150	1.6	750	75	9400	7.65	3.32

It may be noted that composite materials based on glass fibers, carbon fibers and Kevlar fibers are significantly superior to aluminum alloys, titanium, and steel for a variety of important characteristics related to the structural efficiency. Additionally polymer composites have low density, which contributes to structures of a lower weight in comparison with metal structures.

Composite materials are used to manufacture a wide range of aerospace structures. These include fairings of launch vehicles, mesh constructions for different purposes, ultra-light frameworks for solar panels of carbon fiber, space, and other radio telescopes.

2. Technologies of manufacturing of composite structures.

The autoclave method of manufacturing of polymer composite materials is widely used. This molding technology allows a very strong material with low porosity to be obtained. Polymer composite manufacturing by this method includes placing the package of the layered prepreg based on the reinforcing fiber in the mold. Then the preform is packaged in a vacuum bag and placed in an autoclave where curing is performed at increased pressure and high temperatures. A scheme is shown in Figure 1.

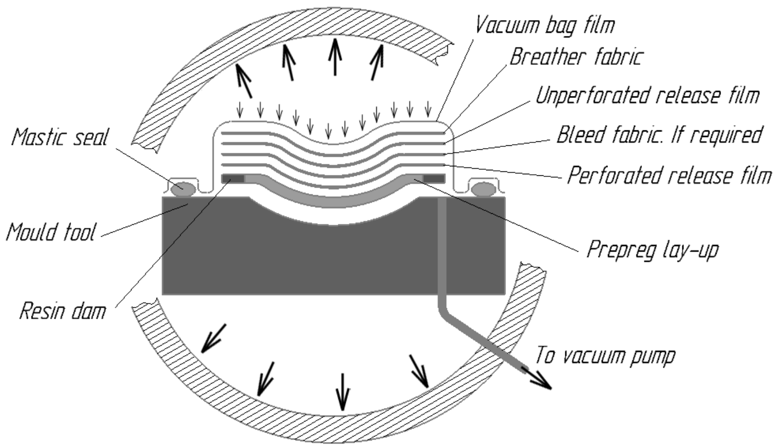

Fig. 1. Scheme of autoclave method manufacturing

The autoclave method enables a product of uniform thickness with high surface quality to be obatined. It possible to obtain large structures. However, the geometric parameters of the future product are limited to the size of the autoclave. Considerable disadvantages of this technology are the high cost of production and high percentage of hand work.

The method of winding for producing structures that represent bodies of rotation (pipes, vessels, tanks) is applied. The manufacturing of products with the winding method is the process of laying a continuous reinforcing material along a predetermined path on a rotating mandrel which defines the geometry of the product. A scheme is shown in Figure 2.