

ABSTRACT

of thesis on the theme:

“Development of methods for modifying epoxy resin and carbon fiber to increase the strength properties of carbon fiber reinforced plastic” 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 reinforced plastic by oxidizing carbon tissue with nitric acid and adding plasticizers and thermoplastics to epoxy resin (ER).

Research Objectives:

-increasing the strength of the ER by modifying it with plasticizers and thermoplastics;

- increasing the strength properties of carbon fiber reinforced plastic by increasing the chemical activity of carbon tissue and the process of oxidation with nitric acid;

-research of the effect of ER modification on the mechanical properties of carbon fiber reinforced plastic;

-research of the combined effect of modified carbon tissue and modified ER on the strength characteristics of carbon fiber reinforced plastic and the effect of vacuum infusion formation.

Research methods:

The main research and analysis methods used in the dissertation are:

-mechanical testing of ER and carbon fiber reinforced plastic samples on tensile machines Instron and Shimadzu (Kazakh National University named after al-Farabi, JSC "IMOB", Institute of Combustion Problems);

- tests for impact strength of samples ER and carbon fiber reinforced plastic on the MK-15 pendulum head. (Machine-building plant named after S.M. Kirov, Almaty).

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

- the effect of modification of ER by plasticizers and thermoplastics on their strength and toughness;

- the effect of carbon tissue modification on the strength characteristics of carbon fiber reinforced plastic;

- the effect of modified ER on the mechanical properties of carbon fiber reinforced plastic;

- the effect of the combined effect of modified carbon tissue and modified ER on the strength characteristics of carbon fiber reinforced plastic and the effect of vacuum infusion formation.

Description of the key research results:

The effect of modifiers on compression and impact strength of ERs ED-20 and Etal Inject-T has been studied. The best results were obtained with the addition of 10% plasticizer:

- for ED-20 resin: compressive strength 99.6 MPa (increased by 2%) and impact strength 39.5 kJ/m² (increased by 2 times);

- for Etal Inject-T resin: compressive strength 122.2 MPa (increased by 15%), and impact strength 80.3 kJ/m² (improved by 90%).

An increase in the strength properties of resins is associated with their chemical interaction with plasticizers and thermoplastics.

To strengthen the carbon fiber reinforced plastic, the effect of oxidation of the surface of the carbon tissue in a nitrogen solution was investigated:

- carbon fiber reinforced plastic, obtained from carbon tissue with a surface oxidized in a nitrogen solution for 2.5 minutes and ED-20 resin, achieved tensile strength from 833 MPa to 900 MPa and compressive strength from 300 MPa to 385 MPa.

- carbon fiber reinforced plastic, obtained from carbon tissue with a surface oxidized in a nitrogen solution for 2 minutes and Etal inject-T resin, increased tensile strength from 1000 MPa to 1150 MPa (by 15%), compressive strength from 425 MPa to 497 MPa (by 17%). By oxidation of carbon tissue in nitric acid, carboxyl groups are formed on the surface of carbon tissue, which can improve the compatibility of carbon tissue and ER. Thus, mechanical properties are increased.

For the first time, results were obtained on the effect of the combined effect of modified ER and modified carbon tissue on the mechanical properties of carbon fiber reinforced plastic. The technology proposed in this dissertation makes it possible for the first time to obtain carbon fiber reinforced plastic with a compressive strength of 600 MPa and a toughness of 250 kJ/m².

Justification of the novelty and importance of the results obtained:

Using the method of modification of carbon tissue and ER, for the first time in the dissertation work, a carbon fiber reinforced plastic with increased strength and toughness characteristics was obtained. The research of the effect of modification makes it possible to develop a new effective technology for producing carbon fiber reinforced plastic with high operational and technological properties, high strength and toughness.

The novelty of the results obtained lies in the fact that for the first time the effect of the combined effect of modified ER and modified carbon tissue on the mechanical properties of carbon fiber reinforced plastic has been researched.

The technology proposed in this dissertation makes it possible for the first time to obtain carbon fiber reinforced plastic with compressive strength up to 425-600 MPa and impact strength up to 250 kJ/m². This makes it possible to increase the stability of the design of carbon fiber reinforced plastic aircraft to shock loads.

The scientific level of the presented dissertation work has scientific value, which is confirmed by the scientific works of the author: a) published articles; b) the results of an international conference c) a patent for a utility model.

The developed technology for the production of impact-resistant carbon fiber reinforced plastic for aerospace purposes has been implemented by “KazTechInnovations” LLP (Implementation Act). This will improve the technical and mechanical characteristics of aircraft manufactured by “KazTechInnovations” LLP.

Compliance with directions of science development or government programs.

Currently, a National Space Center has been built in the city of Nur-Sultan, an integral part of which is an enterprise for the design and production of spacecraft. The Kazakh-French LLP "Ghalam" is engaged in the creation of such production.

Components of aerospace vehicles need impact-resistant carbon fiber reinforced plastic. High-strength carbon fiber is not produced in Kazakhstan, and therefore it is necessary to import it. Such carbon fiber with a strength of over 415 MPa is included in the list of missile and dual-use goods and technologies (the technology is classified by International Export Control Agreements). In this regard, it is necessary to develop domestic technologies for the production of aerospace materials.

To expand the scope of application of carbon fiber reinforced plastic in the aerospace industry, the production of impact-resistant carbon fiber reinforced plastic is relevant. Carbon fiber reinforced plastic is a composite material consisting of a connecting matrix and reinforcing carbon tissue. The production of carbon fiber reinforced plastic, which improves its physical and mechanical characteristics and gives it impact resistance, can be achieved by modifying carbon tissue and ER.

In world practice, a technology for producing impact-resistant carbon fiber reinforced plastic with the preservation of the degree of static strength of carbon fiber reinforced plastic is required. This technology is quite complex, since with an increase in one indicator of strength properties, a negative impact on other properties is possible. For this reason, it is obvious that the simultaneous increase in the strength and toughness of carbon fiber reinforced plastic requires serious research.

Due to the need for high strength and impact resistance of carbon fiber reinforced plastic for domestic production, the main provisions of the dissertation were developed within the framework of state scientific programs funded from the state budget.

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 2018-2020. "Development of technology for the production of impact-resistant carbon fiber reinforced plastic for defense and aerospace products" - Republican budget program 008 "Applied scientific research in the field of space activities, transport and communication".

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

The author's personal contribution consists in setting the goals and objectives of the work, conducting research, processing and analyzing the results, formulating conclusions, writing articles and abstracts.

According to the results of the dissertation work published:

1. Mustafa L.M., Ismailov M.B., Sanin A.F. Study on the effect of plasticizers and thermoplastics on the strength and toughness of epoxy resins / Международный рецензируемый журнал «Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu» <https://doi.org/10.33271/nvngu/2020-4/063>. Украина, –2020. №4. –Р. 63-68: scientific and theoretical justification, preparation and direct participation in research, analysis and generalization of the results obtained, writing the text of the article;

2. Мустафа Л.М., Ермаханова А.М., Исмаилов М.Б. The effect of carbon fibers modification on the strength of carbon fiber reinforced plastic / Комплексное использование минерального сырья. <https://doi.org/10.31643/2019/6445.18>. Алматы, –2019. №2. –С. 68-75: scientific and theoretical justification, preparation and direct participation in research, analysis and generalization of the results obtained, writing the text of the article;

3. Мустафа Л.М., Исмаилов М.Б., Ермаханова А.М., Санин А.Ф. Исследование влияние пластификаторов термопластов на механические свойства эпоксидной смолы и углепластика (Обзор) / Комплексное использование минерального сырья. <https://doi.org/10.31643/2019/6445.37>. Алматы, – 2019. №4. – С. 48-56: scientific and theoretical justification, preparation and direct participation in research, analysis and generalization of the results obtained, writing the text of the article;

4. Мустафа Л.М., Исмаилов М.Б. Исследование методов модификации углеродной ткани с целью увеличения прочностных свойств углепластиков / Вестник КазНИТУ. Алматы, –2019. №5 (135). –С. 72-75: scientific and theoretical justification, preparation and direct participation in research, analysis and generalization of the results obtained, writing the text of the article;

5. Пат. на полезную модель 6006РК. Способ получения углепластика/ Мустафа Л.М.,Исмаилов М.Б.,Жумаханова В.Р., Байсериков Б.М., Аблакатов И.К., патентобладательАО «НЦКИТ»; опубл. 23.04.2021, Бюл. № 16. – 3с: scientific and theoretical justification, preparation and direct participation in research, analysis, generalization of the results obtained, and writing of the patent text;

6. Мустафа Л.М.,Исмаилов М.Б. Исследование влияния пластификаторов на прочность и ударную вязкость углепластика / Международной научно-практической конференции «Наука и инновации: новости, проблемы и достижения». Алматы 29-30 апрель 2020,– Т.2. –С. 179-182: scientific and theoretical justification, direct participation in the search, analysis and systematization of data, writing the text of the article;

7. Мұстафа Л.М., Исмаилов М.Б., Санин А. Ф. Эпоксидті шайырды термопласттармен модификациялаудың және құрамдастырылған арматуралаудың көмірпластиктің беріктігі мен соққы тұтқырлығына әсерін зерттеу / Халықаралық конференция «Қазіргі жастардың ғылыми әлеуметі-2021» 17-18 мамыр 2021. Қарағанды. –2021. –С. 371-375:scientific and theoretical justification, direct participation in the search, analysis and systematization of data, writing the text of the article.