ANNOTATION

dissertation work on the topic:

«INVESTIGATION OF WAYS TO INCREASE THE IMPACT RESISTANCE OF CARBON FIBER» submitted for the degree of Doctor of Philosophy (PhD) in the specialty

6D071000 –"Material science and technology of new materials"

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The aim of the thesis. Increasing the strength and toughness of carbon fiber by modifying epoxy resin with rubbers and combined reinforcement of carbon fiber with aramid and glass fibers.

Research Objectives:

– to develop a method to improve the strength characteristics of epoxy resin;

– to study the methods of formation of carbon fiber in the modification of epoxy resin with rubbers;

– to conduct a study of the combined action of modified epoxy resin and combined reinforcement for the strength and toughness of carbon fiber;

– to study the influence of the main factors and parameters in the manufacture of carbon fiber tubes.

Research methods:

The main research methods used in the performance of the dissertation work include:

– to determine the viscosity of epoxy resins, the VZ-246 viskosimeter ("NCSRT" JSC) was used;

– studies of wetting angles were carried out on the Ossila goniometer (Al-Farabi KazNU);

– mechanical tests of samples of ecoxide resins and carbon fiber for tension/compression were carried out on Instron, WDW-5E testing machines and Shimadzu. (Al-Farabi KazNU, S. Amanzholov EKSU, JSC " The Institute of Metallurgy and Ore Beneficiation", The Institute of Combustion Problems);

– the impact strength test of samples of epoxy resins and carbon fiber was carried out on a pendulum copra MK-30 (JSC "NCSRT").

The main provisions (proven scientific hypotheses and other conclusions that are new knowledge), presented for the defense:

1. The developed method of modification of epoxy resins with rubbers allows to reduce the kinematic viscosity of ED-20 epoxy resin by 25% and increase the impact strength by 126% with a slight loss of compressive strength, for Etal-Injection-T epoxy resin, this method allows to reduce the viscosity by 64% and increase the impact strength by 67% when preservation of compressive strength at the level of 105.7 MPa;

2. The use of epoxy resin modified with 10% polyurethane rubber, in the process of manual molding of carbon fiber, leads to an increase in compressive

strength by 16% and impact resistance by 12%, during the formation of carbon fiber by vacuum infusion, it allows to increase compressive strength by 25% and impact strength by 21%.

3. Using epoxy resin modified with 10% polyurethane rubber and combined reinforcement of carbon and aramid fabrics in a ratio of 1:1, a method has been developed that increases the compressive strength up to 35% and its impact strength up to 42%.

4. Significant factors and parameters have been identified that have a significant impact on the manufacturing process of carbon fiber tubes with high tensile strength up to 710 MPa, compressive strength up to 515 MPa and impact strength up to 201 kJ/m^2.

Description of the key research results:

– The influence of rubbers on the kinematic viscosity, wetting angle, compressive strength and impact strength of unmodified epoxy resins ED-20 and Ethal-Injection-T. The best results were obtained when the epoxy resin was modified with 10% polyurethane rubber: the viscosity of the ED-20 epoxy resin was 95 cSt (a decrease of 25%), the wetting angle of the right and left angles was 49°, the impact strength increased by 45.4 kJ/m^2 (by 126%) and with a slight loss of compressive strength; the viscosity of the Ethal-Injection-T epoxy resin was 56 cSt (a decrease of 64%), the wetting angle of the right and left angles was 40°, the impact strength was 70.8 kJ/m^2 (by 67%) and while maintaining compressive strength at 105.7 MPa;

– The influence of epoxy resin modified with rubbers and molding methods on the strength properties of carbon fiber plastics has been studied. The impact strength increased from 192 kJ/m^2 to 215 kJ/m^2 (by 12%), the strength of carbon fiber samples obtained by manual molding increased with the addition of 10% semi-polyurethane rubber, which showed a positive result for epoxy resin. With vacuum infusion and with the addition of 10% polyurethane rubber to the epoxy resin, the compressive strength of carbon fiber plastics increased by 25%, the impact strength by 21%

– The effect of combined reinforcement on the strength properties of carbon fiber plastics has been investigated. When combining carbon fabric with aramid fabric in a ratio of 1:1, the strength increased from 425 MPa to 458 MPa, the impact strength from 192 kJ/m^2 to 229 kJ/m^2.

– It was found that the introduction of polyurethane rubber into the epoxy resin and the combined reinforcement of carbon fabric / aramid fabric in a mass ratio of 1:1 leads to to increase the impact strength of carbon fiber from 192 kJ/m^2 to 273 kJ/m^2, i.e. increased by 42%, and the compressive strength from 425 MPa to 575 MPa to, i.e. by 35%

– Indicators of important factors and parameters in the manufacture of carbon fiber tubes and increasing strength properties were revealed: the thickness of carbon roving is 24K, the soaking time of carbon roving in an epoxy bath is 9.5 s, the tension force of carbon roving is 18.6 N, the winding angle is 60°, 10% polyurethane rubber, with combined reinforcement of carbon/aramid roving in a ratio of 1:1. Obtained using all the most optimal parameters: tensile strength increased from 541 MPa to

710 MPa (31%), compressive strength increased from 325 MPa to 515 MPa (58%), impact strength increased from 158 kJ/m^2 to 201 kJ/m^2 (27%).

Justification of the novelty and importance of the results obtained:

For the first time, the technology of modification of epoxy resins with rubbers and combined reinforcement with various polymer materials has been developed, which increases the impact strength of carbon fiber while maintaining compressive strength.

The technology provided for the production of impact-resistant carbon fiber, which for the first time allows to obtain carbon fiber with a compressive / tensile strength of 515-710 MPa, impact strength of 201-273 kJ/m2. Since carbon fiber in these indicators is a carbon fiber of the highest category and is not published in foreign publications, this is a new direction for Kazakhstan.

A technical design of a desktop laboratory winding machine for the manufacture of carbon fiber tubes is proposed.

The results of the study have novelty and practical value, significantly complement the existing ideas about the technology of obtaining carbon fiber plastics and can be used to solve similar problems.

The dissertation work has a high scientific value, which is confirmed by the author's scientific works, including published articles; international reports and the patent of the Republic of Kazakhstan for a utility model.

According to the results of the research, an act on the introduction of technologies for the production (production) of aerospace carbon plastics in KazTechInnovations LLP (the Act of Implementation) was drawn up.

Compliance with directions of science development or government programs.

Currently, carbon fiber is widely used in spacecraft hulls due to its high strength and lightness. In connection with the development of the domestic space industry in Kazakhstan, the construction of the National Space Center of the Republic of Kazakhstan (NSC) is being completed in Astana. The Kazakh-French Ghalam LLP is engaged in the design and production of all types of spacecraft as an integral part of the NSC. Kazakhstan plans to gradually develop the production of components.

In Kazakhstan, the project of a domestic ultralight launch vehicle for the Baikonur cosmodrome has been implemented since 2021 at the National Center for Space Research and Technology JSC.

For these two reasons, on behalf of the domestic Aerospace Committee, the technology for the production of high-quality carbon fiber was taken.

For the production of housings, power elements, as well as individual components, special structural materials of increased strength and impact strength - carbon fiber are needed. Carbon fiber plastics of high strength and toughness do not have production in Kazakhstan, and therefore they have to be imported. According to the international agreement "missile technology control regime" (MTCR treaties) and the "Wassenaar Agreements on export control of conventional weapons", "goods and dual technologies" (Wassenaar Agreements), carbon fiber plastics with

a strength of over 415 MPa are included in the categories "secret" and "top secret". Carbon fiber technologies of this category are prohibited for publication and transvert. Therefore, Kazakhstan has to create the technology of production of high-quality carbon fiber for space technology itself.

The dissertation work is aimed at solving one important part of this problem.

This research work is related to the activities of the state program "development of space activities in the Republic of Kazakhstan for 2015-2017" and the republican budget program 008 "development of technology for the production of impact-resistant carbon fiber products for defense and aerospace applications"applied scientific research in the field of space activities» for 2018-2020".

The author's personal contribution consists in conducting experiments, generalizing and interpreting the results obtained, participating in the creation of an experimental laboratory winding machine, writing articles.

Description of the contribution of the doctoral student to the preparation of each publication.

According to the results of the dissertation work published:

1. Смағұлова Г.М., Мейірбеков М.Н., Исмаилов М.Б., Аблакатов И.К. Эпоксид шайырын сұйық олигомерімен модификациялауды жүргізу. Международная научная конференция студентов и молодых ученых «Фараби әлемі», Алматы, 8-11 апреля 2019 г, стр.172
2. Мейірбеков М.Н., Исмаилов М.Б. Влияние каучка на механические свойства эпоксидной смолы и углепластика (Обзор) // Комплексное Использование Минерального Сырья. №1 (312).2020, Алматы, стр. 11-18, ISSN 2224-5243. DOI: 10.31643/2020/6445.02
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5. Мейірбеков М.Н., Манько Т.А., Козис К.В. Прочностные характеристики углепластиков модифицированных пластификаторами. XXIII Міжнаодна молодіжна наукого-практична конференція «Людина і космос», Дніпро, 14-16 квітня 2021 г, стр. 137
6. Патент РК на полезную модель «Способ получения углепластика». Выдан Министерством юстиции Республики Казахстан за № 2952. Дата подачи заявки 06.01.2021, дата опубл. 23.04.2021, бюл. №6007. Авторы изобретения: Исмаилов М.Б. (РК), Мейірбеков М.Н. (РК), Жумаканова Венера Руслановна (РК), Байсериков Б.М. (РК), Аблакатов И.К. (РК).

7. Мейірбеков М.Н., Исмаилов М.Б. Проектирование и изготовление лабораторной установки по формованию углепластиковых стержней методом намотки // News of the National Academy of Sciences of the Republic of Kazakhstan Physico-Mathematical series ISSN 1991-346x vol.6, №340 (2021), 15–27 DOI: 10.32014/2021.2518-1726.97

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