Discipline: Actual problems of chemistry of polymer composites

Lecture 11.

Theme: Manufacturing of Fiber Reinforcements for Polymer Composites

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Objective:

To understand the **methods of producing fiber reinforcements**, their **types, characteristics**, and the **influence of fiber properties** on the performance of polymer composites.

Key Questions:

1. What are the main types of fibers used in polymer composites?
2. How are continuous and short fibers manufactured?
3. What properties of fibers are critical for reinforcement effectiveness?
4. How does fiber manufacturing influence the mechanical and physical properties of polymer composites?

Lecture Content:

- **Overview of Fiber Reinforcements:**
  - Fibers are used to **enhance strength, stiffness, and toughness** of polymer composites.
  - Classification: **continuous fibers** (e.g., carbon, glass, aramid) and **short/chopped fibers**.
  - Selection depends on **mechanical requirements, cost, processing method, and application**.
- **Manufacturing Methods for Fibers:**
  1. **Glass Fibers:**
     - Produced from **molten glass drawn through fine orifices (bushing)**.
     - Types: E-glass (electrical), S-glass (structural), C-glass (chemical resistance).
     - Post-processing: sizing applied to improve **matrix adhesion**.
  2. **Carbon Fibers:**
     - Derived from **precursors** such as polyacrylonitrile (PAN), pitch, or rayon.
     - Process steps:

        - **Stabilization:** oxidation at low temperature to form thermally stable structure.
        - **Carbonization:** high-temperature treatment to remove non-carbon elements.
        - **Surface treatment and sizing:** improve adhesion to polymer matrix.
    - Variants: high-strength fibers (low modulus) and high-modulus fibers (stiffer, brittle).
3. **Aramid Fibers:**
    - Produced by **polycondensation and spinning of aromatic polyamides**.
    - Features: high toughness, impact resistance, low density.
    - Used in **ballistic composites, aerospace, and protective applications**.
4. **Natural Fibers:**
    - Sources: flax, jute, hemp, sisal.
    - Processing: cleaning, retting, and spinning into yarns.
    - Advantages: biodegradable, low density; limitations: variability, moisture absorption.

- **Continuous vs. Short Fibers:**
    - **Continuous fibers:** provide maximum load transfer and directional strength.
    - **Short/chopped fibers:** easier to process, isotropic reinforcement, lower mechanical properties.
    - Fiber length and orientation must be controlled during composite manufacturing.
- **Fiber Surface Treatment:**
    - Critical to ensure **strong adhesion with polymer matrix**.
    - Methods: chemical sizing, plasma treatment, oxidation, silane coupling.
- **Influence on Composite Properties:**
    - Fiber type, length, and orientation determine **tensile strength, modulus, impact resistance, and thermal stability**.
    - Surface treatment affects **interfacial bonding and durability**.
- **Applications:**
    - Aerospace: carbon fiber prepregs for lightweight panels.
    - Automotive: glass fiber reinforcements for structural parts.
    - Sports equipment: aramid fibers for impact-resistant components.
    - Construction: natural fiber composites for eco-friendly panels.

Key Short Theses:

1. Fibers are the main reinforcement in polymer composites, classified as **continuous or short/chopped**.
2. Glass, carbon, aramid, and natural fibers are the most common reinforcement types.
3. Fiber properties—**strength, modulus, toughness, and surface characteristics**—determine composite performance.
4. Fiber manufacturing methods include **drawing (glass), stabilization/carbonization (carbon), spinning (aramid), and processing of natural fibers**.
5. Surface treatment improves **adhesion with the polymer matrix**, ensuring effective stress transfer.
6. Continuous fibers provide high directional strength, while short fibers offer isotropic reinforcement and easier processing.
7. The choice of fiber type and treatment must consider **mechanical requirements, processing method, and final application**.

Control Questions:

1. What are the main types of fibers used in polymer composites?
2. Describe the manufacturing process of carbon fibers.
3. How do continuous fibers differ from short fibers in composite applications?
4. Why is fiber surface treatment important?
5. Name three methods of surface treatment for fibers.
6. How do fiber properties influence the mechanical performance of polymer composites?
7. What are the advantages and limitations of natural fibers as reinforcements?

Recommended references

Main literature:

1. Introduction to Polymer Science and Chemistry: A Problem-Solving Approach, Second Edition 2nd Edition / by Manas Chanda, CRC Press; 2nd edition (January 11, 2013)
2. Polymer Chemistry 2nd Edition / by Paul C. Hiemenz, Timothy P. Lodge, CRC Press; 2nd edition (February 15, 2007)
3. Semchikov Yu.D. High-molecular compounds: Textbook for universities. Moscow: Academy, 2003, 368.
4. S. Thomas, K. Joseph, S.K. Malhotra, K. Goda, M.S. Sreekala. Polymer composites. – Wiley-VCH, 2012. – 829 p.

5. Irmukhametova G.S. Fundamentals of polymer composite materials technology: textbook for universities; Al-Farabi Kazakh National University. - Almaty: Kazakh University, 2016. - 175 p.

Additional literature:

1. Polymer composite materials (part 1): a tutorial / L.I. Bondaletova, V.G. Bondaletov. - Tomsk: Publishing house of Tomsk Polytechnic University, 2013. - 118 p.
2. Polymer composite materials: structure, properties, technology. Edited by Berlin A.A. - St. Petersburg, Publishing house "Profession", 2008. - 560 p.
3. Polymer composite materials: structure, properties, technology: a tutorial / M.L. Kerber et al.; under the general editorship of A.A. Berlin. - St. Petersburg: Profession, 2009.- 556, [4] p.
4. Bataev, A.A. Composite materials. Structure, production, application: a tutorial. manual / A. A. Bataev, V. A. Bataev. - M.: Logos, 2006. - 397, [3] p. - (New University Library).