The BASF Laser Optical Pitch Particle Counter - Current Applications and Future Developments

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ABSTRACT

The occurrence of detrimental substances in the paper machine leads to reduced economic performance of paper mills through reduced capacities due to increased paper breaks and cleaning times. In this article the latest generation of BASF's laser optical pitch particle counter is employed in the examination of a paper mill operating two paper machines and using a mixture of thermo-mechanical pulp and recycled fibres. The potential of the new instrument to differentiate between particles on the basis of size and chemical composition is discussed. In addition, direct evidence of the periodic and locational variation of detrimental substances in the paper machine is given. Finally, an example of the application of BASF's laser optical pitch particle counter in the selection of a suitable fixative system for a complex furnish is presented.

INTRODUCTION

The occurrence of detrimental substances in the paper machine leads to reduced economic performance of paper mills through reduced capacities due to increased paper breaks and cleaning times. Detrimental substances are derived from coated broke in the case of "white pitch", recycled fibres in the case of "stickies" and naturally occurring wood resins in the case of "wood pitch". The presence of these materials in an inappropriate form in the paper or board can also reduce economic performance through increased product reclamations due to deposits in the printing and converting processes. In many cases the issues related to detrimental substances can be negated by the application of a suitable fixative.

Previous articles have discussed the application of the BASF developed laser optical pitch particle counter in the detection and quantification of white and wood pitch [Yu 2003, Yu 2003, Horn 1996, Kroehl 1994, Winter 1992, Lorencak 1992]. In essence the device is based on the selective absorption of a water insoluble fluorescent dye onto the surface of hydrophobic particles. These particles can be wood or white pitch or composites of either pitch with filler or fines. The selective adsorption of the dye onto hydrophobic particles is based on the extremely high partition coefficient of the dye between water and the hydrophobic material. Unpublished data shows that, *ceteris paribus,* the fluorescence intensity of a hydrophobic particle is proportional to its volume and not its surface area [Kaub et al], indicating that selective staining of hydrophobic particles is related to both dye adsorption and absorption phenomena. In addition the dye selected for the staining of the particles displays a significant difference in the Stokes shift between aqueous and hydrophobic mediums.

Once selectively stained the hydrophobic pitch particles are analysed in the laser optical pitch particle counter. This instrument utilises hydrodynamic focusing of a sample stream in a Crosland-Taylor type cell [Watson 1991]. Focusing is based on a velocity differential between the sample and sheath streams, with the sample stream velocity being significantly less than the sheath flow velocity. This differential results in the elongation of the sample stream and when correctly adjusted the division of the sample stream into a flow of single particles. The basic cell geometry and the separation of the sample stream into a single particle flow are presented in Fig. 1.

Having produced a stream of well separated single particles through hydrodynamic focusing the particles are detected by a fluorescence excitation and detection system (Fig. 2). The instrument measures both the existence and intensity of the emitted fluorescent light. The existence of the fluorescent light indicates the presence of a hydrophobic particle while its intensity is primarily a function of the size of the particle. Hence fluorescence detection generates a number based particle size distribution. This fluorescence measurement technology was the basis for the first generation of the pitch particle counters developed by BASF.

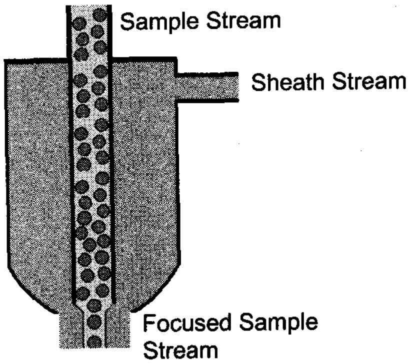


Fig. 1. A schematic of a Crosland-Taylor type cytometric cell illustrating hydrodynamic focusing. The velocity differential between the sample and sheath flow results in the elongation of the sample flow and the production of a flow of single particles.

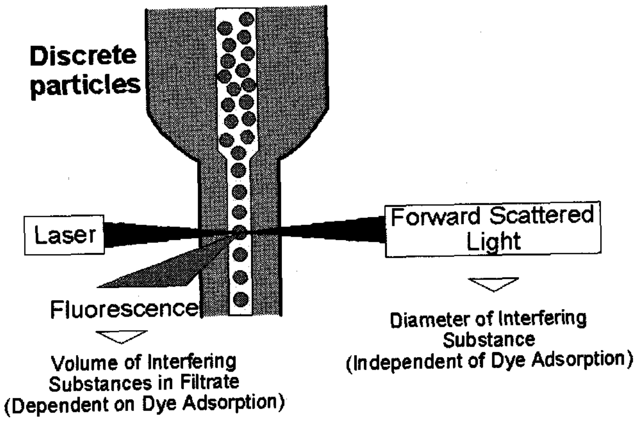


Fig. 2. A schematic of BASF's *2-dimenional laser optical pitch particle counter*. In the instrument each single particle is characterised by the intensity of emitted fluroesence and scattered light.

Although the fluorescence based technology has proved itself to be of great benefit in the development and evaluation of customer specific solutions, it is limited with regard to its ability to differentiate between detrimental substances in the paper machine. Such differentiation would give new insights into the interaction of materials in the wet end of the paper machine and would further assist in the development of new technologies for pitch control. To this end BASF has continued to innovate in the area of pitch particle analysis.

In the latest generation of instruments developed by BASF the existing fluorescence detection system is combined with forward light scattering (Fig. 2); the intensity of light scattered by a particle is a function of its size. In the 2-D pitch particle counter the intensity of scattered light from the laser beam, employed in the excitation of the fluorescent dye, is primarily proportional to particle size. The combination of fluorescence and scattering techniques in a single instrument allows for the identification and differentiation of the various hydrophobic species present in the wet end of the paper machine such as white and wood pitch, and sizing agents. Hence, in the latest generation of pitch particle counters, known as "*2-dimensional pitch particle counters*" the fluorescence and scattering data are measured simultaneously for all hydrophobic particles. The collected data is then plotted in the form of a 3-dimensional plot where the x-axis is the fluorescence data, the y-axis is the scattering data and the z-axis is the number of particle of particles. The z-axis is plotted as a colour scale where white indicates zero particles and red indicates >10 particles (Fig. 3).

The combined plot of particle size distribution, according to the fluorescence and scattering measurements, is of great interest since both dye absorption and light scattering are too a limited extent dependent on the exact chemical composition of the hydrophobic particles. Subtle differences in fluorescence and scattering intensity due to variations in the chemical composition are detected in the *2-dimensional laser optical pitch particle counter* by increasing the sensitivity of the instrument. For instance, differences in the fluorescence and scattering intensity profiles of polyacrylate and polystyrene based white pitch particles have been observed (Fig. 3).

Hence, a combined scattering vs. fluorescence plot generates a fingerprint where each data point is dependent not only on the size but also to some extent the chemical composition of the particle it represents. At present, when dealing with an unknown system, such a plot is used only for comparison on a visual basis, i.e. an unique fingerprint is obtained which can be compared with other such plots in order to ascertain if any change has occurred in a system. An example of the instruments ability to separate different materials is given in Fig. 3. Here a mixture of two previously coated and re-pulped papers was filtered, and the filtrate examined with *2-dimensional pitch particle counter*. Each paper was coated with a different binder. The presence of the binders as two distinct species can be observed. The third population, as indicated by the red area at low fluorescence intensity and moderate scattering intensity, is derived from electronic noise from the instrument, and a mixture of aggregates of fines, filler and white pitch.

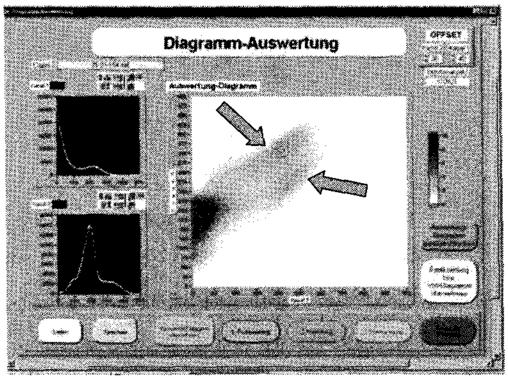


Fig. 3. Actual data plot for *2-dimensional laser optical pitch particle counter* measurement of a mixture of two previously coated and re-pulped papers. Each paper was coated with a different binder. The presence of the two binder species is indicated by arrows.

In this article the *2-dimensional laser optical pitch counter* was employed in the examination of the performance of a fixative system in a paper mill operating two paper machines and using a mixture of thermo-mechanical pulp and recycled fibres. The use of this mixture potentially causes some unique problems, since both white pitch and wood pitch are present in the system. The mill was in fact suffering significant production problems due to deposit formation in the drying section. At the time of the survey the mill was operating with a polyamine based fixative and a bentonite based microparticle retention system.

EXPERIMENTAL

The system surveys of the two paper machines, paper machines 1 and 2, occurred over five days, during which time two machine profiles were carried out per machine. During the surveys samples were collected from various points on the paper machine (Table 1). Each sample (500 ml) was transferred to a DDJ. After 60 seconds of stirring at 800 rpm, the first 20 ml of filtrate was collected and diluted with deionized water. Analysis of the filtrate was conducted as soon as possible to minimize the effects of any changes with time. Following the paper machine surveys a series of laboratory trials was carried out in order to ascertain the effect of BASF's latest generation of polymeric fixatives on the thermo-mechanical and recycled fibre based furnishes. For the comparison of fixative products a known amount of product was added to the furnish during stirring, the first 20 ml of filtrate was collected and diluted with deionized water.

Table 1. Samples from paper machines 1 and 2 examined during the trial of BASF's *2-dimensional laser optical pitch particle counter*

Section	*Sampling Point*
Stock Approach	Recycled Fibre Chest Before Addition of Fixative
	Recycled Fibre Chest After Addition of Fixative
	Thermo-mechanical Pulp Chest Before Addition of Fixative
	Thermo-mechanical Pulp Chest After Addition of Fixative
	Broke Chest
	Blend Chest
	Machine Chest
Short Circuit System	Headbox
	White Water
	White Water Tank
	Cloudy Filtrate
	Clear Filtrate
	Recovered Fibre

RESULTS

The initial results presented here are particle number and volume data as measured by the *2-dimensional laser optical pitch counter* from the fluorescence based data. Figs. 4 and 5 give total particle number and total particle volume data for two machine surveys. Total particle number indicates how many particles are present while total particle volume indicates the total quantity of material present. As can be seen in Fig. 5 paper machine 1 contains significantly more material than paper machine 2. In addition paper machine 1 contains a higher concentration of larger material as indicated by the fact that while the difference in the particle numbers are relatively small the difference in volume is very much larger. Additional evidence of this difference can be seen in the 2-dimensional plots; all samples from paper machine 1 have a characteristic tail of large material (Fig. 6). It should also be noted that there appears to be no significant decrease in particle number or volume between samples taken before and after fixative addition (Figs. 4 and 5). Any differences between the machine chest and the headbox samples can be related to differences in sample consistency, which were 3% and 0.8% respectively, rather than any effect of the retention aid.

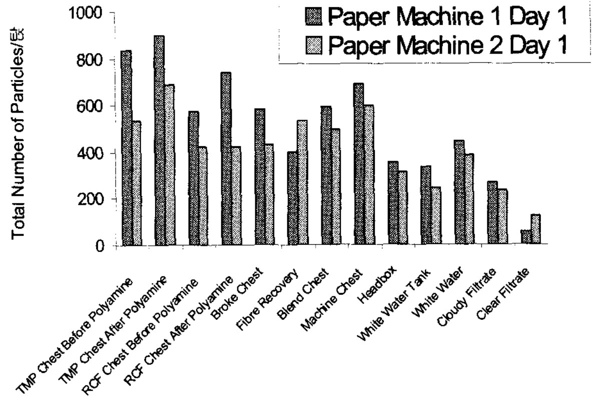


Fig. 4. Total particle number data for paper machines 1 and 2 on day 1 of the analysis.

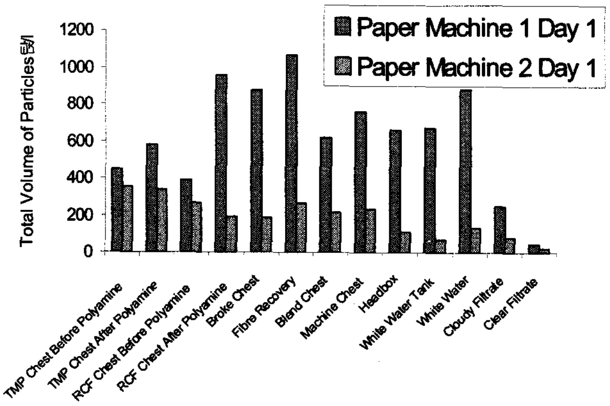
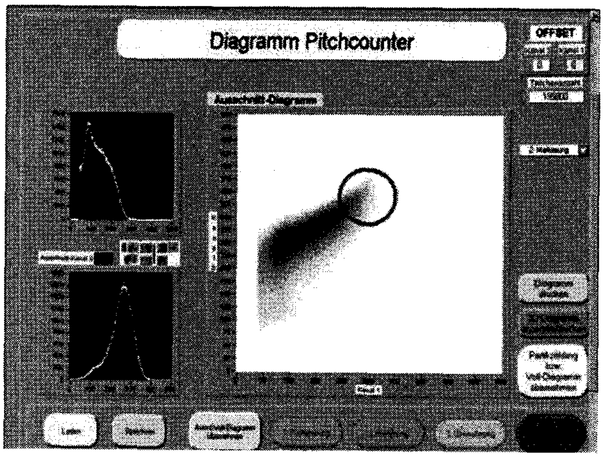
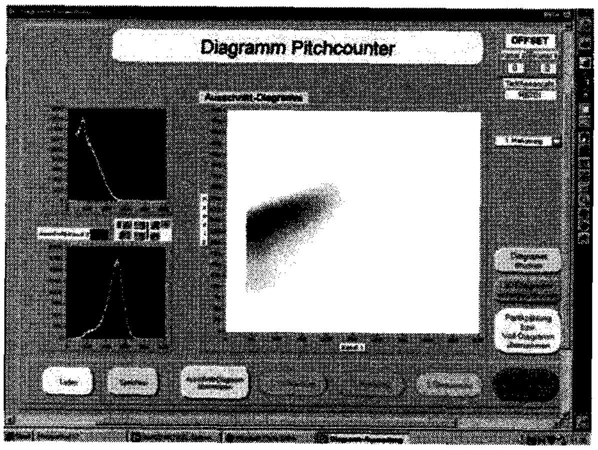


Fig. 5. Total particle volume data for paper machines 1 and 2 on day 1 of the analysis.



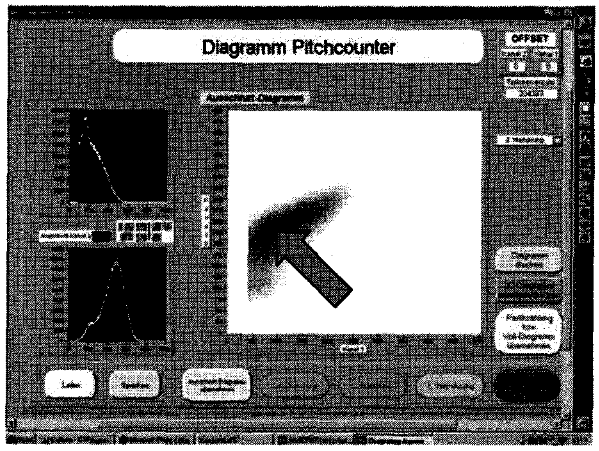
Paper Machine 1



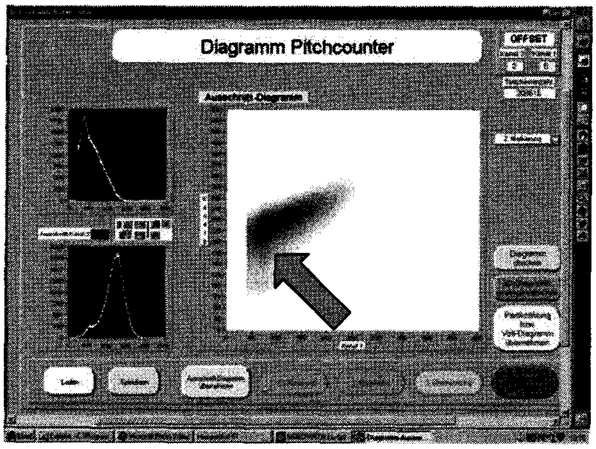
Paper Machine 2

Fig. 6. 2-Dimensional pitch particle counter plots for the machine chest samples of paper machine 1 and paper machine 2. The encircled area indicates the presence of larger materials.

It is observed that on addition of the fixative to the thermo-mechanical pulp or recycled fibres of paper machine 1 there appeared to be an increase in the number and volume of material measured. This is due to the aggregation of white and wood pitch, which before aggregation was below the measurement range of the instrument. Evidence of this aggregation is also presented in Figs. 7. Here it can be seen that there is little change in the general population of material and in fact it is only a small range of materials that increases dramatically in number and volume. Later it will be shown that the polyamine fixative induced aggregation in both white and wood pitch during the BASF laboratory based trials.



Before Polyamine



After Polyamine

Fig. 7. Thermo-mechanical pulp samples from paper machine 1 illustrating the aggregation of wood pitch due to the addition of the polyamine based fixative employed in the mill. The arrows indicate the perceived change in wood pitch aggregation.

The periodic variation in hydrophobic material content on consecutive days of analysis was determined to be significant (Figs. 8 to 11). It can be seen that there is some variation in material volumes between paper machines and again the effect of the fixative appears minimal. However, in Fig. 11 it appears that the large amount of non-fixed hydrophobic materials present in the stock preparation section of paper machine 2 on day 1 of the analysis to the thin stock section of the machine by day 2. This material will presumably remain within the short circuit of paper machine 2 until either the system is drained or all the white water has passed through the stock preparation system in the thick stock section multiple times and the volume of detrimental substances reduced significantly. It is easy to imagine the problems such a situation could cause if untreated.

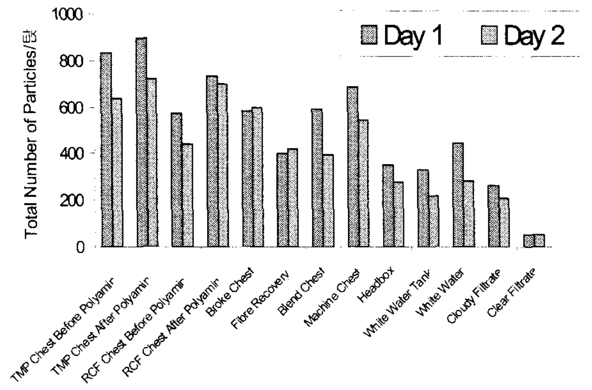


Fig. 8. Variation of hydrophobic particle numbers in paper machine 1 on consecutive days of analysis.

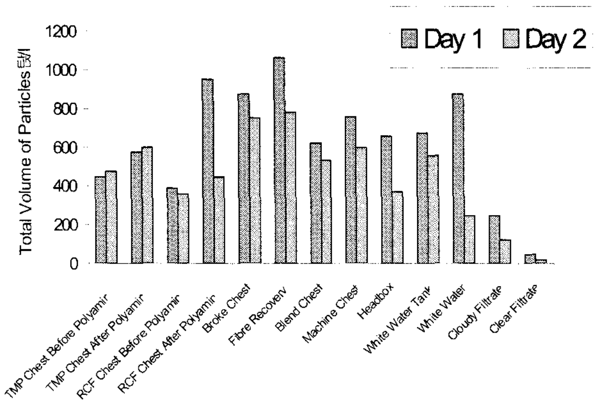


Fig. 9. Variation of hydrophobic particle volume in paper machine 1 on consecutive days of analysis.

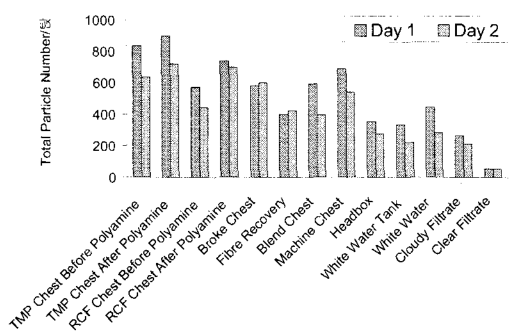


Fig. 10. Variation of hydrophobic particle number in paper machine 2 on consecutive days of analysis.

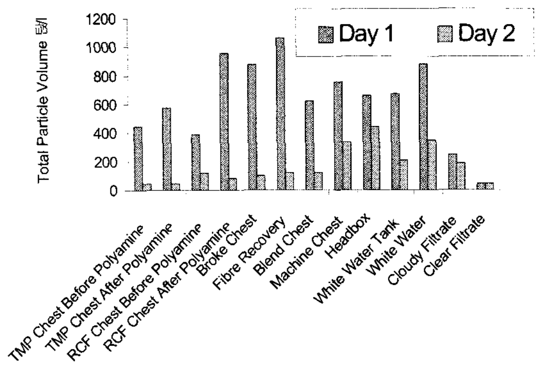


Fig. 11. Variation of hydrophobic particle volume in paper machine 2 on consecutive days of analysis.

From Fig. 6 it can be seen that paper machine 1 and paper machine 2 have similar hydrophobic materials with respect to chemical content. However, paper machine 1 contains a higher concentration of these materials and also has a fraction of particles that are larger in size than those in paper machine 2. This difference can be related to differences in the cleaner technology built into the recycled fibre preparation lines of the two machines. The results also indicate the extent to which the quantity of detrimental substances can vary on a daily basis. There is also an indication that due to inefficient fixation of these materials by the polyamine the issue of pitch contamination is transferred between sections of the paper machine.

The results of the analysis clearly indicate the inappropriate nature of the polyamine as a fixative in this mill. In order to advise the customer and provide an optimum fixative system a series of screening experiments were carried out. After exhaustive testing an optimal fixative system was developed based on Catiofast VFH®. Catiofast VFH® is a poly(vinyl amine) with molecular weight and charge density tailored specifically for pitch fixation. This product was shown to give optimum reduction in detrimental substances arising from thermo-mechanical pulp and recycled fibres. A comparison of the fixative efficiency of Catiofast VFH® and a polyamine is given in Figs. 12 and 13. It can be seen from Figs. 11 and 12 that Catiofast VFH® produces a reduction in the concentration of detrimental material without any associated particle aggregation. This effect has been previously observed and is related to the tailored structure and chemistry of the polymer.

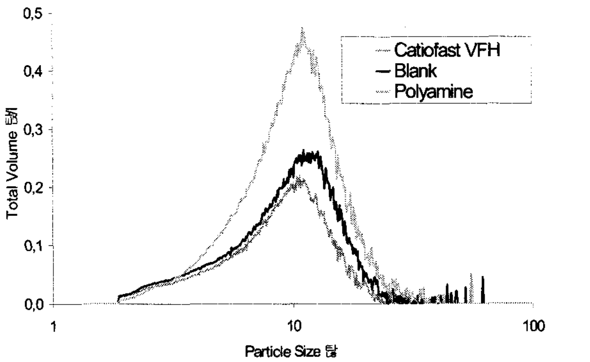


Fig. 12. A plot illustrating the change in the volume of detrimental substances in the thermo-mechanical pulp on addition of Catiofast VFH® and a polyamine.

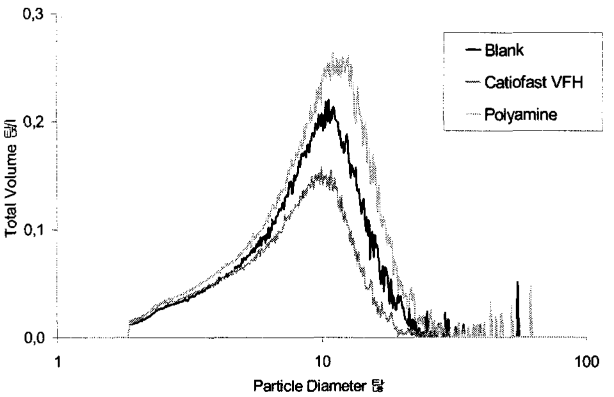


Fig. 13. A plot illustrating the change in the volume of detrimental substances in the recycled fibre furnish on addition of Catiofast VFH® and a polyamine.

CONCLUSIONS

Although the presence of detrimental substances, such as white and wood pitch, in the paper machine can have serious economic consequences for the papermaker little is known about the form of such substances in the paper machine or how such materials interact with other components of the furnish. Such knowledge is of great importance when selecting effective chemical treatments. The present article illustrates BASF's competence in this area as well as its latest innovation in pitch analysis. Using both these facets BASF's technical specialists are providing papermakers with optimal solutions to the issues of furnish contamination by detrimental substances.

Finally, although the *2-dimensional laser optical pitch particle counter* is in its early stages of development it is the authors' goal to provide the papermaker with a technology capable of mapping both physically and chemically the entire papermaking furnish. Such a technology will provide invaluable insights into the wet end of the paper machine, and provide the papermaker with opportunities for greater economic profitability.

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