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A Summary of Recent Pilot Machine and Commercial Machine Trials Comparing a New Microparticle Retention System with Existing Microparticle Technologies

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ABSTRACT

The benefits of high performance retention systems have been long recognized by the paper maker. The inter-relation between chemical retention and drainage and their effect on paper production efficiency and paper quality is significant. The subject of this paper is a summary of recent studies comparing three microparticle programs made under highly controlled pilot and commercial paper machine conditions. The results presented in this paper suggest that, in addition to improvements in machine operation, the retention, drainage and formation program can have a marked influence on the paper quality. Improvement of the topographical characteristics of the base paper was observed when the microparticle was a colloidal borosilicate inorganic oxide.

Keywords: Microparticle, drainage, first pass retention, formation, permeability, roughness, mercury porosimetry, printability.

INTRODUCTION

Retention and drainage chemicals added to the wet-end of the paper machine enhance the retention of fines and filler materials and modify their distribution in the z-direction of the paper sheet. As a result, these additives alter micro-structural properties of paper and may be used by the papermaker to target, for example, the desired paper porosity. They may also produce macro-flocculation and alter the larger length scale of formation. The relative degree of "micro" vs. "macro" flocculation depends on the chemical program, dosage, and feed point in the process, and is affected in a very complex manner by the shear level on the machine and other machine parameters.[1]

The drainage performance of a paper machine is affected by numerous factors (chemical, physical - fiber, and operation). In the specific case of improved retention and distribution of fines and filler material in the paper web, drainage is generally seen to improve. This is due to the reduction of fines migration during the early stages of paper formation. Fines migration due to low first pass retention causes concentration of filler and fines towards the wire side of the web, which impedes water flow. However, over-flocculation of the paper web with strong macro flocculation can lead to a poorly formed sheet that is difficult to de-water in the vacuum and press sections.

Retention and drainage programs based on microparticle systems are used in an increasing num-

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ber of machine applications and paper grades. These programs are reported to provide papermaking benefits beyond those achievable with single flocculant programs, such as improved formation for the same level of machine retention, and filler distribution in the final sheet.[4] The improvement in formation has been explained by improvement in dewatering observed in general with microparticle systems compared to single flocculant programs; whereas the improvement in filler distribution has been attributed to formation of stronger and more compact flocs.[5]

Paper structural properties such as formation, permeability, and roughness have a strong influence on its printability. Correlations were shown between paper formation and mottling in the case of wood-free offset papers.[2] Additionally, topographical characteristics of the base paper influence the uniformity of the coating and, as a result, the printability of coated papers. This is especially the case for LWC papers, since the coating layer in this grade is too thin to mask non-uniformities of the base paper.[3] Thus, in addition to machine parameters, the choice of the right retention, drainage, and formation-program may have a dramatic impact on the printing quality of the final sheet.

The microparticle component is commonly added after the papermaking furnish, containing either starch or a high molecular weight cationic or anionic polymer, has been subjected to shear.

Ondeo Nalco's newest microparticle program, *Ultra* POSITEK(®)[1], is based on the combination of a flocculant and the new microparticle technology, which is a colloidal borosilicate nanosize material.[6,7] Ondeo Nalco sells this colloidal borosilicate nanosize material as NALCO(®) 8692. Laboratory, pilot and commercial paper machine studies of this microparticle program have demonstrated its superior retention and drainage performance relative to other microparticle systems, and benefits in terms of sheet properties.[8,9] The basis of this paper is to present a summary of the key results obtained during pilot machine and commercial paper machine trials where the *Ultra* POSITEK(®) system was compared to a bentonite-based microparticle program. The results suggest that *Ultra* POSITEK(®) is a highly flexible microparticle program that allows the papermaker to target the desired paper quality.

RESULTS AND DISCUSSION

Pilot Machine Trials - Eurofex Machine, STFI, Sweden

Retention chemicals added to the wet end of the paper machine cause flocculation and alter the distribution of fines and filler in the z-direction of the paper web. Hence they may affect formation, porosity and roughness. Benefits related to dewatering and sheet structure are not readily demonstrated in laboratory experiments. As such, the realistic and dynamic conditions possible in a pilot paper machine offer a better alternative to the laboratory. Also, the stability and flexibility offered by pilot machines is ideal to accurately study the relative performance of various chemical retention programs. The constant conditions maintained in a pilot machine allow a true comparison of program performance without having results masked by fluctuations in stock and process conditions typical of a paper machine in a commercial environment.

Several pilot machine studies were undertaken during the period 1999 - 2000 to compare the *Ultra* POSITEK(®) retention system with existing reference microparticle systems. These studies were conducted at the Eurofex machine at STFI in Sweden, Valmet in Finland and Voith in Germany over a range of furnish types (LWC, Wood Free), machine speeds and basis weights. For the purpose of this paper, the work at STFI will be discussed.

The Eurofex machine at STFI is a roll-blade type former (STFI) with wire tension set-up at 6.0 kN. Operating speed during the trials was 900 m/min with a slice opening of 14 mm. The press consists of 3 nips with a pressure profile of 50, 500 and 700 kN. Drying is on a single cylinder and multiple cylinders. The paper grade produced during the trials was a standard wood free offset paper produced at 74.9 gsm. The fur-

1. *Ultra* POSITEK(®) is a registered trademark of Ondeo Nalco Company.

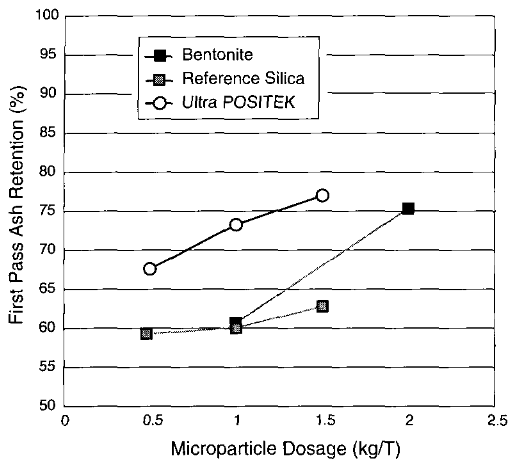

Fig. 1. shows that the borosilicate based microparticle gives significantly better first pass ash retention than the reference colloidal silica:

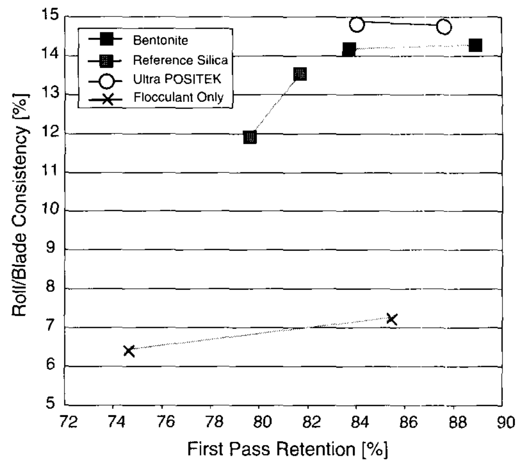

Fig. 2. (using first pass retention as the basis for comparison of physical properties), the borosilicate microparticle showed slightly better drainage in the Roll/Blade dewatering unit than the reference bentonite program and significantly higher performance than the reference colloidal silica program:

nish was prepared using a 60/40 hardwood to softwood relation with a 30% ground calcium carbonate filler loading (HYDROCARB HO from Omya). Headbox pH was 8.0 with consistency adjusted to 0.6%. In combination with the three microparticles compared, cationic starch (HICAT 1164A) was added at 5 kg/T and the flocculant utilized was a liquid emulsion cationic polyacrylamide type (NALCO 74503) added at 0.5 kg/T. Microparticles tested were a conventional colloidal silica, bentonite and the new borosilicate program, NALCO(®) 8692, over the dosage range 0.5 to 2.0 kg/T. The performance of the programs in terms of roll-blade drainage, press dewatering and paper porosity was compared over a range of first pass retention levels. Microparticle dosage levels were adjusted to increase first pass retention levels accordingly.

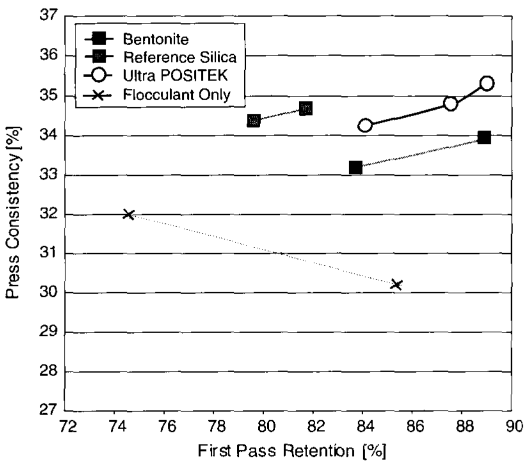

Fig. 3. after pressing, the borosilicate microparticle program achieved over 1% higher dryness than the reference bentonite system:

In the following figures the test results are summarized from the pilot machine studies.

With respect to sheet structure, measured simply by porosity, the borosilicate microparticle program showed a reduction in porosity over the conventional silica microparticle and the bentonite reference program, indicating a tighter formation, as seen in Figure 4:

In conclusion, it can be seen that under the controlled conditions of the pilot paper machine, the borosilicate based microparticle system achieves high levels of retention with better formation than conventional silica and bentonite based programs. The improvement seen in paper sheet porosity, indicating a tight sheet formation would appear to be consistent with the observed improvement in press consistency, which can be related to formation.

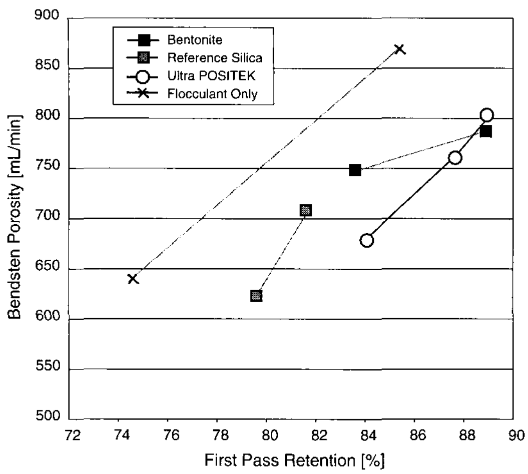

Fig. 4. Bendsten porvsity vs. first pass retention.

The improvements in retention and drainage observed, while maintaining and improving formation over the bentonite program would appear to be of great advantage to the paper maker in optimizing paper quality and production levels on the paper machine.

Commercial Paper Machine Trials - Finland

Previous studies run on various pilot paper machines had demonstrated that it is possible to control paper porosity by choosing different retention chemistries.[8] In particular, it was found that the *Ultra* POSITEK(Ⓡ) microparticle program produced, for the same level of machine retention, a sheet with lower porosity than single flocculant, conventional silica, and bentonite-based microparticle programs. To determine if similar trends can be observed on commercial paper machines, systematic sheet property data was collected on a machine producing coated offset paper. This machine was of a gap former configuration producing coating base over the range of 130 - 200 gsm.

The properties of the base paper produced with *Ultra* POSITEK(Ⓡ) were compared to those of paper produced on the same machine with another retention program utilizing bentonite as a microparticle system. The machine was provided with an on-line retention

	Basis Weight	Ultra POSITEK	Bentonite
Bendsten Permeability (mL/min)	Low	457	492
	Medium	484	595
	High	355	503
Beta Formation	Low	0.539	0.535
	Medium	0.575	0.580
	High	0.633	0.667

Fig. 5. Comparison of formation

control system, and sheets produced with the two microparticle programs were produced at the same level of machine retention. As shown in Figure 5, formation of the base paper was, in most cases slightly better for sheets produced with *Ultra* POSITEK(Ⓡ) compared to those produced with the bentonite-based program:

As seen, application of *Ultra* POSITEK(Ⓡ) led to a dramatic reduction of permeability of the base paper compared to the bentonite-based program, confirming the trend observed in the pilot paper machine studies. The reduction in sheet permeability was observed for all the grades and grammages produced on machine. In coating applications, permeability of the base paper is controlled to achieve optimal coating penetration. High permeability is not desirable since it may cause the coating to strike through the paper, leaving an inadequate film thickness at the paper surface.

Permeability in the above studies was measured with a Bendtsen Permeability Tester, an air-leakage device that measures only the pores that channel all the way through the sheet from one surface to the other. To get information on the pore size distribution of paper, the same base sheets were analyzed by using mercury porosimetry.[16] By using this technique; mercury is forced into paper at increasing pressures. Since mercury is a non-wetting liquid, its penetration follows laws of capillary pressure (Laplace equation):

$$P = - \gamma \cos\theta / d_e \qquad [1]$$

where,

γ = surface tension (480 mN/m for mercury)
θ = contact angle (140° for mercury)
d_e = equivalent pore diameter
P = applied pressure

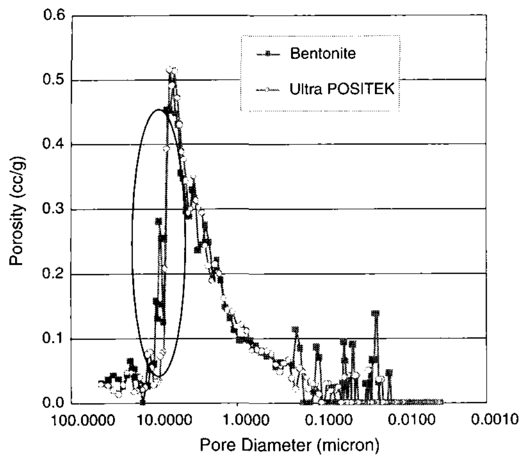

Fig. 6. Pore size distribution curves for base papers.

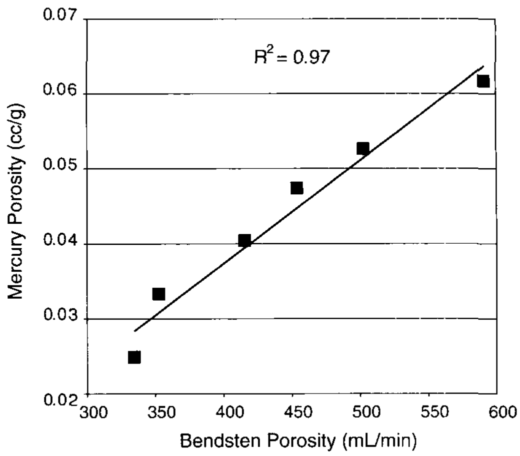

Fig. 7. Correlation between Bendtsen permeability and mercury volume intruded into pores between 7 and 40 microns.

Monitoring mercury volume intruded into paper as a function of the applied pressure permits the generation of cumulative pore volume curves from equation 1. Differential distributions similar to the one presented in Figure 6 were obtained by differentiation of the cumulative plots.

Figure 6 below shows the pore size distribution curves by volume obtained for base paper. As seen, *Ultra* POSITEK(Ⓡ) shifted the pore diameter toward smaller sizes compared to the bentonite-based program. The pore size distribution of paper was measured for several paper grammages produced on the machine.

A very good correlation (Figure 7 below, $r^2 = 0.97$) was found between Bendtsen permeability values and mercury volume intruded into pores between 7 and 40 microns (macropores). Thus, pores within this size range are the ones contributing to permeability. The permeability/pore size distribution studies suggest that *Ultra* POSITEK(Ⓡ) produces a base paper with a smaller number of macropores than the bentonite-based programs.

In order to determine whether the more uniform base sheet structure obtained with *Ultra* POSITEK(Ⓡ) leads to a more uniform coating weight distribution, coated sheets produced from the same machine base paper were subjected to a burnout test. The burnout sheets produced with *Ultra* POSITEK(Ⓡ) showed clearly an improved coating weight distribution com-

Borosilicate Bentonite

Fig. 8. Pictures of coated papers obtained with a stereo microscope at 20x magnification, using diffused reflected light.

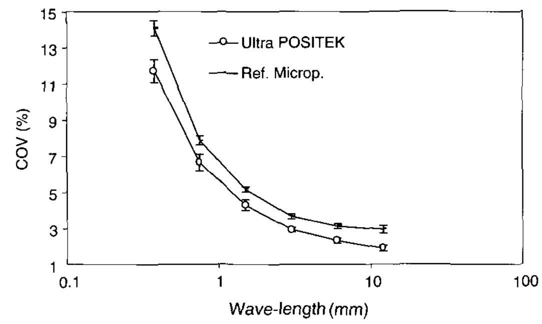

Fig. 9. COV(%) of coat weight for two systems.

pared to the sheets produced with the bentonite-based microparticle system. Figure 8 shows pictures of coated papers obtained with a stereo microscope at 20x magnification, using diffused reflected light. The more uniform base paper produced with *Ultra* POSITEK(®) led to a visible improvement in the uniformity of the coating.

In addition, the sheets were scanned using reflected light and the length-scale of variation of the coating distribution was determined. It was found that *Ultra* POSITEK(®) produced sheets with lower coefficient of variation of coating weight distribution (more uniform coating) over the 0.25-16 mm wave-length range than the bentonite-based microparticle system (Figure 9). This improvement was observed for both the wire and felt sheets sides. The improvement in coating uniformity observed with *Ultra* POSITEK(®) over the range 4-8 mm was of the order of 12% for the high grammage sheets produced on machine. Several studies have been published showing a correlation between coating uniformity and print unevenness.[17] The reduction in print mottling reported by the mill with the application of *Ultra* POSITEK(®) can be attributed also in this case to a more even coating distribution.

In conclusion, improvement of formation of the base paper and a lower sheet permeability/porosity were observed using the *Ultra* POSITEK(®) program to make wood-free offset paper. The higher uniformity of the *Ultra* POSITEK(®) produced base paper resulted in a more even coating layer. At the same time, the mill has reported not only a reduction of print mottling for the coated paper, but also an improvement in its whiteness. Application of the *Ultra* POSITEK(®) program has also increased the stability of the wet-end, and improved overall machine runnability.

Overall Conclusions

The results reviewed in this paper from both pilot and commercial paper machines clearly demonstrate that the new borosilicate-based microparticle technology has superior perfomance over existing colloidal silica and bentonite systems when comparing the following criteria:

- First pass retention
- Table drainage
- Press dewatering
- Formation
- Porosity - Printability

The ability of the paper maker to balance the need for high retention while at the same time preserving a tightly formed, low porosity sheet would make the new borosilicate microparticle a very valuable tool for today' s papermaker to meet high paper machine efficiencies and paper quality and to remain competitive in today' s global economy.

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