Substituting pulp for filler is increasingly attractive for papermakers.

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ABSTRACT

Market pulp is traded globally and has the kind of price volatility often found among true commodities. In recent years the price has been moving upwards, much to the agony of papermakers who face price pressure in the wake of declining paper demand. Mineral fillers commonly used in papermaking are exhibiting a higher degree of price stability, meaning that the already large price gap between pulp and filler has been tending to increase. This increased gap is reinforcing the interest for higher filler loading in papers. Balancing the strong cost incentive to increase filler loading is an expectation of negative impact on papermachine operational efficiency and paper quality. Pushing filler up means that the operation of paper machines would tend to be more challenging in terms of having more fine material to retain and in maintaining overall runnability despite having an inherently weaker paper web. Managing this balance is a value creation opportunity for papermakers as well as for their suppliers.

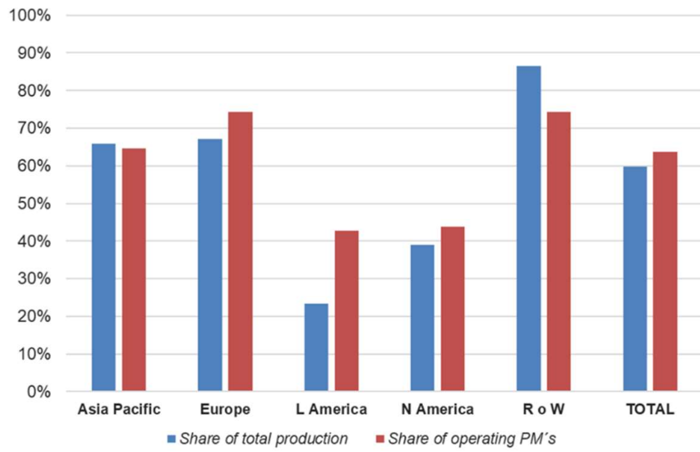
Today there is strong interest in using microfibrillated cellulose (MFC) to facilitate higher filler loading. This presentation will however take a wider look at the various “filler increase concepts” available in the market, describe the way they work and what trade-off´s one will have to expect. Particular attention will be given to what impact different additives will have on the filler funtionality. It is clear that fillers can provide other value than simply acting as cheap extenders. Important filler funcionality and its impact on paper properties such as opacity, smoothness, porosity, ink absorption and bulk will be influenced by the choice of additives.

BACKGROUND

The use of fillers in papermaking was established already 150-200 years ago. The term “filler” implies that the purpose of mixing in white mineral pigments in the paper furnish was primarily viewed as a way of avoiding use of a more expensive raw material, pulp. It is easy to see that this is not the full story. Simply looking at in which segments of papermaking fillers are used tell us something about the value they offer. Fillers are used to enhance optics and print properties, and this is always done at some expense of mechanical properties. In segments where optics and printing are not valued there is very little use of fillers. Interest in increasing filler is high in Printing & Writing, where optical and print properties are a priority. To judge the performance of “high filler systems” it is therefore important to consider what impact these will have in this prioritized area. Even more important is the impact that filler increase will have on paper machine operational efficiency. The cost saving potential is large, especially at today´s pulp prices but this advantage could soon be lost if the filler increase resulted in more downtime, higher broke rate or critical paper properties were to be compromised.

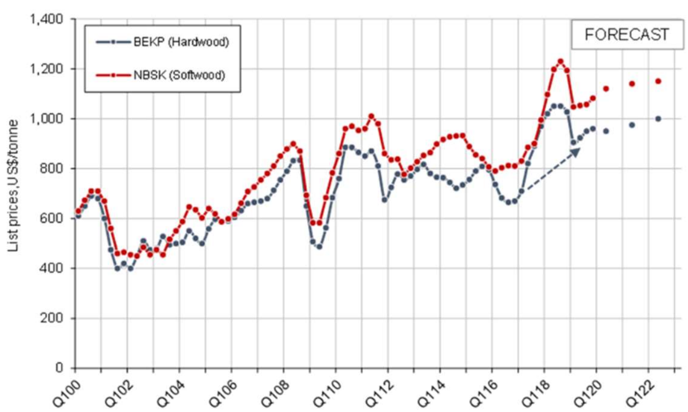
COST DRIVERS AND RISKS

A majority of all global P&W paper machines use at least 10% market pulp in the furnish. There are clear regional differences with more mills in the Americas being fully integrated than in Europe and Asia where use of filler is also much higher.



1. FisherSolve data on share of global P&W paper machines using >10% market pulp

Market pulp is a typical commodity with high price volatility in response to changes in supply and demand. Demand for pulp has increased by 12 million metric tonnes over the last 10 years as a consequence of growth in tissue and packaging boards as well as P&W papers production moving to geographies where integrated pulp production is not an option. Pulp is increasingly being produced in South America and used to make paper in China. Consolidation of the market pulp industry has increased rapidly and today the top-5 producers account for some 40% of capacity. Despite recent turbulence it is clear that the long-term pulp price trend is pointing up. For P&W paper producers this is causing an issue, especially as the paper market conditions with falling demand makes it very difficult to pass on the cost increase. Fillers tend to be more regional products with a higher degree of price stability. For standard fillers it is also clear that the price level is significantly below that of pulp. As a rough approximation, it is fair to assume that today there will be a price difference of $500 per ton of dry product.



2. Hawkins Wright data and forecast on market pulp list price CIF European ports

Being able to respond to cost increases by substituting pulp for filler is therefore very desirable. The gross benefit is substantial as $5 is saved for every 1% increase in filler. In reality, the cost saving will have to be significant for any filler increase project to be worthwhile. Papermakers will always look at the balance between risk and reward, and the net saving will need to be adjusted for:

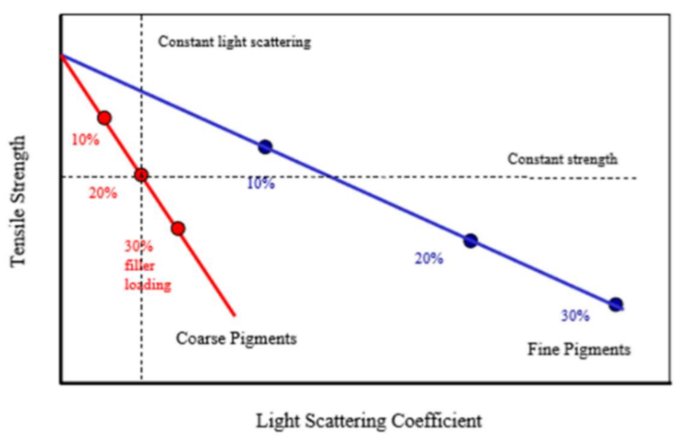
- Cost of “strength additive concept”
- Any increase in use of chemicals
- Machine clothing life time
- Reductions in drying costs

It is even more important to understand the potential impact of filler increase on paper machine operational efficiency and on the general quality of the paper:

- Strength performance control and stability over time
- Impact on initial wet web strength
- Ability to maintain a constant and high retention
- Impact on formation
- Distribution of filler in the sheet Z-direction
- Impact on drainage and press solids
- Impact on size press pick-up
- Impact on coating hold out
- Surface smoothness before calendering
- Net impact on bulk and stiffness
- Net impact on optical properties
- Net impact on quality of print surface
- Look and feel of the paper

IMPACT ON OPTICAL PROPERTIES

Fillers generally have a positive impact on opacity and brightness. Brightness of a filler is a function of mineral type and purity. For high opacity, without sacrificing brightness, it is important to have high light scattering. As most fillers, except TiO_2, have similar refractive index, the route to high light scattering is to have the correct size of the mineral particles. Within the particle size range of commercially available fillers this means the finer the better. Scalenohedral PCC and Calcined Clay are effectively larger aggregates built up by fine particles.



3. Relationship between tensile strength and light scattering for coarse and fine filler.

Use of fine fillers result in more strength loss, but actually less strength loss at any given level of light scattering. As long as the fine filler can be adequately retained this should make them attractive when the goal is to reach high opacity. High opacity is obviously desirable for P&W papers. For some other grades, such as thin print specialty paper and for thin layers designed to cover a dark base, it will allow a reduction in basis weight and thus be of great importance. Increased filler loading and selection of filler type has the potential to create more value through its impact on opacity.

IMPACT ON PAPER MACHINE OPERATION

Retention

It is obvious that fillers are harder to retain than fibers. The first pass ash retention will always be lower than total first pass retention. This is a challenge in connection with increasing filler loadings. The filler, and sometimes also the strength aid used to allow higher filler loading, will increase the available surface area and sometimes also the anionic charge. Modern retention aid systems are capable of handling this, but the dose rates will need adjustment. Typically, this means a small incremental cost for retention aids. At the same time, any increase in retention aid dosage will be a challenge for formation. As a result, a paper maker will need to find a balance between an acceptable ash retention and formation.

Water removal

Reducing the amount of fibers and replacing with mineral is generally beneficial for drainage as well as for pressing as the amount of water bound to filler particles is much less than to fiber or fines. The need for maintaining strength and the additives used to achieve this can however have a big impact. It is important to reach a good balance here. Slowing down the paper machine is typically not an option.

Wet web strength

Xujun Hua et al. showed very nicely at PaperCon 2011 the impact of increased filler loading on wet web strength and press solids. They were using scalenohedral PCC in a chemical pulp furnish. When increasing filler loading from 20% to 30% they observed:

- Wet TEA Index dropping 24%, at constant 50% press solids
- Press solids increasing by 1% unit, at constant press impulse
- Wet TEA Index drop was reduced to 17% as a result of the increase in press solids

The wet TEA is however only some 1-2% of the final dry paper TEA! Uncoated and coated woodfree papers usually have more than enough dry tensile strength to meet customer requirements. Tensile is here an important proxy for runnability of the paper machine, but it is the initial wet web tensile that is most important. A good strength aid for use in a “filler increase system” should be able to give improved initial wet web strength in order to help maintain good paper machine runnability.

PAPERMAKING COMPROMISES

The minerals used to make fillers have much higher density than pulp. Adding more filler will often result in loss of bulk and stiffness. This is often the key limiting factor to high filler loading. More filler distributed well in the sheet will however also have a positive impact on smoothness. Filler increase concepts may further contribute to this or they may distract. Reductions in calendering made possible by better smoothness is important to mitigate bulk loss. For coated papers there can be an additional effect based on changes in coating hold out. Adding more filler will often result in a more open sheet structure with negative effect on hold out. Strength additives used in filler increase concepts can however have a significant effect on closing up the sheet structure and improve the hold out of coating. With reduced coating penetration into the base sheet follows better coverage, smoothness and glossing potential. With the aim of winning back bulk this can be traded for coat weight reduction or reduced calendering. By adding strength to the sheet, it can be possible to allow room for using a bulkier fibre mix. The use of bulky fibers, such as BCTMP is common practice. This will effectively be a way of trading strength for bulk. Regaining the inevitable bulk loss from more extensive use of high-density minerals is possible but will always involve some compromises

ALTERNATIVE FILLER INCREASE APPROACHES

The paper industry and its suppliers have been very innovative in field of filler increase. After wider market adoption of nano-particle based retention aids, filler increase systems have become focused on solving the strength issue associated with using more filler. The approaches taken are very diverse. Several “systems” are in commercial use while others are still under development. It would be difficult to capture them all. With no ambition to provide an exhaustive list we can mention lumen loading, co-precipitation of PCC on fines, use of coarser minerals, increased refining, pigmented starch in size-press, pre-flocculation of filler, wet-end starch in different ways, other water-soluble polymers, microfibrillated cellulose, etc. Our closer scrutiny will focus on the last four.

Pre-flocculation of filler

The basic idea is to reduce the de-bonding effect of fillers through adding them in an agglomerated form. The aim is to create soft aggregates, or flocs, of a controlled size out of 1-3 micron fillers. Information on the preferable size of aggregates varies from 15-30 micron to as high as up to 100 micron. Considerable effort is made to control the size of aggregates to optimize strength, retention and formation. Limiting the distribution of filler across fiber surfaces through introducing filler in soft agglomerates will reduce de-bonding and give higher strength. It will also inevitably compromise light scattering as the filler particles end up being positioned close together. Contrary to hard agglomerates such as PCC and calcined clay the soft agglomerates will not create extra bulk and air voids helping with light scattering. If the filler increase is large enough this may be compensated for by having more filler in the sheet and end up with net positive impact on light scattering and opacity. This is probably why most pre-flocculation systems are combined with addition of dry strength polymers.

Wet-end starch

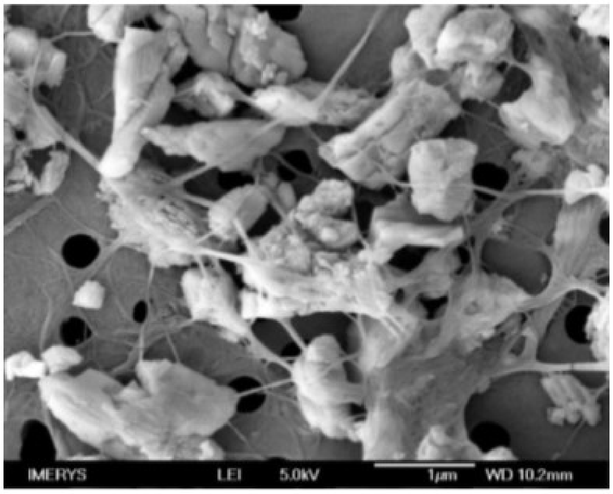
Starch has a long history as a papermaking additive, both for surface sizing and for wet-end application. Today, cationic wet-end starch is used in most paper mills. The effect of adding cationic starch on retention and strength is generally found to be a good complement to other retention and filler increase systems. The limitation of cationic starch is its dependence on charge balance. Adding more cationic starch than the anionic charge of the furnish can handle will result in loss of starch retention, loss of overall retention, high COD load in effluent and often foaming or other problems. A way around this is to add anionically charged surfaces, such as colloidal silica or bentonite. This will allow adding more cationic starch for increased strength. The combination of cationic starch and “nano-particles” will also create strong flocculation and act as a retention aid. For filler increase, this is an attractive combination. However, starch will not offer any positive impact on initial wet web strength and to some extent light scattering will be compromised through flocculation. Anionic polymers have also been used as an alternative to nano-particles, but not with the same level of success. Another approach to add large amounts of starch is adding only partially cooked starch granules. The idea is to get high physical retention of these large swollen “gel balls”. Final cooking of the starch will take place in the paper machine dryers.

Other water-soluble polymers

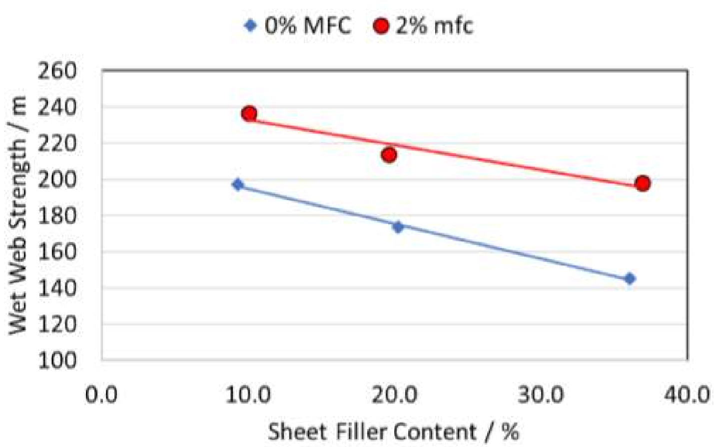
Polymers such as PVAm, GPAM and CMC can be used to enhance paper strength and thus offer an opportunity for filler increase. These products tend to be highly charged, PVAm and GPAM cationic, CMC anionic, and will require integration with the overall wet-end chemistry regime on order to maintain good retention, drainage and formation. They can also be used in combination with pre-flocculation to boost the filler increase potential. A clear advantage of this chemical solution is the ease of implementation, not least in connection with trials. No equipment is needed, except for dose pumps.

Microfibrillated Cellulose

Paper wet-end application of “nanocellulose” is dominated by the relatively coarse MFC and the even coarser Cellulose Filaments. Cost is probably the primary driver for this, but it is also advantageous to have long fibrils. The ideal MFC needs to retain well and be reasonably easy to drain. By strongly associating the filler with MFC it is possible to create an “entanglement” that can also aid retention of filler while still distributing the filler well in the x-, y- and z-direction of the sheet. Through this MFC will actually increase the gain in opacity from adding more filler. The addition of MFC will slow down initial drainage and this will help retention and filler distribution. Solids after the press section will be compromised by the water retention of the MFC but the increase in filler loading will dominate to yield increased web dryness. More important, the web will be stronger due to the effect of MFC on initial wet web strength.

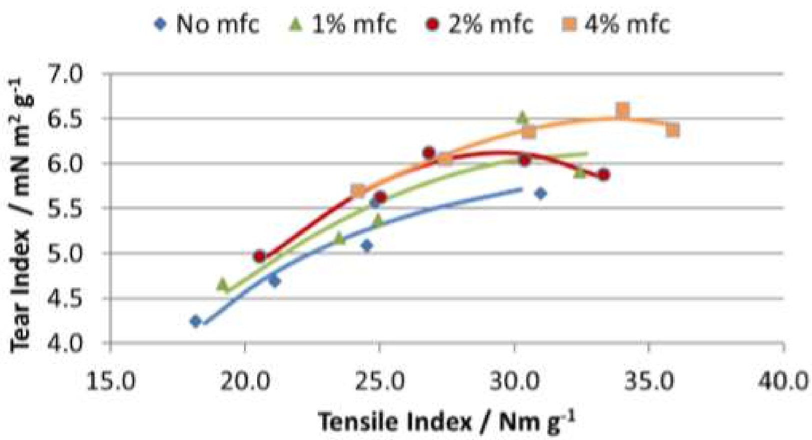


4. Picture of MFC and GCC filler showing "entanglement".



5. The effect of MFC addition on initial wet web strength from pilot machine trial.

MFC creates strength by providing bonded area in a different way compared to what can be achieved by increased pulp refining. The negative strength impact of filler is reduced and the relationship between tensile and tear strength is different.



6. Impact of MFC dose on Tensile and Tear strength at 20% filler and increasing refining.

PRACTICAL EXPERIENCE USING MFC

As an illustrative example of a filler increase application, MFC was used in a commercial paper mill making 75 g/m^2 uncoated woodfree paper at about 700 m/min on a fourdrinier machine. Filler loading (GCC) was increased from 25% to 36% using 2% MFC. Retention was broadly maintained at the high reference level, only dropping to 81% from the 85% FPR start. This was achieved through relatively minor adjustments in the mills retention system. Polymer was increased 10%, alum by 40% (although used at very low levels), Cationic starch up 0,3 kg/ton and the microparticle was reduced by 25%. To further aid dewatering there was also a small change in HB dilution through closing up the lip by ca 1 mm. With less fibers in the furnish this can be done without detriment to formation.

Initially there was bulk loss as a result of the higher loading. To mitigate this the calendering nip pressure was reduced by 20%. Also pulp refining was reduced by 6 kWh/ton and BCTMP dosage was increased by 2%. The degree of refining, measured as Schopper Riegler degrees in the headbox, still increased from 37 to 40, this due to the high water-retention of the MFC. After these changes there were still some bulk loss remaining.

The web solids after the press section have not been measured but reductions in steam usage were a good indicator that it had increased. Given the improvement seen it was decided to trade some of this for improvement in bulk by reducing the 3rd press nip load by 5%. With these changes sheet bulk could be brought back to normal level, at about 1,2 cm^{3}g^{-1}, albeit with a small penalty on surface roughness. This went from a Bendtsen roughness of ml 250/350 to 300/380, so the sheet was a bit rougher but also less two-sided. Reduced pressing meant some loss of steam savings, but overall steam usage was still reduced by 7%.

The good runnability experienced on the paper machine is evidence of a positive impact on initial wet web strength. The dry paper strengths were compromised to some extent. Burst and Tensile were reduced by 10% while surface and Z-direction strength has remained constant. The real bonus in this example, over and beyond the substantial cost saving, is a 2,1%-units increase in opacity!

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