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TECHNOLOGICAL ASPECTS OF CREATION OF CARBON PLASTICS WITH STABLE PHYSICAL AND MECHANICAL CHARACTERISTICS

The paper discusses the technological aspects of creating carbon fiber reinforced plastics. Indicators of the prospects for the use of infrared radiation and modifying fillers in the manufacturing process of products in order to obtain stable and improved physical and mechanical characteristics.

A comparative analysis of the interlayer hardness at the filler-binder boundary of carbon plastics made on the basis of natural and modified fillers using standard technology (convective heating) and using infrared radiation was carried out. [dx.doi.org/10.29010/89.3]

Keywords: *carbon fiber; modified filler; infrared radiation.*

Introduction

Carbon plastics — composites based on high-strength carbon fibers — along with organoplastics and fiberglass are the most promising type of composite materials. They are distinguished by high characteristics of strength and rigidity, heat resistance, low temperature coefficient of linear expansion and erosion resistance to aggressive environments.

CFRPs are used in aviation, rocket and space technology, in the automotive industry and in other fields.

The formation of carbon fiber products is currently given considerable attention, since increasing their physical and mechanical characteristics during process intensification requires an individual approach to solving the problems posed.

Several technological approaches to obtaining products from polymer composite materials with stable high physical and mechanical characteristics are known [1]. They can be divided into two main areas — the modification of the fillers and the use of infrared radiation in the process of composite formation and curing. The search for solutions led to the development of chemical and physical methods for the modification of reinforcing materials and polymer binders. This is atmospheric plasma treatment of fillers and infrared heating during the curing.

Problem statement

The traditional way to obtain products from polymer composite materials includes three main stages. At first, the preparation of the starting materials (filler, binder) is carried out, then the products are formed and, finally, the composition is cured [2].

In this work, we studied carbon plastics obtained by wet winding on winding machines with numerical control, which allowed us to obtain a uniform distribution of the binder. In turn, this provides a strong adhesive contact at the filler-binder interface [3]. Also, in order to activate the surface of the filler and increase the reactivity to crosslinking with the matrix, sizing is applied on it [4].

After winding, the responsible operation of obtaining carbon fiber products is curing, which is traditionally carried out in convective heating furnaces [5]. In order to eliminate large temperature stresses and ensure uniformity of the temperature field, the curing cycle is long. It includes smooth heating, holding at the curing temperature, and smooth cooling. An increase in the heating temperature leads to an increase in the activity of molecules. This leads to an oscillation of molecular units, due to which the polymerization process proceeds more intensively. In addition, the molecular weight of macromolecules increases, their rigidity increases, there is a danger of thermal degradation of the binder, and this leads to a decrease in mechanical characteristics [6].

The intensification of the curing process and counteracting the thermal degradation of the binder are currently paying particular attention to the development of various methods of thermo-radiation or induction effects on the composition. So, in [7], the results of studies of epoxy resin cured under the influence of ultraviolet radiation are presented and a decrease in residual stresses and an increase in the strength of the material are established.

A technological solution for obtaining a composite under the influence of physical fields is the use of low-wave infrared radiation [8].

Object of research

Carbon plastics based on traditional carbon fibers УКН/5000 and treated with atmospheric plasma in an acrylic medium acid and cured by infrared radiation.

Main material

To obtain carbon plastics, we used traditional filler, carbon fibers УКН/5000, treated with atmospheric plasma in an acrylic acid medium. Sizing was carried out according to the following regime: a dielectric barrier discharge was created between the two electrodes through which carbon fiber was passed; as plasma forming gas protruded air. The use of acrylic acid as a chemical precursor to a plasma-forming gas ensured its saturation with functional groups: OH, COOH, C = O, C-O-C, -O-O-, NH2, NH, etc., responsible for the ability of the material to crosslink with an epoxy matrix [9].

Table 1

Characteristics of samples of carbon fiber cured by convective heating

№	Width, mm	Thickness, mm	Load, N	Breaking stress, MPa
Carbon fiber based on carbon fiber UKN/5000 (traditional) and epoxy binder				
1	14,92	2,58	1742,75	33,96
2	14,13	2,53	1614,19	33,87
3	14,9	2,81	1729,53	30,98
4	14,3	2,65	1691,55	33,48
5	14,15	2,52	1618,59	34,04
6	14,65	2,58	1708,57	33,90
			Average	33,37
			Dispersion (standarddeviation)	1,19
Carbon fiber based on carbon fiber brand UKN/5000 treated with atmospheric plasma with acrylic acid and an epoxy binder				
1	15,24	2,29	2176,93	46,78
2	15,31	2,67	2312,05	42,42
3	14,95	2,61	2294,31	44,10
4	15,45	2,30	2123,75	44,82
5	15,26	2,15	2084,21	47,64
6	15,20	2,20	2207,14	49,50
			Average	45,88
			Standarddeviation	2,58

Table 2

Test results of cured carbon fiber samples using infrared heating

№	Width, mm	Thickness, mm	Load, N	Breaking stress, MPa
Carbon fiber based on carbon fiber УКН/5000 (traditional) and epoxy binder				
1	15,43	2,48	2185,24	42,83
2	15,75	2,53	2195,54	41,32
3	15,32	2,54	2124,65	40,95
4	15,99	2,39	2175,24	42,69
5	15,12	2,41	2141,64	44,08
6	15,38	2,52	2241,53	43,38
			Average	42,54
			Standarddeviation	1,2
Carbon fiber based on carbon fiber brand УКН/5000 treated with atmospheric plasma with acrylic acid and an epoxy binder				
1	15,44	2,54	2752,75	52,64
2	15,71	2,61	2737,73	50,08
3	15,38	2,6	2785,55	52,24
4	15,49	2,55	2703,68	51,34
5	15,42	2,58	2693,8	50,78
6	15,51	2,45	2740,47	54,09
			Average	51,86
			Standarddeviation	1,48

When winding carbon plastics, halogen incandescent lamps NIK-220-1000 were used, which provided a temperature $T_{max} = 323^{-10}$ K. This contributed to low viscosity of the binder, which makes it possible to penetrate into the interfiber space of the filler [10].

After the formation of the composite, its additionalcuring was also carried out using infrared radiation in the following mode: exposure at a temperature of 323^{-10} K for 30 minutes, then a gradual increase in temperature to 353^{-10} K and exposure at this temperature for 30 minutes. After exposure under infrared heater at a temperature of 353^{-10} K, it was raised to 393^{10} K and the object was irradiated for 60 minutes at this temperature. The total curing time of a multilayer carbon fiber composite with a thickness of up to 1.5 mm using infrared radiation was 2 hours; the cure time by convective heating was 8–10 hours.

When assessing the quality of the obtained carbon plastics using infrared heating, the physical and mechanical characteristics of the samples were evaluated.

The assessment was carried out by comparing the strength of the interlayer shear materials obtained by traditional technology and developed.

Used samples: "traditional filler – convective heating", "modified filler – convective heating", "traditional filler – infrared heating" and "modified filler – infrared heating".

The characteristics of carbon fiber samples of both traditional and modified cured by convective heating are presented in table 1.

As a result of tests for interlayer shear of the samples, an increase in strength was established when using УКН/5000 carbon fiber treated with atmospheric plasma in an acrylic acid medium as a filler. The breaking stress value for traditional carbon fiber reinforced plastic is 33.37 MPas with a standard deviation of 1.19, and for a modified one — 45.88 MPa with a standard deviation of 2.58 (the percentage of increase in interlayer shear strength is up to 27%).

The test results of cured carbon fiber samples using infrared heating are shown in table 2.

From the obtained test results of samples cured using IR heating, it follows that when using traditional filler, the average value of the breaking stress at the interlayer shift is 42.54 MPas with a standard deviation of 1.2, and when using a modified (plasma-treated carbon fiber УКН/5000 in an acrylic acid medium) — 51.86 MPas with a standard deviation of 1.48.

The obtained increase in the strength of modified carbon fiber using IR heating confirms the ability of the material to crosslink with an epoxy matrix and obtain stable high physical and mechanical characteristics of the composite.

Conclusions

Based on the conducted studies, it was established that the use of UKN/5000 carbon fiber modified with atmospheric plasma in an acrylic acid medium can increase the operational characteristics of carbon fiber plastic by 27%.

The use of IR heating throughout the entire process of winding and curing the composite made it possible to obtain stable material characteristics.

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ТЕХНОЛОГИЧЕСКИЕ АСПЕКТЫ СОЗДАНИЯ УГЛЕПЛАСТИКОВ СО СТАБИЛЬНЫМИ ФИЗИКО-МЕХАНИЧЕСКИМИ ХАРАКТЕРИСТИКАМИ

В работе рассмотрены технологические аспекты создания углепластиков. Показана перспективность применения инфракрасного излучения и модифицирования наполнителей в процессе изготовления изделий с целью получения стабильных и повышенных физико-механических характеристик.

Проведен сравнительный анализ межслойной прочности на границе «наполнитель–связующее» углепластиков, изготовленных на основе традиционных и модифицированных наполнителей по штатной технологии (конвективный нагрев) и с применением инфракрасного нагрева. [dx.doi.org/10.29010/89.3]

Ключевые слова: *углепластик; модифицированный наполнитель; инфракрасное излучение.*

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