



THE RHEOLOGY OF SUSPENSIONS BASED ON ORGANIC SUBSTANCES (ON THE EXAMPLE OF CELLULOSE)

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ABSTRACT

In this article, we will explore the rheology of suspensions based on organic substances, focusing on cellulose as a case study. We will examine the properties of cellulose suspensions, factors affecting their rheology, characterization techniques, and their applications in various industries. By understanding the rheological behavior of cellulose suspensions, we can optimize their performance and enhance their usability in different applications.

Rheology is a branch of science that studies the flow behavior of materials and how they deform under applied stress. Understanding the rheological properties of suspensions, which are mixtures of solid particles dispersed in a liquid, is crucial in various industries such as pharmaceuticals, cosmetics, paints, and food processing [3, 201]. Organic substances, such as cellulose, are commonly used in the formulation of suspensions due to their environmentally friendly and renewable nature. Cellulose, a polysaccharide found in the cell walls of plants, has unique properties that influence the rheological behavior of suspensions in which it is used.

Cellulose suspensions are composed of cellulose particles dispersed in a liquid medium, typically water or organic solvents. The properties of cellulose suspensions play a crucial role in determining their rheological behavior.

1. **Cellulose Concentration:** The concentration of cellulose in a suspension has a significant impact on its rheology. Increasing the cellulose concentration can lead to higher viscosity and greater resistance to flow due to the greater interparticle interactions and a higher volume fraction of solids in the suspension.
2. **Particle Size and Shape:** The size and shape of cellulose particles also influence the rheology of suspensions. Smaller particles tend to form more stable suspensions and exhibit lower viscosity, while larger particles can lead to a more viscous suspension. The shape of the cellulose particles can affect their packing in the suspension and influence the flow behavior.
3. **Surface Chemistry:** The surface chemistry of cellulose particles, including their surface charge and functional groups, can affect the interaction between particles and the liquid



medium. Surface modifications or the presence of additives can alter the rheological properties of cellulose suspensions [4, 16].

4. **Polymer Chain Length:** Cellulose molecules consist of long chains of glucose units linked by hydrogen bonds. The length of these chains can affect the overall rheology of suspensions, with longer chains typically leading to higher viscosities due to increased entanglement and interactions between molecules.

Understanding these properties of cellulose suspensions is essential for controlling their rheological behavior and optimizing their performance in various applications. By adjusting factors such as concentration, particle size, and surface chemistry, it is possible to tailor the rheology of cellulose suspensions to meet specific industrial requirements.

Several factors can influence the rheology of cellulose suspensions, impacting their flow behavior and deformation under stress. Understanding these factors is crucial in controlling and optimizing the rheological properties of cellulose suspensions for specific applications.

1. **Cellulose Concentration:** The concentration of cellulose particles in a suspension is a key factor affecting its rheology. Increasing the cellulose concentration can lead to higher viscosity, as more particles are present to interact and form a network structure that impedes flow.

2. **Particle Size and Distribution:** The size and size distribution of cellulose particles play a significant role in determining the rheological behavior of suspensions. Smaller particles typically lead to lower viscosity due to reduced interparticle interactions, while larger particles can result in a more viscous suspension[1, 3481].

3. **Solvent Type and Properties:** The choice of solvent or liquid medium used in cellulose suspensions can impact their rheology. Different solvents can affect the interactions between cellulose particles and the solvent molecules, influencing dispersion, viscosity, and flow behavior.

4. **Surface Chemistry and Functionalization:** The surface chemistry of cellulose particles, including their surface charge and functional groups, can influence the rheological properties of suspensions. Surface modifications or the addition of surfactants can alter particle interactions and affect viscosity and stability.

5. **Temperature and pH:** Both temperature and pH can affect the rheology of cellulose suspensions by influencing the solubility and conformation of cellulose molecules. Changes in temperature or pH can lead to alterations in viscosity, stability, and flow behavior.

6. **Shear Rate and Stress:** The rheological behavior of cellulose suspensions is sensitive to applied shear rate and stress. Changes in shear rate can lead to variations in viscosity, shear-thinning behavior, or thixotropic properties in cellulose suspensions.

By considering these factors and their interactions, it is possible to manipulate and control the rheological properties of cellulose suspensions for a wide range of applications, including coatings, adhesives, inks, and biomaterials. Experimentation and characterization techniques can help in understanding the specific effects of these factors on cellulose suspensions' rheology and optimizing their performance in different industrial processes[2, 2679].

In addition, rheological characterization techniques are crucial for understanding the flow behavior and deformation properties of cellulose suspensions. By employing various



measurement methods, researchers and engineers can assess the rheological properties of cellulose suspensions and optimize their performance for specific applications. Some common rheological characterization techniques for cellulose suspensions include:

1. **Viscometry:** Viscometry is a widely used technique for measuring the viscosity of cellulose suspensions. By applying a controlled shear stress or shear rate to the suspension and measuring the resulting flow behavior, viscometry provides valuable information on viscosity, shear-thinning behavior, and rheological parameters such as consistency index and flow behavior index.
2. **Rheometry:** Rheometry involves the use of a rheometer, a specialized instrument that applies controlled deformation or stress to measure the viscosity and viscoelastic properties of cellulose suspensions. Rheometers can provide detailed information on rheological parameters such as storage modulus, loss modulus, and complex viscosity, as well as yield stress and thixotropic behavior.
3. **Dynamic Mechanical Analysis (DMA):** DMA is a technique that measures the mechanical properties of materials as a function of temperature, frequency, and strain. In the case of cellulose suspensions, DMA can provide valuable insights into the viscoelastic behavior, storage modulus, loss modulus, and damping properties of the suspension under varying conditions [5, 63].
4. **Rotational and Oscillatory Measurements:** Rotational and oscillatory tests on a rheometer can help characterize the flow behavior and viscoelastic properties of cellulose suspensions. By subjecting the suspension to controlled rotation or oscillation, researchers can assess parameters such as shear stress, shear rate, complex viscosity, storage and loss moduli, and yield stress.
5. **Creep and Stress Relaxation Testing:** Creep and stress relaxation tests involve applying a constant stress or strain to cellulose suspensions and monitoring the resulting deformation over time. These tests can provide information on the viscoelastic behavior, long-term stability, and relaxation properties of the suspension under applied stress or strain.
6. **Particle Size and Zeta Potential Analysis:** Determining the particle size distribution and zeta potential of cellulose particles in suspension can also impact their rheological behavior. Techniques such as dynamic light scattering (DLS) and electrophoretic light scattering can provide valuable information on particle size, distribution, and surface charge, influencing particle interactions and rheology.

By combining these rheological characterization techniques, researchers can gain a comprehensive understanding of the flow behavior, viscoelastic properties, and stability of cellulose suspensions. This knowledge can help in optimizing the formulation, processing, and performance of cellulose-based materials for various applications in industries such as papermaking, coatings, food, pharmaceuticals, and biomaterials.

Besides that cellulose suspensions have a wide range of applications in various industries due to their unique properties, biodegradability, renewability, and sustainability. Some of the key applications of cellulose suspensions in industry include:

1. **Paper and Packaging:** Cellulose suspensions are extensively used in the paper and packaging industry for producing diverse products such as paper, cardboard, cartons, and



packaging materials. Cellulose suspensions are crucial components in the papermaking process, providing strength, durability, and printability to paper products.

2. Coatings and Adhesives: Cellulose suspensions are utilized in the production of coatings, paints, inks, and adhesives due to their film-forming properties, adhesion strength, and rheological behavior. Cellulose suspensions can enhance the performance, appearance, and durability of coatings and adhesives in various applications.

3. Textiles: Cellulose suspensions are used in the textile industry for manufacturing fibers, fabrics, nonwoven materials, and composites. Cellulose fibers derived from suspensions exhibit properties such as moisture absorption, breathability, biocompatibility, and thermal insulation, making them ideal for textile applications.

4. Food and Beverages: Cellulose suspensions are employed in the food and beverage industry as thickeners, stabilizers, emulsifiers, and texture modifiers in various products such as sauces, dressings, dairy products, and bakery items. Cellulose suspensions can improve the texture, mouthfeel, and shelf-life of food formulations.

5. Pharmaceuticals and Cosmetics: Cellulose suspensions find applications in the pharmaceutical and cosmetic industries for producing drug delivery systems, oral formulations, skincare products, and personal care items. Cellulose suspensions can act as gelling agents, binders, controlled release matrices, and viscosity modifiers in pharmaceutical and cosmetic formulations [6, 3359].

6. Biomedical and Biotechnological Applications: Cellulose suspensions are utilized in biomedical and biotechnological fields for developing biomaterials, tissue engineering scaffolds, drug carriers, and medical devices. Cellulose suspensions exhibit biocompatibility, bioactivity, and tunable properties that make them suitable for various biomedical applications.

7. Environmental and Sustainable Applications: Cellulose suspensions are increasingly being explored for environmentally friendly and sustainable applications such as biodegradable plastics, nanocellulose materials, renewable energy sources, and wastewater treatment. Cellulose suspensions offer eco-friendly alternatives to conventional materials and processes, contributing to sustainable development.

As it is clear, cellulose suspensions play a significant role in a wide range of industries, offering versatile properties and functionalities that can be tailored to meet specific application requirements. With ongoing research and innovation, the potential for utilizing cellulose suspensions in diverse industrial sectors continues to expand, driving advancements in sustainable materials and green technologies.

In conclusion, cellulose suspensions hold tremendous potential for diverse industrial applications due to their unique properties, renewability, sustainability, and biodegradability. From papermaking and packaging to coatings, textiles, food, pharmaceuticals, cosmetics, biomedical, and environmental applications, cellulose suspensions play a crucial role in enhancing product performance, sustainability, and eco-friendliness. Overall, cellulose suspensions have become indispensable in modern industrial processes, offering a viable alternative to traditional materials and contributing to the advancement of sustainable and green technologies. With ongoing research and collaboration across industries, the future



outlook for cellulose suspensions looks promising, opening up new opportunities for innovation and sustainable development.

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