FINE PARTICLES SEPARATION IN RECOVERED PAPER SUSPENSIONS

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Abstract

Stock preparation systems for recycling paper production deliver furnishes of high qualities and with defined properties, although their input is a heterogeneous material of varying qualities. One of the various separation objectives is separation of organic and inorganic fine particles.

The separation problem of inorganic and organic fines is concretely interesting especially for:

- washer filtrates in recovered paper stock preparation systems for hygiene paper production,
- furnishes and process waters for/in the production of packaging papers and
- flotation foams of recovered paper stock preparation systems for graphic paper production.

This paper covers analysis of realistic multiple component suspensions and model suspensions with virgin fibre and mineral materials. Combinations of various measurements are introduced. Interesting observations regarding settling behaviour and agglomeration are discussed.

The analysis of inorganic and organic fines in mixed suspensions is prerequisite for proposing separation technologies for the above named fields of application. In a comparative study promising options of sedimentation processes for this objective were discussed. The resulting process is being developed in the authors’ university department in cooperation with Karlsruhe Technical University.

KEYWORDS

Ash, Fine Particle, Gravity separation, Image Analysis, Laser Diffraction, Particle Interaction, Particle Separation, Pulp and Paper, Sedimentation, Separation
Introduction

Separation of organic and inorganic fine particles is an objective in paper recycling because of high ash contents in recovered paper and disposal problems for huge tonnages of rejects. Rising ash contents in recovered paper grades may cause strength property decreases of packaging papers produced of this raw material. For the production of packaging papers until now a lot of effort is spent to compensate the decreasing strength potential but not yet de-ashing established. Only for hygiene paper production, de-ashing is a must. It is achieved by washing. Rejects of processes with too low efficiency separating organic or inorganic fines like flotation and washing lower profitability for recycling paper production. High organic content in reject on the one hand causes production losses. Their disposal is very expensive and their land filling prohibited in Germany. Incineration efficiency decreases on the other hand with increasing ash contents.

A solution would be a process being able to de-ash a suspension containing inorganic and organic fines. Organic fines are small fibres, fibre broke, fibrils or hemicelluloses. Inorganic fines are minerals used as pigments in paper finishing and fillers in paper production like calcium carbonate or kaolin. These particles differ regarding sedimentation behaviour. This fact can be used by sedimentation processes.

Research targets

The fines’ sedimentation behaviour has to be quantified. More than just virgin raw material has to be analysed. Virgin minerals may be dispersed to completely different size distributions than minerals being parts of a paper coating layer for one or multiple production cycles. Organic fines of a virgin pulp for example can have different surfaces because of hornification during drying steps of paper production. An answer has to be found, if agglomerations between these particles that should be separated by sedimentation exist and if they may be dispersed by a chemical dispersing agent. Analysis of model suspensions from paper produced with defined composition from a pilot plant coating trial helps to quantify the realistic fines’ settling behaviour, then.
Description of the particles to be separated in the suspension and the separation strategy

No matter, which kind of production of recycling paper will be the application of a separation process for inorganic and organic fines, the mixture is a composition of fibres, fibre broke, fibre fibrils, hemicelluloses, various chemical additives of the paper production and finishing process, inorganic fillers and coating pigments as well as printing ink and adhesives from the printing and converting of paper products. Long fibre material will dominate sedimentation because of their size and flocculation ability. Therefore a first process step has to be their separation by filtration with a 150 µm holed screen delivering a filtrate with the desired fine particles.

In such a filtrate of recovered paper suspensions, mainly calcium carbonate and clay particles are in focus regarding inorganic components. These minerals are shown in figure 1 beside organic fines of a length around 30 µm.

![Figure 1](image1.png)

Figure 1: Inorganic and organic fine components in a flotation foam of a graphic recycling paper production line

![Figure 2](image2.png)

Figure 2: Calcium carbonate and birch sulfite pulp fines in a model suspension with 50 % by weight of every component after desintegration of a laboratory paper sheet and extensive drying
The composition of the suspension in figure 1 and the identification of the various particles are difficult to analyse. Therefore this complexity is reduced by using model suspensions. An analogous picture of a simple model suspension is given in figure 2. Simulating the paper recycling process, from the mixture of 50 % calcium carbonate and 50 % birch sulfite pulp fines laboratory paper sheets were prepared, dried and stored for 48 hours at 60 °C, a standard procedure. With figure 2 may be concluded, that even with the formation of a paper sheet the inorganic particles are not forced to attach to organic fine particles.

Because this simulation of a paper production process is rather simple and the finishing step of coating with pigments is not considered, a pilot coating trial has been realised. A picture of the coating pigments calcium carbonate and clay – each of them 50 % by weight – is given in figure 3.

![Figure 3: Calcium carbonate and clay particles of a coating slurry before application](image)

**Analysis**

Two kinds of results are of interest: separate particle size distributions for inorganic and organic particles and their settling behaviour. Separate particle size distributions are useful to explain settling behaviour.

For before described fines, Ripperger evaluates particle size distribution analysis systems [1]. The combination of various systems can help to solve the problem of determining separate particle size distributions in multiple component suspensions. The Sedigraph ignores the organic fraction because the measurement technique uses X-ray. Results of a laser diffraction spectrometer are doubtful for prolate particles as the regarded organic particles are. The more fibrillated the organic fines are, the more significant the measurement error is [2]. These effects can be quantified consulting an image analysis measurement system. For the above described organic fines the FiberLab system from Metso is convenient. It ignores the inorganic fraction, because resolution is detecting particles bigger than 20 µm.
The settling behaviour may be analysed by sedimentation balance. Trials with this equipment resulted in huge experimental time efforts because of very small particles staying in gray phase. Organic fine particles flocked very fast. These flakes settle very fast and cause turbulences. The Sedigraph analysing the settling velocities directly ignores the fine organic particles. Plugging problems in the Sedigraph measuring chamber occurred. A measurement equipment for determining the settling behaviour of the organic particles in a multi component suspension using image analyses is being developed actually at PMV. Existing measurement equipments that should be usefull theoretically are tested in the external laboratories of the suppliers.

The combination of systems which measure the sedimentation velocity with systems which measure the particle size distribution needs a new mathematical equation between particle size and sedimentation velocity for organic fines because their forms differ wide from spherical shapes. This new equation has to include form factors and maybe orientations during sedimentation [3].

Results

Results from model suspensions are much easier to interpret than of complex real suspensions as shown in figure 1. The presented results therefore start with the easiest mixtures and end up with the complex suspensions.

Organic and inorganic fines have been observed in single component suspension and heterogeneous suspensions during sedimentation. The heterogeneous suspension was shown in figure 2. Figure 4 shows a drawing of the sedimentation observations.

![Figure 4: Simplifying drawing summarising the observations during sedimentation of single component suspensions and heterogeneous suspensions.](image-url)
Organic fines seem to flocculate into bigger and more flakes if they are dispersed in a homogeneous suspension and their sedimentation is the fastest of the three examples discussed here. Calcium carbonate particles act like hindering the flocculation of the organic fines and with this slowing down their heterogeneous sedimentation. [4]

Sedimentation balance results are shown in figure 5. The settling velocity of the particles that should be separated is significantly differing so that a sedimentation separation process should succeed. Combined with the observations it might be necessary to add a chemical dispersing agent to avoid the capturing of calcium carbonate particles by the organic fines' flakes.

If a density is assumed for a heterogeneous suspension, e.g. by identifying and counting consulting REM pictures, mass distribution sums may be plotted over an equivalent spherical diameter. For the complex suspension in figure 1 2.65 g/cm³ was assumed and given as constant for the analysis of sedimentation balance and sedigraph. Figure 6 compares both results.
Figure 6: Results of particle size distribution measurements in sedimentation balance and Sedigraph assuming a density of 2.65 g/cm³ for a heterogeneous suspension shown in figure 1 consisting of various organic and inorganic fines.

Two effects explain the difference of the curves' shape. On the one hand, the Sedigraph does not regard the organic particles settling. The organic fines are bigger and they are missing in the blue curve but measured with the pink curve. On the other hand, the Sedigraph cannot exclude the capture effect of the organic fines flakes on the inorganic particles.

Results of the FiberLab system from Metso aren't possible to compare with the results of sedimentation balance and Sedigraph at this moment. Figure 7 shows the problem. The calculated particle size from sedimentation velocity by using the Stokes equation diverges from measured particle size of an image analysis, if there are organic fines in the suspension.
Sedimentation methods like sedimentation balance and Sedigraph deliver sedimentation velocities of particles. Counting methods like Coulter LS 200 and FiberLab Analyzer deliver particle size distribution. The Calculations of organic fines' sedimentation velocities in particle sizes with the Stokes equation aren’t possible because this equation posits spherical shape. Organic fines differ far from spherical shapes. A new mathematical equation employing particle size and sedimentation velocity distributions for calculating organic fines’ particle size distributions have to be found. The new measurement equipment for determining the settling behaviour of the organic particles in a multi component suspension actually being developed at PMV could be useful for finding this equation.

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