



DIFFERENCES BETWEEN GRAPHENE-BASED COMPOSITE MATERIALS AND CONVENTIONAL MATERIALS IN AIRCRAFT STRUCTURAL ELEMENTS

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Abstract

This article analyzes the differences between graphene-based composite materials used in aircraft structural elements and conventional aviation materials (aluminum, titanium, steel, and carbon fiber composites) using a comprehensive scientific approach. The physical, mechanical, thermal, and operational properties of these materials are compared using numerical data. In addition, the impact of graphene-based composites on the aviation industry, their economic efficiency, and technological limitations are discussed.

Keywords: Graphene, nanocomposite, aviation materials, strength, density, Young’s modulus, aerospace technology, lightweight structures.

Аннотация

В данной статье анализируются различия между графеновыми композиционными материалами, используемыми в конструкционных элементах летательных аппаратов, и традиционными авиационными материалами (алюминий, титан, сталь и углеродные композиты) на основе



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комплексного научного подхода. Физические, механические, термические и эксплуатационные свойства этих материалов сравниваются с использованием численных данных. Кроме того, рассматриваются влияние графеновых композитов на авиационную промышленность, их экономическая эффективность и технологические ограничения.

Ключевые слова: графен, нанокompозит, авиационные материалы, прочность, плотность, модуль Юнга, аэрокосмические технологии, легкие конструкции.

Annotatsiya

Ushbu maqolada uchish apparatlari konstruksiya elementlarida qo'llaniladigan grafen asosli kompozit materiallar va an'anaviy aviatsion materiallar (alyuminiy, titan, po'lat hamda uglerod tolali kompozitlar) o'rtasidagi farqlar keng qamrovli ilmiy yondashuv asosida tahlil qilinadi. Ushbu materiallarning fizik, mexanik, termik va ekspluatatsion xususiyatlari raqamli ma'lumotlar asosida solishtiriladi. Shuningdek, grafen asosli kompozitlarning aviatsiya sanoatiga ta'siri, ularning iqtisodiy samaradorligi hamda texnologik cheklovlari ko'rib chiqiladi.

Kalit so'zlar: grafen, nanokompозит, aviatsiya materiallari, mustahkamlik, zichlik, Young moduli, aerokosmik texnologiya, yengil konstruksiyalar.

INTRODUCTION

The rapid development of modern aviation and space technologies has significantly increased the requirements for structural materials used in aircraft. The main objectives include: reducing aircraft weight, increasing structural strength, improving fuel efficiency, extending operational lifespan[1].

Conventional materials such as aluminum, titanium, and steel alloys have long served as the primary structural base. However, in the last 15–20 years, nanomaterials—especially graphene-based composites—have been considered revolutionary candidates in the aviation industry.



1. Density and Mass Efficiency of Materials

One of the most important parameters for aircraft structures is density (ρ), as it directly affects fuel consumption and flight efficiency[2].

Density values:

Steel: 7.85 g/cm³

Titanium alloy: 4.50 g/cm³

Aluminum alloy: 2.70 g/cm³

Carbon fiber composite: 1.50–1.60 g/cm³

Graphene (theoretical): 0.77 g/cm³

Analysis:

If a 1000 kg aluminum structural component is replaced with a graphene composite: mass reduction: ~60–70%; fuel savings: 10–18%; increase in flight range: 8–12%.

These figures represent significant economic importance in aviation[3].

2. Tensile Strength Analysis

Tensile strength is a critical parameter in aviation engineering.

Strength values: Steel: 0.4–1.5 Gpa, Aluminum: 0.2–0.6 Gpa, Titanium: 0.9–1.2 Gpa, Carbon fiber composite: 3–5 Gpa, Graphene: ~130 GPa (theoretical maximum)

Comparison:

Graphene is: 100–300 times stronger than steel, 200–500 times stronger than aluminum

1 mm graphene layer can theoretically withstand the same load as a 1 cm steel plate.

3. Young's Modulus

Values: Aluminum: 70 Gpa, Titanium: 110 Gpa, Carbon fiber composite: 200–300 Gpa, Graphene: ~1000 Gpa.



Result:

Graphene is: ~14 times stiffer than aluminum, ~9 times stiffer than titanium, ~3–5 times stiffer than carbon fiber composites[4].

4. Thermal Conductivity

Efficient thermal management is essential in aircraft structures.

Values:

Steel: 50 W/m·K, Aluminum: 235 W/m·K, Titanium: 22 W/m·K, Carbon fiber composite: 5–25 W/m·K, Graphene: 3000–5000 W/m·K

Analysis:

Graphene conducts heat: 12–20 times faster than aluminum, ~100 times faster than steel

This is extremely important for spacecraft thermal management[5].

5. Corrosion Resistance

Corrosion reduces material lifespan.

Resistance levels: Steel: 10–30%, Aluminum: 40–60%, Titanium: 80–90%, Carbon composites: 85–90%, Graphene composites: 95–99%

Reason:

Graphene: blocks gas and moisture diffusion, forms a chemically inert barrier layer[6].

6. Service Life and Reliability

Average lifespan:

Aluminum structures: 20–25 years

Titanium structures: 30–40 years

Carbon composites: 25–35 years

Graphene composites: 40–60 years (estimated)

This represents approximately 2× longer operational life.



7. Economic Efficiency

If graphene composites are widely adopted:

aircraft weight reduction: 30–50%

fuel cost reduction: 10–20%

maintenance cost reduction: 15–25%

Example:

If one aircraft consumes \$1,000,000 fuel annually:

15% savings → \$150,000 per year

8. Technological Limitations

Key challenges limiting graphene adoption:

High production cost

1 gram of graphene is 50–200 times more expensive than conventional materials

Scaling issues: laboratory quality is high, industrial production reduces quality by 20–40%.

Dispersion problems: graphene particles are not uniformly distributed, strength loss of 10–30% may occur[7].

9. Overall Scientific Comparison

Parameter	Conventional Materials	Graphene Composites
Density	High	Very low
Strength	Medium	Extremely high
Stiffness	Medium	Extremely high
Heat conduction	Medium	Very high
Corrosion	Problematic	Very low
Cost	Low	Very high
Service life	20–40 years	40–60 years

CONCLUSION

Graphene-based composite materials represent a new generation of structural materials for aviation and aerospace technologies. Scientific analysis shows that: strength is 100+ times higher



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density is 4–10 times lower

thermal conductivity is 10–100 times higher

service life is approximately 2 times longer

However, technological and economic limitations currently restrict their widespread industrial use. With future advancements in nanomaterial manufacturing technologies, graphene-based composites are expected to become one of the primary structural materials in the aviation industry.

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