APPLICATION OF FILLERS IN CELLULOSIC PAPER BY SURFACE FILLING: AN INTERESTING ALTERNATIVE OR SUPPLEMENT TO WET-END ADDITION

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The application of fillers at the surface of cellulosic paper is an interesting and industrially-commercialized but not very well-known concept, in which the filler particles are essentially added to the voids of the fibrous matrixes. This so-called "surface filling" can be achieved by the use of fillers together with a polymer solution via film press or size press, an approach that is distinct from both wet-end filling and conventional coating of paper. As an easily practicable process, surface filling has some advantages over direct wet-end addition of fillers, such as minimizing the adverse effects of filler addition on paper strength. Efficient surface filling is somewhat dependent on the specific characteristics of both fillers and fibrous matrixes. Surface filling may provide interesting possibilities for the papermaking discipline; for example, it would open the door to maximizing the cost-effectiveness of paper mills, and efficiently adding new functionalities to cellulosic paper. From both practical and fundamental points of view, systematic exploration and understanding of surface filling of cellulosic paper would be of great significance to the papermaking industry.

Keywords: Surface filling; Papermaking; Fillers; Cellulosic paper; Paper strength; Functionalities; Wet-end addition of fillers; Possibilities and potentials; Commercialization; Process concept

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Traditional Way of Using Fillers in Cellulosic Paper

Fillers have been used in the papermaking industry since the eighth century. A lot of benefits can be achieved though the use of fillers, such as cost and energy savings, as well as improved optical properties/printability/writability. Conventionally, fillers are mainly used in printing and writing paper grades; however, their use in specialty/ functional paper grades is also rather attractive to papermakers. Globally, the commercially used fillers in paper mills are predominately mineral products, mainly including calcium carbonate, clay, and titanium dioxide. The commercial application of organic fillers is rather rare, only limited to certain paper grades.

In the traditional practice of using fillers, they are added to the wet-end of the paper machine, where sufficient mixing is always required to achieve homogeneous distribution of filler particles in the aqueous pulp-containing system. The resultant aqueous filler-containing admixture is then allowed to form on the wire mesh screen, followed by pressing, drying, finishing, and/or other treatments. The wet-end addition of fillers can be combined with the use of various additives, such as retention polymers.

Filler engineering technologies, such as pre-treatment/modification and formation of fiber/filler complexes, can also be adopted to improve the cost-effectiveness of wet-end addition of fillers, or to add interesting functionalities to the paper products.

Concept of Surface Filling

Different from the traditional wet-end addition of fillers, surface filling is an interesting process concept involving the addition of fillers at the surface of cellulosic paper. This is an already commercialized but not very well-known process that can be achieved by the use of fillers together with a polymer solution, for example starch solution, via a film application process or size press. One of the key features of surface filling is that fillers are expected to be essentially placed or inserted into the voids of the matrixes provided by the cellulosic fibers. In this regard, surface filling is evidently different from surface coating. For surface coating of cellulosic paper, mineral particles are essentially anchored onto the paper surface by using delicately formulated aqueous coating colors, which may comprise pigments, dispersants, binders, thickeners, defoamers, etc. In addition to the typical use of a polymer solution, the use of other additives, such as dispersing agents and viscosity regulators, is usually not needed for surface filling. The use of the polymer solution during surface filling can result in the firm insertion of filler particles into the matrixes and a stable fibrous structure, and of course, it can also serve the purpose of surface-sizing and/or surface-strengthening of cellulosic paper.

For successful surface filling applications, the fillers may need to meet at least three requirements:

- The particle size and shape of fillers should be suitable for them to readily penetrate into the voids of the cellulosic matrixes. It would be easier for round and small particles to fill the voids.
- The density of fillers is larger than that of water or pulp fibers, so the gravitation force will tend to drop them into the inside of the paper, rather than onto the surface.
- The structure of cellulosic paper is “open” enough to provide acceptable accessibility.

Superiorities and Limitations of Surface Filling

Due to the fact that surface filling essentially involves filling the voids of the already-formed fibrous cellulosic matrixes, the fiber-fiber bonding is expected to be well preserved; therefore, the negative effect of filler addition on paper strength would be significantly alleviated. This is a key superiority of surface filling in comparison to direct wet-end addition of fillers. Also, the void-filling effect of surface filling is also capable of decreasing the porosity of cellulosic paper, which can be much advantageous to such paper grades as envelope paper, opening the door to reducing the refining of short fibers for decreasing porosity. Additionally, surface filling often can employ existing equipment, achieving good operability and ease of commercialization. For instance, one can use film presses or puddle-type size presses, which have long histories of use in paper mills.

However, due to its unique process concept, surface filling can be somewhat sensitive to the characteristics of fillers, essentially particle size, particle shape, and

density. For example, large and bulky fillers would not be quite suitable for surface filling applications. One the other hand, surface filling would not be easily applied to cellulosic paper with relatively "closed" fibrous matrixes, such as may be caused by intensive pulp refining. Also, the addition of mineral particles to the polymer solution, in relatively large amounts, may play a negative role in the development of surface strength of the cellulosic paper.

Possibilities and Potentials of Surface Filling

As mentioned above, there are superiorities as well as limitations associated with surface filling. However, a delicate balance may be developed to utilize the interesting process concept. The following are some of the illustrative possibilities and potentials:

- Surface filling may be applied to traditionally unfilled paper grades to achieve filler-for-fiber substitution and cost reduction.
- Surface filling may be used to substitute for direct wet-end addition of fine fillers, so that the negative effect of filler addition on paper strength would be alleviated, allowing increased maximum filler loading levels.
- Surface filling may be combined with wet-end filling, resulting in an integrated filling process. In this process, different types of fillers with varied characteristics can be used. For example, the fillers used for surface filling can be finer and rounder than those used for wet-end addition. By utilizing such a process, the economic potential of the paper mills would be further optimized or maximized.
- In the context that fillers can be used in cellulosic paper to make it suitable for specific functional applications, surface filling may be efficiently used in the development of cellulosic paper with some unique functionalities or even "smartness". For example, the development of performance-tailored magnetic paper may lead to the production of various "smart" cellulosic paper grades. Filling of voids in fibrous matrixes with relatively heavy and fine magnetic metal compounds may be a superior option compared to such somewhat fancy processes as lumen/cell wall loading, in terms of its suitability for commercialization.

In addition to the above-mentioned aspects, based on the process concept of surface filling, one can also consider various imaginative possibilities and potentials. Globally, the successful practices of surface filling in paper mills are already available, but these are still limited to a certain degree, and the industrially available practices mainly address the use of ground calcium carbonate filler together with the starch solution. There is still a strong ongoing potential for worldwide commercial applications, and it is interesting to extend the use of the surface filling concept to various types of fillers. In the area of fillers for papermaking applications, published reports dealing with surface filling are generally rather rare in comparison to other aspects associated with more conventional uses of fillers. However, it is expected that further development and application of surface filling would provide more possibilities and potentials for the papermaking discipline. At a minimum, it can provide an interesting alternative or supplement to the wet end use of fillers.

Potential Questions to Be Answered

From the above discussion, it may be evident that there are lots of interesting possibilities and potentials associated with the adoption of surface filling concept. However, there are still some potential questions that remain to be answered, for example:

- Since this technology is not quite new to the industry, why are its commercial uses not very well-known in comparison to wet-end filling? Are there still some technical and/or economical bottlenecks in its industrial use?
- Is the sparse use of surface filling in paper mills somewhat due to the fact that its published reports are extremely rare? That is to say, does the limited exposure of the relatively simple technology hurdle its commercialization?
- Since the time interval between surface filling application and the drying of the polymer is rather limited, will the density of fillers have a very significant influence during its industrial practice? If so, what are the governing factors?
- Can a carefully controlled combination of fillers and the polymer solution result in optimal development of surface strength of the cellulosic paper?
- For surface filling and wet-end filling, are there some specific differences in recyclability of the cellulosic paper?
- What about the possibility of surface filling with organic fillers?
- What kinds of impacts/influences would surface filling provide when fillers with such functionalities as magnetic, electrically conductive, and thermally sensitive properties, are used?

To answer these questions, continuing research is needed, including practical investigations and fundamental studies. Fundamental studies need to be balanced by insights from those in the industry who are using surface filling on a day-to-day basis. The authors of the present editorial wish to encourage others to publish in this area, pursuing either a commercially oriented or a mechanistic viewpoint. We would be especially grateful if scientists/engineers/experts having direct experience with surface filling could share their own valuable understandings/ideas, which could well be much different from what has been presented here, so that this interesting concept would be better understood.

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