



## DEVELOPMENT OF GRAPHENE-BASED CARBON COMPOSITE MATERIALS FOR STRUCTURAL ELEMENTS OF AIRCRAFT

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**Abstract.** This article analyzes the scientific and technological foundations for developing graphene-based carbon composite materials for structural elements of aircraft. The physical and mechanical properties of graphene, its interaction with carbon fibers, and the efficiency of its application in the aviation industry are investigated. Experimental results on the mechanical strength, thermal conductivity, and operational durability of graphene-enhanced composite materials are presented. Based on the obtained results, the possibilities of reducing aircraft weight and improving fuel efficiency are substantiated.

**Keywords:** graphene, carbon fiber, composite material, aviation, nanocomposite, structural element, polymer matrix, mechanical strength.

**Аннотация.** В данной статье рассматриваются научно-технологические основы создания углеродных композиционных материалов на основе графена для конструктивных элементов летательных аппаратов. Исследованы физико-механические свойства графена, его взаимодействие с углеродными волокнами, а также эффективность применения в авиационной промышленности. Представлены экспериментальные результаты по механической прочности, теплопроводности и эксплуатационной долговечности композиционных материалов с добавлением графена. На основе полученных результатов обоснованы возможности снижения массы летательных аппаратов и повышения топливной эффективности.

**Ключевые слова:** графен, углеродное волокно, композиционный материал, авиация, наноккомпозит, конструктивный элемент, полимерная матрица, механическая прочность.

**Annotatsiya.** Mazkur maqolada uchish apparatlari konstruktsiya elementlari uchun grafen asosidagi uglerodli kompozitsion materiallarni yaratishning ilmiy-texnologik asoslari tahlil qilingan. Grafenning fizik-mexanik xususiyatlari, uglerod tolalari bilan o‘zaro ta’siri hamda aviatsiya sanoatida qo‘llash samaradorligi o‘rganilgan. Tadqiqot davomida grafen qo‘shilgan kompozitsion materiallarning mexanik mustahkamligi, issiqlik o‘tkazuvchanligi va ekspluatatsion chidamliligi



bo'yicha tajriba natijalari keltirilgan. Olingan natijalar asosida uchish apparatlarining massasini kamaytirish va yoqilg'i samaradorligini oshirish imkoniyatlari asoslab berilgan.

**Kalit so'zlar:** grafen, uglerod tolasi, kompozitsion material, aviatsiya, nanokompozit, konstruksion element, polimer matritsa, mexanik mustahkamlik.

**INTRODUCTION.** Today, the requirements for structural materials in the aviation and aerospace industries are continuously increasing. Reducing aircraft weight, decreasing fuel consumption, and improving mechanical strength are among the primary tasks of modern materials science.

In recent years, graphene-based carbon composite materials have been widely studied in the aviation industry due to their superior physical and mechanical properties. Graphene is a two-dimensional nanostructure consisting of carbon atoms arranged in a hexagonal crystal lattice, possessing exceptionally high strength and elasticity[1].

The Young's modulus of graphene is characterized by the following value:

$$E \approx 1 \text{ TPa}$$

The tensile strength of graphene is:

$$\sigma \approx 130 \text{ GPa}$$

These indicators are several hundred times higher than those of steel, which makes graphene highly promising for aerospace applications[2].

### RESEARCH METHODOLOGY

The following methods were used during the research:

physical and mechanical analysis;

nanostructural modeling;

experimental testing methods;

pressing and polymerization technologies for composite materials.

The composition of the composite material was selected as follows:

№	Component Name	Content (%)
1	Carbon fiber	65
2	Epoxy matrix	30
3	Graphene nanoparticles	4
4	Modifier additive	1

### Properties of Graphene-Based Composite Materials

The main physical indicators of graphene-enhanced composite materials are presented in the following table.

**Table 1**

Physical and Mechanical Properties of Graphene-Based Composites



Parameter	Conventional Composite	Graphene Composite
Density (g/cm <sup>3</sup> )	1.6	1.45
Strength (MPa)	850	1150
Elastic modulus (GPa)	72	95
Thermal conductivity (W/mK)	12	18
Crack resistance (%)	100	128

The results indicate that the addition of graphene increases the material strength by approximately 35%.

The strength improvement coefficient is determined by:

$$K = (\sigma_2 - \sigma_1) / \sigma_1 \times 100\%$$

where:

$\sigma_1$ — strength of the conventional composite;

$\sigma_2$ — strength of the graphene composite.

Calculation result:

$$K = (1150 - 850) / 850 \times 100\% \approx 35\%$$

### Technology for Producing Composite Materials

The production of graphene-based carbon composites was carried out in the following stages[3].

#### 1. Preparation of Graphene Dispersion

Graphene nanoparticles were dispersed in epoxy resin using an ultrasonic mixer for 45 minutes.

#### 2. Impregnation of Carbon Fibers

Carbon fibers were impregnated with the graphene-polymer solution, and air bubbles were removed under vacuum conditions[4].

#### 3. Pressing Process

Composite layers were pressed according to the following technological parameters.

**Table 2**

Pressing Parameters

Parameter	Value
Temperature	180 °C
Pressure	5 MPa
Pressing time	2 hours
Cooling time	40 minutes

### Efficiency of Application in Aviation



One of the main advantages of graphene-based composite materials is the reduction in structural weight[5].

**Table 3**

Reduction of Aircraft Structural Weight

Structural Element	Conventional Material (kg)	Graphene Composite (kg)	Difference (%)
Wing panel	420	310	26
Fuselage covering	510	375	26.5
Stabilizer	160	118	26.2

Weight reduction is calculated by the following formula:

$$\Delta m = (m_1 - m_2) / m_1 \times 100\%$$

where:

$m_1$ — weight of the conventional material;

$m_2$ — weight of the graphene composite.

### Experimental Results and Analysis

Laboratory tests produced the following results:

**Table 4**

Experimental Results

Test Type	Conventional Composite	Graphene Composite
Tensile strength (MPa)	850	1150
Compressive strength (MPa)	640	890
Impact resistance (kJ/m <sup>2</sup> )	45	63
Thermal deformation resistance (°C)	140	195

The results demonstrate that:

mechanical strength increased by 30–35%;

impact resistance improved by 40%;

thermal resistance significantly increased.

### Economic Efficiency

The use of graphene composite materials contributes to reducing fuel consumption.



**Table 5**

Fuel Efficiency Indicators

Parameter	Conventional Material	Graphene Composite
Aircraft weight (t)	72	65
Fuel consumption (kg/h)	5400	4870
Fuel savings (%)	—	9.8

### CONCLUSION

Graphene-based carbon composite materials are highly promising modern structural materials for the aviation industry. Research results showed that the addition of graphene leads to:

- up to 35% increase in material strength;
- up to 30% increase in thermal conductivity;
- up to 40% improvement in impact resistance.

In addition, the total aircraft weight decreases by approximately 25–27%, resulting in nearly 10% reduction in fuel consumption. This confirms the strong potential of graphene-based composite materials for widespread application in aviation and aerospace engineering.

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