Advanced use of filler close to headbox together with retention aid additives with TrumpJet® Flash Mixing system

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Abstract
An immediate and effective mixing with TrumpJet® Flash mixing process makes it possible to inject papermaking additives e.g. retention aid and sizing chemicals into stock very close to the headbox. The developed versatile mixing technology makes it possible to mix also filler into headbox feed stock simultaneously and together with retention aid agent at the same location. As a result the process is simpler, it has a very short response time, filler retention can be better and sheet properties develop positively.

Introduction:
Inorganic mineral, filler is an important raw material for several paper and board grades. It replaces expensive fiber material and it gives important quality properties for paper or board product. Filler can be e.g. kaolin, talc, GCC, PCC, titanium in different forms, shapes and qualities. Filler is mixed with the fiber stock normally at quite early stage into the process. Mixture of fibers, fines and filler is pumped to a headbox and further led to the paper machine wire section or former for sheet dewatering and formation.

Fibers can have very high retention – 90–98%. Retention of fines is much less and normally retention of filler is the lowest. By aid of additives it is possible to increase the filler retention considerably. Without retention aid retention is low, only 5–15%. With the retention aid it is better. By adding more retention aid it will improve also retention of fibers and increase size of fiber flocks, due to this sheet formation typically becomes worse. Formulation requirement gives a practical limit and an absolute stop to increase the filler retention too much. Accordingly paper maker has today to compromise when trying to increase filler retention and simultaneously he has to maintain good formation. Normally formation wins and filler retention gives up.

Drawbacks of low filler retention are numerous. At first low retention can be seen in high filler content of white water. The increased solid content of white water lowers cleaning efficiency of centrifugal cleaners, loss of filler in cleaner and screen rejects can be accordingly higher. Wear of forming elements and wire fabric, cleaner cones and screen cylinders is increased as well. Due to the low retention control and adjustment of filler content of sheet is slower and response time longer.

In the PM Approach system the same basic filler is at least in four different forms 1) Fresh, virgin filler, 2) Filler circulated back to the process with broke, 3) Filler circulated back to the process from white water recovery/save all system, 4) Filler circulated back to the process in the white water from former/wire section. They all differ from each other e.g. in cleanliness, charge, whiteness. In this paper the focus is given to the treatment of fresh virgin filler.

1. Injection points of virgin filler
Today virgin filler is added to alternative locations depending on type of the filler and application (figure 1):
   1. Thick stock: Blend chest or machine chest or thick stock line from machine chest before dilution
   2. Before mixing pump (cleaner feed pump, fan pump1):
   3. Before headbox feed pump (fan pump 2)

The figure 1 shows also delay time from each dosage location to the slice of paper machine.

In some cases filler is added partly into thick stock and partly before headbox feed pump (trim). Often local mixing arrangement of filler is poor. In mixing point of view location of dosage has been selected so that the distance from a mixing point to a former is long enough to provide decent mixing before sheet formation. Mixing happens on the way from mixing point to the headbox.
1.1 Circulating loops of PM Approach / short circulation process

If the dosage location has a long distance to the headbox, it offers some significant disadvantages. However, it has been thought not possible e.g. to bring the mixing point of filler after the headbox screen.

The extended delay time keeps the filler particles long time together with stock components and disturbing colloidal material. Thus the whiteness of filler decreases once it gets “dirty” compared to virgin filler.

Several circulating loops of the PM short circulation process will keep part of the filler in circulation longer periods thus extending the time and above, explained effect. The figure 2 shows the circulating loops and the first pass percentage of additive of flow to the slice.

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**Figure 1**: The different conventional mixing locations with delay time from dosage point to the slice of paper machine headbox.

**Figure 2**: PM short circulation process showing different circulation loops. Single pass percentage to the slice is also shown in a table at upper right corner.
If filler is added into the mixing chest, approximately only 50% of the flow has a straight and direct access as the first pass flow to headbox and as much as 50% of the flow begins to circulate in loops. The long delay time with circulations slow down and make it more difficult to perform production adjustments. The extended delay time, multiple re-circulations of partial flows plus the returning filler low from the wire section with white water make the whole process complex: Chemical reactions and the wet end surface chemistry is difficult to predict and follow - specially in situations when the process is not well balanced. System cleanliness also can be widely reduced due to these facts. The process can generate deposits in uncontrolled situations.

2. Simulation of the process:
With a dynamic simulation model (figure 3), the response times of filler flow adjustments for different dosage locations are calculated. In a presented example filler material is added into five alternative locations: 1. thick stock 2. before cleaner feed pump, 3. before deaeration, 4. before headbox feed pump 5a. before headbox, 5b. before headbox with 10% higher filler retention

In tests of the simulator two step tests were concluded:
1. Filler step response test (figure 4): An increase of filler flow 1 kg/s is made for 1500 seconds at a moment of time at 9 min in x-scale, change of filler content of sheet is measured and presented in the graph. It can be seen that stabilization time of filler content of the sheet is very long, if filler is added into thick stock – about 50 min. The shortest time is about 15 min close to the headbox. If filler retention is increased the stabilization time is even better.

2. Filler impulse test: In this simulation test a sudden impulse of filler flow of 100 kg/s impulse is added into the process at the filler mixing point. The results are in figure 5 and 6. Filler content in the process is then measured and shown from the suction line of centrifugal cleaner feed pump (just before addition point no 1). The graphics of figure 5 show how the system reacts.
The smallest disturbing peak is formed when filler is added after the screen. The disturbance is dampened down in some minutes. Numerous repeating peaks are generated, if filler is added before centrifugal cleaners – dampening time is also longer. Figure 6 shows that these peaks are mainly generated by re-circulation of secondary stages of the centrifugal cleaner plant. If filler is added into thick stock the curve is flat and dampening time is very long up to 40 minutes.

Figure 4: Simulation of filler dosage in to PM short circulation: Filler step response test.

Figure 5: Filler impulse response test: 100 kg/s in one second (filler content is measured before mixing pump).
3. Changes and development of retention of filler when approaching the headbox

Papermaking stock includes also a lot of dissolved and colloidal material (DCS). Depending on type and quality of filler it has a strong ability to absorb DCS material on filler surface. This will reduce brightness of filler and also change retention characteristics of the filler component. The magnitude of the development depends on dosage location of virgin filler. It is: for how long time the filler particle is in contact with stock and DCS material and for how much the filler circulates in the process loops. If retention is low, it will increase re-circulation of filler particles resulting also to the above problem.

In a series of lab test filler retention was measured with different filler delay times in a pulp for SC-paper. The results presented in figure 7 show that retention of filler decreases rapidly when delay time is longer than 30 seconds.

**Figure 7: Development of retention of kaolin filler in SC paper stock with function time between filler and retention agent**
4. Simultaneous mixing of retention aid and filler with TrumpJet® Flash Mixing

Based on the above it is beneficial to inject and mix virgin filler as close to the headbox as possible. This will:
- conserve the brightness potential of virgin filler as high as possible
- increase retention for filler particles
- give very fast response time in quality changes of production
- reduce filler content in circulating process loops
- reduce loss of filler in reject flows of screens and centrifugal cleaners
- reduce wear of machine components
- if filler is used also as a DCS collector on purpose, this part of the filler can be added to a proper location at earlier stage. However, the optically efficient filler should be added at the later stage close to the headbox.

Wetend Technologies Ltd has developed a TrumpJet Flash Mixing concept where additives can be mixed with fast and efficient method. Generally speaking mixing has to be completed before mixture of stock, filler material and wet end additives reach headbox feed manifold. TrumpJet mixing process exploits circulated headbox feed stock and completes mixing in less than two seconds. It is possible to locate e.g. two mixing stations between accept outlet of headbox screen and headbox feed manifold. Figure 8 presents the concept in detail.

The technology gives an opportunity to mix additives together or simultaneously just a fraction of a second before the flows are mixed into the main process. It is also possible to mix e.g. two completely different additives combined, but through separated layers and simultaneously into the main stream. The wide versatile number of mixing variables has made it possible to develop a process to bring also the filler mixing point close to the headbox with the same manner and combine mixing of filler into mixing process of wet end chemicals - especially with retention aid agents.

In a TrumpJet Flash Mixing system filler is mixed simultaneously with retention aid agent. It is injected into the process together with retention polymer or with micro/nanoparticle. Depending on the charge, filler and chemical can be even mixed together but typically the filler and retention aid are added in the TrumpJet system as a combined mixing process simultaneously but in separated layers.

Figure 8: TrumpJet Flash Mixing process for filler wet end chemicals close to headbox.

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5. Laboratory tests for Flash Mixing

In laboratory tests it has been found that, if retention aid additive and filler are added simultaneously, it will give a better filler retention than, if filler is added separately before the polymer or after the polymer. The lab tests have been made with a MBF (moving belt former) laboratory instrument in cooperation with FiberLaboratory of Lappeenranta Technical University in Savonlinna, Finland.

In the laboratory tests influence of the delay time between filler and retention aid has been studied close to the “zero” time-difference with MBF tester (figure 10). Time delay varied from +2 to -2 seconds. Figure 11 shows results of two tests with a papermaking stock where filler is added at first with conventional manner 26 seconds before and then the delay time is reduced between the two additives. In the last test point filler is added 2 seconds after retention aid additive. When mixing of the two additives is simultaneous, retention reaches the highest value.

Figure 9: Principle of TrumpJet Flash Mixing flow sheet for simultaneous mixing of filler and retention aid.
The both two cases show about 9 - 11% (units) increase in filler retention. Case1: from 36% to 45% and case 2: from 47% to 58%. Comparison is made to a delay times from +26 seconds to -2 seconds.

Figure 12 shows difference of light scattering values of front and back side of hand sheets prepared in the tests with MBF device. The light scattering difference is the smallest once filler is injected simultaneously with polymer (zero time difference). This tells that the filler distribution in the sheet is more even on both sides of the sheet with simultaneous mixing.

The reasons why retention is improved can be considered to be:
- minimum opportunity to collect DCS material of surfaces of virgin filler: retention capabilities of a single filler particle improve.
- fresh retention aid and fresh virgin filler interact better in simultaneous mixing conditions.
- in the simultaneous mixing also some small weak filler flocks are created. Because there are no very aggressive shear forces (e.g. no screen in place) left in the process before dewatering the flocks will stay together. Shear forces of mixing stations are present, but the shear force and treatment is gentle enough not to generate dispersing of established tiny flocks.

In the beginning of this article it was explained how filler material can be divided into different groups that are present in the papermaking stock. Based in the results and the operation of the TrumpJet® Flash Mixing concept a conclusion can be drawn that mainly the injected and mixed virgin filler has the increase of filler retention. If improvement of total retention of filler is e.g. from 25% to 35%, then the actual retention of the mixed virgin filler is much higher.

6. Mill results
The developed concept has been tested in mill scale production and in mill scale tests; example of installation is in figure 13:

Case A: Directory paper, wood containing stock; retention aid and GCC filler, the TrumpJet installation close to the headbox: It is possible to increase filler retention depending on grade. Optical properties are the same. Filler content was significantly decreased in rejects from centrifugal cleaners. Filler distribution was slightly better in z-direction of paper.

Case B: Coated fine paper. Filler and retention aid agent were mixed together for a coated fine paper machine. As a result filler retention was increased. Sheet quality was unchanged.

Case C: Board. Opacity pigment and retention aid were mixed simultaneously for a top ply of a multi ply board machine. Sheet brightness was increased and consumption of the pigment was reduced.

Case D: Coated fine paper machine: Opacity pigment, TiO₂ and retention aid were mixed simultaneously. As a result opacity was increased by 0.9% and TiO₂ consumption was reduced about 20%. Consumption of retention aid was decreased.

Figure: 13: A TrumpJet® Flash Mixing station for retention aid and filler material, TrumpJet mixers are circled with red. On the right: an individual TrumpJet mixer in operation
Conclusions and summary
Effective TrumpJet Flash mixing makes it possible to mix the additives with a short delay time from headbox. The short delay time gives an additional advantage in grade changes. Response time is very short and the process finds new balance quickly.

As summary the following objectives and benefits can be presented for TrumpJet Flash Mixing of filler and retention aid:

- Improved homogeneity of micro structure of sheet
- Higher purity of filler in paper sheet
- Improved brightness
- Improved retention of filler or reduced consumption of retention aid chemicals to the same retention
- Reduced consumption of retention aid gives better formation
- Improved filler distribution in X, Y and Z directions
- Lower filler content in white water circulation
- Reduced foaming and deposits
- Less wear of process machines and components
- Better operation of screens and centrifugal cleaners
- Shorter grade change time (< 20 min, typical)
- Short delay time from dosage to dewatering (3–4 s)
- Reduced loss of filler in rejects of centrifugal cleaners or screens

The TrumpJet Flash Mixing makes it possible to inject and mix wet end filler just alone or together with wet end additives into the papermaking feed stock with short delay time before dewatering and formation. Retention of fresh virgin filler can be considerably higher and sheet quality can be developed as well depending per individual case. This has been tested and experienced with laboratory tests and actual installations in paper production. Variety of process applications is very wide. Accordingly further application efforts are needed to establish the concept details for various production cases and raw materials. Versatility of the TrumpJets Flash Mixing process variables helps to meet objectives together with good cooperation of all parties involved.