Discipline: Actual problems of chemistry of polymer composites

Lecture 5.

Theme: Short Fiber Reinforced Polymer Composites. Orientation and Length of Fibers

---

Objective:

To understand the **behavior and properties of short fiber reinforced polymer composites**, with a focus on how **fiber length, orientation, and distribution** influence the mechanical and physical performance of the composite material.

Key Questions:

1. What are short fiber reinforced polymer composites?
2. How does fiber length affect the strength and stiffness of composites?
3. How does fiber orientation influence composite anisotropy and performance?
4. What are the critical factors in processing short fiber composites?
5. How to optimize fiber length and orientation for specific applications?

Lecture Content:

- **Definition:**
  - Short fiber reinforced composites contain fibers that are **significantly shorter than the dimensions of the composite part**.
  - Fibers can be **chopped, milled, or discontinuous**, typically in the range of micrometers to a few millimeters.
  - They are easier to process than continuous fibers and can be used in **injection molding, extrusion, and compression molding**.
- **Influence of Fiber Length:**
  - **Critical Fiber Length (Lc):** Minimum fiber length required to effectively transfer stress from matrix to fiber.
  - Fibers shorter than Lc contribute less to reinforcement.
  - Longer fibers increase tensile strength, modulus, and toughness but may complicate processing.
  - Fiber length distribution affects uniformity of mechanical properties.
- **Influence of Fiber Orientation:**
  - **Aligned fibers** provide high strength and stiffness in the fiber direction.

    - **Randomly oriented fibers** give more isotropic properties but lower maximum strength.
    - Processing methods (injection molding, extrusion, compression) influence fiber orientation patterns.
    - **Anisotropy** occurs when fibers are preferentially aligned, leading to directional mechanical behavior.
- **Processing Considerations:**
    - Short fibers are easier to handle and mold compared to continuous fibers.
    - Fiber breakage can occur during processing, reducing effective length.
    - Proper control of **processing parameters** ensures optimal orientation and minimal fiber damage.
- **Applications:**
    - Automotive parts: dashboards, bumpers, and structural components.
    - Electrical housings and consumer goods.
    - Industrial components requiring moderate strength with good manufacturability.

Key Short Theses:

1. Short fiber reinforced composites use **discontinuous fibers** embedded in a polymer matrix for reinforcement.
2. **Fiber length** is critical: fibers longer than the critical length efficiently transfer stress to the matrix.
3. **Fiber orientation** controls anisotropy: aligned fibers maximize directional strength, random fibers improve isotropy.
4. Fiber **length distribution** affects uniformity of mechanical properties.
5. Processing methods influence **fiber breakage, orientation, and effective reinforcement**.
6. Short fiber composites are **easier to process** than continuous fiber composites but have lower maximum strength.
7. Optimal performance requires balancing **fiber length, orientation, and processing conditions**.

Control Questions:

1. What defines a short fiber reinforced polymer composite?
2. How does fiber length influence the mechanical properties of composites?
3. What is the critical fiber length and why is it important?
4. How does fiber orientation affect anisotropy and overall composite performance?
5. How do processing methods affect fiber orientation and breakage?

6. Give examples of applications of short fiber reinforced composites.

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).