

Particle deposition on pulp fibers

The influence of added chemicals

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SUMMARY: Many chemicals added to a papermaking suspension are of a polymeric nature and affect the interactions between fibers, fines and fillers. Optimization of fines and fillers retention is important in making optimum use of resources and minimizing recycling and effluents problems. Three strategies for optimizing the retention of small particles can be identified: (i) optimizing the rate of particle deposition on fibers, (ii) minimizing the rate of particle detachment, and (iii) capturing fines and aggregates of fillers in the forming sheet during drainage.

The process of filler deposition and flocculation can be described by 4 parameters: the rate constants of deposition and flocculation and those of particle removal and break-up. Each of these rate constants can be separated in two terms, which depend on the hydrodynamic and physicochemical conditions, respectively. This allows the effects of added chemicals to be studied, independent of the complex hydrodynamic conditions.

Added chemicals can "switch" the deposition or flocculation efficiency from 0 to 1 and they can affect the bond strength between fillers, fibers and fines.

Since papermaking is a high speed process, added chemicals must act quickly. Each of the 4 rate constants for deposition, flocculation and break-up, as well as those for adsorption and desorption of polymeric retention aids, has a time scale associated with it, which also depends on the concentration of the various components. The relative magnitude of these time scales determines the sequence of events in a papermaking furnish.

Contaminants in mill water can have a great effect on the performance of a retention aid. Dissolved material can form complexes with retention aids, which usually has a detrimental effect. An exception might be PEO (polyethylene oxide) which, by itself, is a poor retention aid, but in the presence of other material (e.g. lignin derivatives) can be very effective. To counteract the negative effects of dissolved materials, various strategies are available.

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The interactions among the various particles in papermaking suspensions are complex. A papermaking suspension contains particles of many sizes and shapes, all subjected to turbulent flow conditions. Typically, pulp fibers have a length of up to a few millimeters, while their cross section is around 30 pm. Fines, usually fiber fragments, have a similar cross section but their length is much shorter, typically up to 150 pm. Colloidal additives, such as clay, TiO₂ or CaCO₃, are much smaller, in the order of a fraction of a micrometer to several micrometers. Very small fines, which can be present as well, behave very much like fillers. Finally, dissolved polymers (either naturally present or added as bond strength agents, retention aids, etc.) are typically in the range 10-100 nm. Under turbulent conditions, all these particles are moving, rotating and colliding at various rates. The interactions among particles can lead to aggregation or

deposition of small particles on bigger ones. Some of these interactions are desirable, others are not. E.g. the interactions among fibers leading to fiber flocs is undesirable since it will lead to inhomogeneities in the sheet. Interactions between fibers and fines or fillers is desirable, since it is useful to incorporate the small particles in the sheet to improve white water recycling and paper properties such as printing. For the same reason, fines-fines and fines-fillers interactions are desirable. Interactions among fillers can be either desirable or not. If the aim is to incorporate a large amount of fillers to lower the cost of paper, these interactions are desirable, since flocs of fillers can be more readily incorporated in a sheet of paper. If the aim is to improve the optical and printing properties of paper, the coagulation of fillers is undesirable, since individual particles scatter light better. Finally, the interactions of the dissolved polymer with the suspended particles can be either desirable or undesirable, depending on a variety of circumstances. If the polymer is required to bridge particles, only those interactions which lead to the required bridging flocculation are desired, others are not.

From this description it is clear that the best strategy for optimizing the wet-end papermaking chemistry is to selectively influence the various interactions. To achieve this one must try to optimize the efficiency of the various coagulation and deposition processes that take place. The efficiency is defined as the ratio of the number of collisions that lead to flocculation or deposition and the total number of collisions. For some interactions an efficiency of zero is required, while for others an efficiency of 100% is desired.

These efficiencies can be altered by chemical additives. In this paper we outline which parameters are important in fines and filler retention and how they can be controlled by chemical means. We will start by describing the kinetics of particle interactions in order to identify the parameters that can be controlled and subsequently indicate how, in principle, these parameters can be altered to improve the control of the wet-end papermaking chemistry on a paper machine.

Kinetics of particle interactions

Collision kinetics

To estimate the number of collisions between particles subjected to turbulent flow is a difficult problem. The common approach is to define an equivalent shear flow and compare the flow with an ideal simple shear flow for which simple theories are available. The equivalent shear flow in a more complex flow system can be estimated from the mean velocity and the geometry of the flow or from a measurement of the power needed to create the flow (Levich 1962). Despite the large shear rates to which papermaking suspensions are being subjected, not all the collision rates are orthokinetic (caused by flow). Because of their small size, interactions among fillers and polymers can be perikinetic (due to Brownian motion), especially for small fillers (of size \approx 0.1 pm). In a