

## INVESTIGATION OF PHYSICAL, CHEMICAL, AND FUNCTIONAL PROPERTIES OF POLYMER COMPOSITE MATERIALS

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**Abstract.** This article analyzes the composition, structure, and physicochemical properties of polymer composite materials. The mechanical strength, density, heat resistance, and chemical stability of polymer composites are studied. In addition, their application in various industrial sectors and their importance in modern technologies are highlighted. The research results show that polymer composite materials are promising materials due to their light weight and high performance characteristics.

**Keywords:** polymer, composite material, physicochemical property, matrix, strength, corrosion, nanocomposite, polymerization.

**Introduction.** At present, due to the development of Materials Chemistry and materials science, the demand for high-quality, lightweight, and durable materials is increasing. Therefore, polymer composite materials are widely used in many industrial fields. Compared to conventional materials, they are distinguished by high mechanical strength, corrosion resistance, and low density. Polymer composite materials are complex systems consisting of two or more components. The main part is a polymer matrix to which various reinforcing fibers or particles are added. As a result, a new material with high exploitation properties is obtained. Today, polymer composites are widely used in aviation, automotive engineering, construction, electrical engineering, medicine, and space technologies. Studying their physicochemical properties is of great scientific and practical importance in creating next-generation materials.

Structure of Polymer Composite Materials. Polymer composite materials mainly consist of three parts:

- polymer matrix;
- reinforcing component;

-additives.

The matrix is the main part of the composite and serves to distribute external loads evenly. The reinforcing component increases the mechanical strength of the material. The following substances are widely used as polymer matrices: epoxy resins, polyesters, polyethylene, polypropylene, and phenol-formaldehyde resins. As reinforcing components, glass fibers, carbon fibers, Kevlar fibers, and nanoparticles are used.

The interaction between the components within the composite determines the overall properties of the material.

Physical Properties of Polymer Composite Materials. Polymer composite materials possess high mechanical and physical properties. Their main advantage is the possibility of achieving high strength with low weight.

The strength of composite materials is determined by the following equation:

$$\sigma_c = \sigma_m \cdot V_m + \sigma_f \cdot V_f$$

Where:

$\sigma_c$  — total strength of the composite;;

$\sigma_m$  — matrix strength;

$\sigma_f$  — strength of the fiber (or filler) component;

$V_m$  — volume fraction of the matrix;

$V_f$  — volume fraction of the reinforcing component.

If the reinforcing fibers bear the major part of the load, the overall strength of the composite increases significantly. In particular, polymers reinforced with carbon fibers and glass fibers exhibit high performance characteristics.

Elastic Modulus (Rigidity). The elastic modulus of composite materials is also an important indicator and is expressed as: If the reinforcing fibers bear the major part of the load, the overall strength of the composite increases significantly. In particular, polymers reinforced with carbon fibers and glass fibers exhibit high performance characteristics. This equation shows that the rigidity of the composite mainly depends on the type and amount of reinforcing fibers.

### Comparison of Mechanical Properties of Polymer Composites

Material Type	Material Type	Material Type	Material Type
Conventional polymer	0.9–1.2	20–60	60–120
Glass fiber composite	1.5 – 2.0	200 – 600	150 – 250
Carbon fiber composite	1.4 – 1.8	500 – 1500	200 – 400

As seen from the table, composite materials have several times higher strength than conventional polymers while maintaining relatively low density. Factors Affecting Strength. The strength of polymer composites depends on the following factors:

- type and quality of reinforcing fibers;
- orientation of fibers within the matrix;
- degree of adhesion between components;
- manufacturing technology;
- operating conditions (temperature, humidity, type of load).

Especially when the bonding force between fibers and matrix is weak, the overall strength of the composite decreases sharply. Heat Resistance. The heat resistance of polymer composite materials is one of the main factors determining their performance properties. This property reflects the ability of the composite to retain its shape, strength, and physical structure under high-temperature conditions.

Heat resistance mainly depends on the type of matrix. Thermosetting polymers (epoxy and phenol-formaldehyde resins) are more stable at high temperatures. Thermoplastic polymers, however, may soften and lose their shape above certain temperatures.

The coefficient of thermal expansion of composites is expressed as:

$$\alpha_c = \alpha_m \cdot V_m + \alpha_f \cdot V_f$$

Where:

$\alpha_c$  — coefficient of thermal expansion of the composite;;

$\alpha_m$  — coefficient of thermal expansion of the matrix;;

$\alpha_f$  — coefficient of thermal expansion of the fiber component;

$V_m$  — matrix volume fraction;

$V_f$  — fiber volume fraction.

Composites reinforced with carbon and glass fibers exhibit very low thermal expansion, making them highly suitable for aviation and space technologies.

#### Chemical Resistance

Polymer composite materials are highly resistant to aggressive chemical environments. They maintain stability against acids, alkalis, salt solutions, and various organic solvents.

Chemical resistance mainly depends on:

- chemical composition of the matrix;
- type of reinforcing component;
- density and porosity of the composite;
- operating temperature.

Epoxy- and polyester-based composites are highly resistant to corrosion and are widely used in the manufacture of chemical industry equipment and pipelines.

#### Resistance to Chemical Environments

##### Kimyoviy muhit ta'siriga chidamlilik (jadval).

Environment Type	Conventional Polymer	Glass Fiber Composite	Carbon Fiber Composite
Acids	Medium	High	Very high
Alkalis	Low–medium	High	High
Salt solutions	Medium	Very high	Very high
Organic solvents	Low	Medium–high	High

Applications of Polymer Composite Materials. Polymer composites are used in almost all areas of modern technology. Aviation and Space Technology

-Carbon fiber composites are used in aircraft bodies, wings, and spacecraft structures. This reduces aircraft weight and decreases fuel consumption.

-Automotive Industry. Composite materials are used in the production of bumpers, body parts, and interior components. As a result, vehicle weight decreases while strength increases.

-Construction Industry. In construction, composites are used as panels, reinforcing elements, and thermal insulation materials.

Medicine. Polymer composite materials are used in the production of prostheses, implants, and various biomaterials.

#### Physical Properties of Polymer Composite Materials

Material Type	Density (g/cm <sup>3</sup> )	Strength (MPa)	Heat Resistance
Glass fiber composite	1.8–2.0	300–900	200
Carbon fiber composite	1.5–1.8	600–1500	350
Kevlar composite	1.4	500–1200	250
Polyethylene-based composite	0.9–1.2	100–300	120

Application areas. Polymer composite materials are currently used in a wide range of fields:

- **Aviation and aerospace industry:** aircraft bodies, rocket elements, lightweight structures;
- **Automotive engineering:** body parts, bumpers, interior details;
- **Construction industry:** durable panels, reinforcing elements, water-resistant coatings;
- **Electrical engineering:** insulating materials, electronic boards;
- **Medicine:** prostheses, implants, surgical instruments;
- **Chemical industry:** corrosion-resistant pipes and reservoirs.

**Conclusion.** Polymer composite materials possess advantages such as high strength, low density, and resistance to heat and chemical environments, making them strategically important materials in modern technologies. Deep study of their physicochemical properties serves as an important scientific basis for creating next-generation functional materials.

Polymer composite materials occupy an important place in modern industry. Their lightness, high mechanical strength, corrosion resistance, and heat resistance allow effective use in many technological processes.

With the development of nanotechnology, new types of polymer composites are being created. In the future, the use of stronger, lighter, and more functional composite materials will continue to expand.

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