FILLER ENGINEERING FOR PAPERMAKING: COMPARISION WITH FIBER ENGINEERING AND SOME IMPORTANT RESEARCH TOPICS

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Fibers and fillers are important raw materials for the preparation of paper products. Similar to fiber engineering, filler engineering for papermaking has become an active research area. There are similarities as well as differences between engineering involving each of these classes of materials. There are differences in such aspects as the nature of materials to be engineered, applicable engineering methods, and engineerablity of the material surfaces. The co-development of fiber engineering and filler engineering can potentially provide many benefits to the papermaking industry. For filler engineering, the relevant research topics broadly can include fibrous filler engineering, hollow/porous filler engineering, acid-stabilization of calcium carbonate fillers, surface encapsulation of naturally occurring polymers or their derivatives, preflocculation, precoagulation, cationic modification, filler/size hybrid formation, organic filler engineering, using combinations of different types of available fillers, multilayer deposition modification, modification with polymer latexes or dispersants, physical modification, mechanical modification, surface functionalization, fines-filler composite/hybrids or fiber-filler composite/ hybrid formation, in-situ polymerization modification, surface grafting, physical treatment in the presence of polymeric additives, filler precipitation, and core-shell composite filler engineering.

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Similarities

Fibers and fillers are two important categories of raw materials used in the formation of paper products. Fiber engineering for papermaking is a discipline that has attracted worldwide attention, and the relevant approaches (such as mechanical, chemical, enzymatic, and genetic modifications) are expected to impact process energy performance, improved and new forest products, sustainable forestry, and breakthrough technologies. Similarly, filler engineering for papermaking is a discipline concerning the engineering of fillers for enhanced performances or new functions and utilities, and the relevant engineering technologies can potentially create many benefits, such as lowered

manufacturing cost, upgraded paper attributes and quality, environmental friendliness, and sustainability. Fiber engineering and filler engineering have certain similarities. For example, similar engineering methods including polymer coating, cationic modification, hydrophobic modification, layer-by-layer deposition of modifiers on matrix surfaces, using combinations of different grades of raw materials, pretreatment using functional papermaking additives, and surface functionalization to confer specifically desired properties (such as electrical and antimicrobial) to the matrix, each can be suitable for use under certain conditions. Sometimes, the ultimate functions of fiber engineering and filler engineering can possibly be overlapped. For example, when attempting to lower the cost of papermaking, enhanced filler retention, increased filler loading level, or improved paper brightness is considered to be the goal, and either fiber engineering or filler engineering can possibly fulfill the objectives under certain carefully controlled conditions. Also, fiber engineering and filler engineering can both include optimization, modification, or improvement of the manufacturing and preprocessing processes of fibers and fillers for enhanced product performances. Due to the similarities between fiber engineering and filler engineering, some of the relevant engineering technologies of fibers can possibly be used as effective references for filler engineering, and vice versa. For example, the engineering of pulp fibers to obtain fiber-based sizing agents is a very good concept, and this idea is also applicable to inorganic fillers. In the future, the co-development and worldwide successful industrialization of fiber engineering and filler engineering will potentially provide significant benefits to papermaking industry.

Differences

Although there are some similarities between fiber engineering and filler engineering, there are also certain obvious differences. For fiber engineering, the relevant fibers are derived from lignocellulosic plant materials, and these materials have certain unique attributes; for example, they are usually tough, fibrillar, compliant when wet, and plastic when heated or stressed under certain conditions. However, for filler engineering, the fillers potentially usable for papermaking can vary widely in their characteristics. The paper engineers can choose among kaolin clay, natural ground calcium carbonate, precipitated calcium carbonate, talc, sericite, titanium oxide, silica, calcium silicate, aluminosilicate, aluminum trihydrate, precipitated calcium sulphate, starch-based non-mineral fillers, etc., and the chemical compositions and key properties of the different fillers fall within wide ranges. The inorganic fillers are usually hard, brittle, abrasive, non-complaint, and subject to fracture at certain planes; these attributes may possibly make them behave differently from fibers. Generally, in the papermaking industry, the research fields of filler engineering seem less extensive and strategic than those of fiber engineering. Also, the surfaces of inorganic fillers are perhaps considered to be less engineerable than those of pulp fibers. However, in some sense, filler engineering still has certain room for further development or improvement, especially when possible trends such as high filler loading, low cost, comprehensive resource utilization, and high paper opacity are considered. Moreover, filler engineering can surely be usable to provide certain troubleshooting solutions as well as cost and energy savings in specific applications. It is also worth noting that successful engineering methods such as high-temperature treatments of certain inorganic fillers may possibly be contributable to

substantial performance improvements, while subjecting pulp fibers to such treatments is absolutely not applicable due to their organic nature.

Some Important Research Topics of Filler Engineering

In the papermaking industry there is now still an urgent need to propel the development of filler engineering. Based on available publications, some of the relevant important research topics (many of which already have demonstrated their potential to contribute to the development of the papermaking industry) can be listed as follows:

- Fibrous filler engineering
- Nanostructured filler engineering
- Hollow/porous filler engineering
- Acid-stabilization of calcium carbonate fillers
- Filler engineering by encapsulation of naturally occurring polymers or their derivatives
- Filler engineering by preflocculation or precoagulation
- Filler engineering by cationic modification
- Filler engineering by hydrophobic modification or filler/size hybrid formation
- Organic filler engineering
- Filler engineering by combination of different types of available fillers for performance balancing and optimization
- Filler engineering by multilayer deposition
- Filler engineering by modification with polymer latexes or dispersants
- Filler engineering by physical or mechanical modification
- Filler surface functionalization using functional or even smart modifiers with specifically desired functional properties
- Filler engineering by fines-filler or fiber-filler composite/hybrid formation
- Filler engineering by in-situ synthesis of synthetic polymers and their deposition on filler surfaces
- Filler engineering by surface grafting
- Filler engineering by physical treatment in the presence of polymeric additives
- Engineering of filler attributes by controllable filler precipitation
- Core-shell composite filler engineering

The above research topics sometimes can overlap each other. For example, fibrous filler engineering is very close to nanostructured filler engineering when the engineered fillers are both fibrous and nanostructured. The relevant engineering technologies can possibly create many benefits, such as lowered cost, reduced energy consumption, improved acid tolerance and optical properties of fillers, enhanced fiber-filler bonding and paper strength, improved filler retention and filler sizability, alleviated filler abrasiveness, improved filler dispersability, and functionalization of the filled paper. In the area of filler engineering, there is considerable work that is much needed, and the development of cost-effective and environmentally friendly engineering methods is central to the improved attributes of the engineered fillers. Also, systematic optimization of the engineering processes is desirable for performance improvement, and potentially viable methods for the development of engineered fillers of new types with new attributes and new functions should be identified and developed.

Filler engineering has now been an active research area, and considerable work has been done to engineer fillers. However, there is still an urgent need to foster the maturity and successful industrialization of the relevant engineering technologies. With the development of the papermaking industry and other relevant industries, new technologies will possibly be available, and correspondingly, the scope of filler engineering will be conceivably further widened.

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