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Challenges remain but benefits include increased filler use, cost optimization and sustainability effects

INCREASE HYP IN FINE PAPER FURNISH

Replacement of HWK pulp with high-yield pulps (HYP) in UCFS and CFS offers some furnish cost optimization, but is also driven by certain quality improvements and sustainability benefits. Recent renewed interest in this trend could be expected as HYP addition assists another very important trend in the industry – increasing sheet filler content. The increased bulk, stiffness and opacity offered by HYP have allowed papermakers to reach even higher filler levels.

There are technical and regulatory barriers that affect the introduction of HYP into fine paper furnish. Standards for paper permanence vary by country, but most agree to; the paper being produced under alkaline pH, inclusion of carbonate as filler (minimum 2% is often quoted), and defining maximum level of lignin content (typically <1%). The lignin content limitation was included in early standards and was based on the belief that lignin contributes to the increased rate of degradation of paper produced with mechanical fiber. Extensive research in Canada determined that the effect of lignin on permanence of paper produced at alkaline pH, filled with calcium carbonate and without alum is negligible. This led to the new Canadian permanence standard (CAN/CGSB-9.70-2000), the first to be based on physical performance criteria rather than on furnish composition. The limit on lignin content (below 1%) remains in place only for papers with a brightness stability requirement.

Furnish cost reduction is different for integrated mills versus mills using purchased HYP and depends strongly on normal pulp price fluctuations. With $100/ton price differential, a mill producing 200,000 tons/yr at 10% substitution rate could save $20,000,000/yr. With all other conditions constant, 20% HYP substitution increases bulk up to 10%, stiffness up to 5%, and opacity up to 2%. Although these numbers may differ between applications, they provide a general picture of the benefits that HYP may offer. Increased wood utilization, lower effluent flows and concentrations, lower air emissions and less solid waste sent to landfill are some of the sustainability benefits when comparing the production processes of HYP and HWK.

It may be expected that with further understanding of the permanence mechanisms and the benefits offered by HYP application, changes in regulations will gradually follow and lead to further extension of grades and regions where these pulps are utilized. In some countries, HYP levels in woodfree paper are commonly 10-15%, with some mills exceeding 30%.

As regulatory barriers on permanence diminish and HYP levels increase, both operational and quality issues will become more important. The purpose of this paper is to define the current solutions and future needs for papermakers seeking higher utilization of HYP

DISCUSSION

Different HYP production processes (BCTMP, APMP, PRC-APMP) involve mild chemical treatment, mechanical refining and bleaching resulting in pulps of similar quality regardless of process at a yield of 80-90%. According to Ni[1], up to 50% of HYP could be used in most printing and writing grades, coated and uncoated.

As mentioned previously, HYP offer many benefits in terms of economics, environmental footprint and paper properties. At the same time, the use of HYP can impact paper machine operation and final product quality therefore presenting serious challenges to papermakers. . The benefits and challenges presented by the use of HYP are listed in Table 1.

Table 1 - The most important benefits and barriers in HWK replacement with HYP

Benefits	Negative Impact
Cost	More anionic surface
Bulk	More soluble anionic "trash"
Bending stiffness	Reduced brightness
Opacity	Reduced brightness stability
Printability	OBA efficiency
Sustainability benefit	Increased system conductivity
	Increased extractives content
	Reduced strength (tensile, surface)
	Surface roughening on re-wetting

CATIONIC DEMAND

Exposure of HYP to high pH in the bleaching and/or refining stages affects the surface chemistry of the fiber and the level of soluble and colloidal impurities impacting paper machine performance and final product quality. Higher the brightness and strength specifications for HYP pulps require higher caustic dosages in pre-treatment or bleaching stages, and cause higher levels of contamination[2]. The limited washing capability of HYP manufacturing installations and a trend to reduced water consumption further magnifies levels of contaminations and related challenges.

De-acetylation of hemicelluloses and de-methylation of pectins generates low-molecular weight organic acids, contributing to COD and higher-molecular weight pectic acids, such as polygalacturonic acids (PGA) that contribute to increased cationic demand and affect performance of retention, drainage, pitch control and sizing applications. PGA may represent up to 50% of the cationic demand found in peroxide bleached mechanical pulps[3]. Ni[1] reported un-pressed aspen HYP having a total cationic demand of 108.4µeq/g as compared with 16.6µeq/g and 19.4µeq/g for bleached SWK and HWK pulps, respectively. The dissolved colloidal fraction of cationic demand was reported as 34.5, 2.7 and 3.9µEq/g for HYP, BSWK and BHWK, respectively. It was observed in our field studies that increasing the pH of furnish from 5 to 7 results in approximately a 30% increase in cationic demand. Our experience indicates that at 30% HYP replacement, FPAR can drop by as much as 20% if no modifications to chemical programs are made. This is in agreement with data published by Ni[2]. Pruszynski[4] discusses the pros and cons of various strategies used to control anionic trash. Ni et al.[2], reported that once soluble anionic trash is neutralized with coagulants, HYP fibers, due to their higher surface charge, can contribute positively to filler retention.

AVAILABLE STRATEGIES

- Closely monitor HYP cationic demand levels for variability.
- Pruszynski and Orlowski[5] presented the development of cationic demand specifications for market BCTMP pulp.
- Coagulant application:
  - Set reasonable goals for reducing cationic demand. Excessive charge reduction targets may not be cost effective and could lead to runnability problems.
  - Different ratios of organic and inorganic coagulants used in a given system often provide best results.
  - In selecting and applying coagulants for charge control in fine paper applications, avoid eroding surface charge and agglomeration of colloidal material, and minimize effect on optical brightening agents (OBA). Nalco HYBRID™ technology of lower charge fixatives meets all these requirements.
  - Since most fine paper systems operate at high pH, quaternized coagulants are recommended to eliminate pH charge sensitivity.
  - Target HYP stream prior to mixing with other components of furnish.
  - Use coagulants strategically prior to such applications as starch, synthetic strength products and sizing to shield from undesired interaction with anionic trash.
- Optimize bleaching processes (replacing NaOH with $Mg(OH)_2$, optimizing the alkalinity ratio in peroxide bleaching, optimizing the usage of chelants and sodium silicate) and maximize washing through available thickening stages.
- Enzymatic treatment of PGA with pectinase displays high effectiveness without any negative impact on paper machine operations or paper quality[4,6-8] (Fig.1). Although many mills would be prevented from using this technology, mainly due to process pH (pH 5-5.5 optimum), the exceptional effective-

ness of pectinase justifies reviewing this opportunity.

- Modification of the retention program with the goal of reducing sensitivity to cationic demand level and its variability, may include new chemistry selection, modification of addition points and filler pre-treatment strategy.

Filler pre-treatment was found to be a very effective solution in a case based on a machine producing SC grades with an operating system running at very high cationic demand conditions[3]. Figure 2 demonstrates how the removal of 1kg/ton of coagulant added directly to the filler line resulted in approximately a

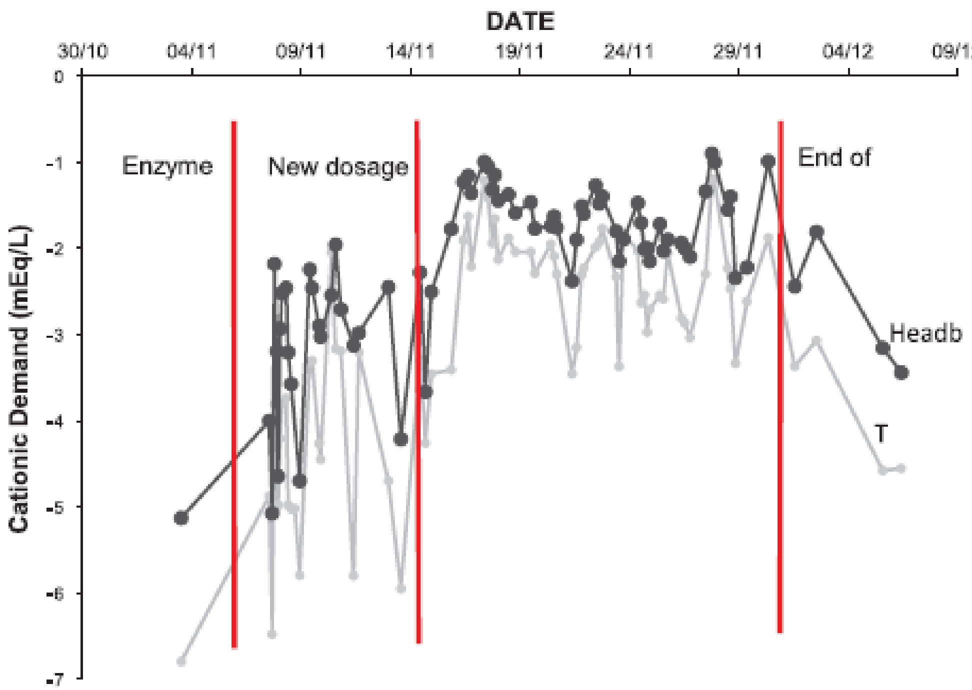

Fig. 1 - **Impact of pectinase treatment (80 g/ton) on the cationic demand in the TMP and headbox of an improved newsprint machine. Initial cationic demand of about 5mEq/L was reduced to 1.5 mEQ/L (70% reduction)**

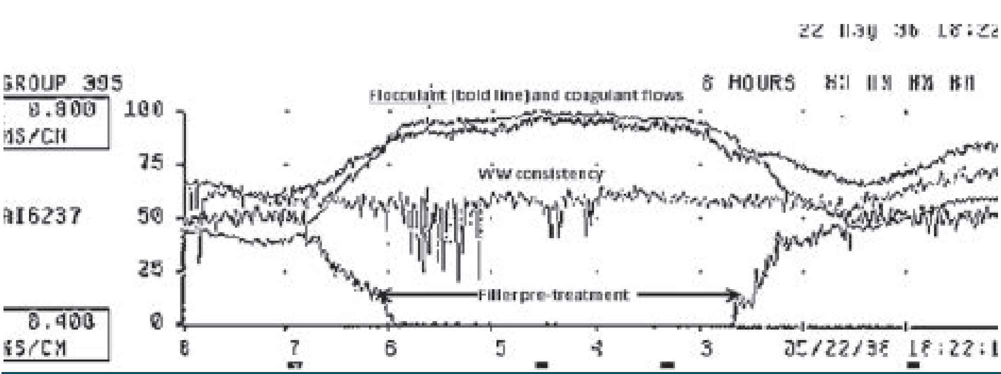

Fig. 2 - **Removing coagulant addition to filler line increased flocculant dosage required to meet target WW consistency**

30% increase of the flocculant flow required to reach sheet ash target at a constant whitewater consistency.

CONDUCTIVITY

Conductivity affects the degree to which individual charges interact and has impact on colloidal stability and the performance of polymers for retention and drainage. Increased conductivity reduces repulsive forces between charges on the flocculant molecule as it assumes coiled conformation that reduces its ability for bridging.

Pruszynski[10] studied the effect of increased conductivity on performance of a number of typical retention programs at pH=5 and pH=7, Fig. 3.

AVAILABLE STRATEGIES

- Monitor the conductivity level of the HYP stream, determine its variability and understand its sources.
- Install an online conductivity probe in the HYP stream and HB and look for correlations with paper machine data.
- Consider pre-mixing coagulant with a cationic flocculant solution. This has typically improved the performance of the flocculant especially at increased conductivity levels, Fig.4.
- If needed, in case of extreme conductivity buildup, consider more extensive changes to the retention program including multi-component programs (dual flocculant programs) or incorporation of bentonite typically added upstream in the thick-stock area.
- High and varying conductivity negatively affects colloidal stability and requires early and gentle fixation of colloidal particles (pitch) to avoid agglomeration.
- Consider a higher degree of substitution (DS) starches to better survive higher conductivity levels and improve strength and sizing applications[11].

EXTRACTIVES

Hardwood HYP introduces increased levels of relatively unstable natural pitch to the system and may potentially increase machine deposit potential.

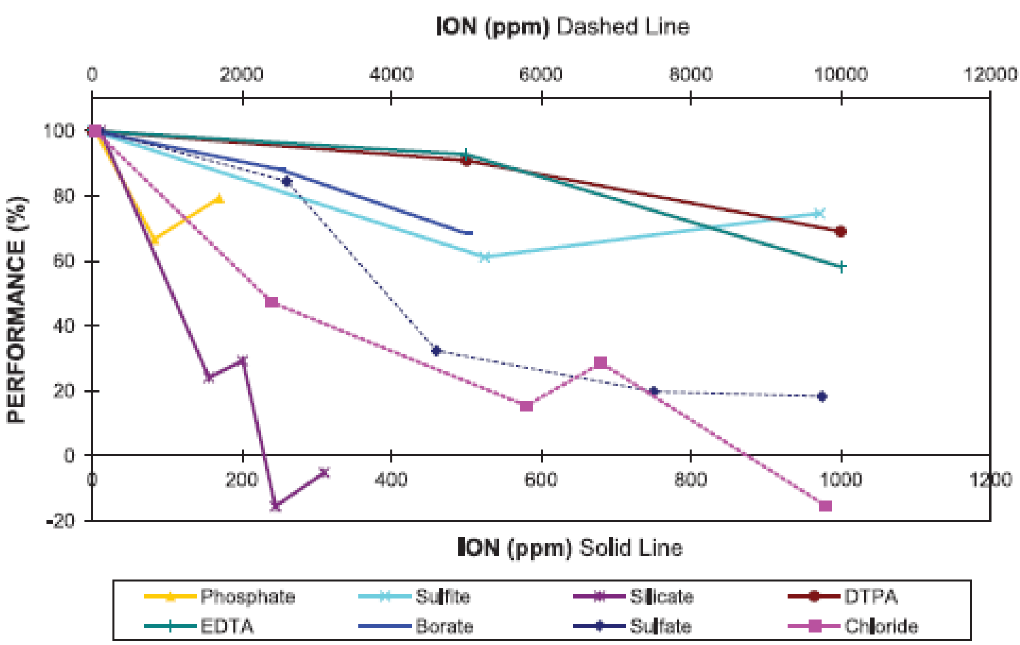

Fig. 3 - **Impact of various ionic impurities on the drainage loss (100% represents drainage gain from the chemical program in clean system) for dual polymer program at pH=7**

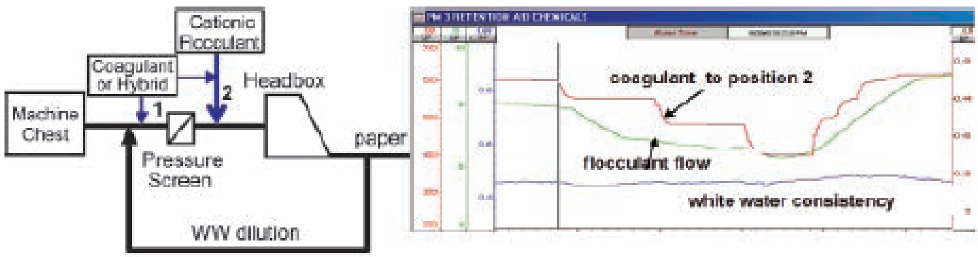

Fig. 4 - **With total coagulant dosage constant, moving the feed point of coagulant from pre-screen (1) to the flocculant dilution water line (2) significantly reducesflocculant flow required to meet the whitewater consistency target**

AVAILABLE STRATEGIES

- Measure the level of extractives in your source of HYP with a consistent total extractives measurement.
- Evaluate the physical form of extractives in HYP slurry microscopically to determine amount and particle size. A pitch particle that increases to twice its diameter is 8-times heavier and much less stable.
- Application of Nalco HYBRID coagulants was found to promote desired attachment to the fiber with limited colloidal agglomeration[12] and have low impact on fiber zeta potential and OBA performance.
- Operate thickening stages in the pulp mill at as high a pH level as possible to maximize extractives removal without brightness loss.
- Fix colloidal particles to fibers and fines as early as possible to prevent agglomeration.
- Apply fixative treatment to the thick stock but closer to the headbox (machine chest pump inlet) for final polishing treatment.
- Measure the hardness level and control pH in systems that use calcium carbonate fillers to avoid calcium ion saponification of pitch.
- Optimize microbiological treatment and broke operating strategies to prevent pH depression anywhere in the system, especially in large broke towers.

BRIGHTNESS AND OBA PERFORMANCE

HYP can be produced at a very high brightness and their addition even at high fiber substitution levels may not affect brightness significantly. However, the lignin content of these pulps results in a yellowing tendency in the paper when exposed to UV or heat and impacts the performance of OBA additives.

UV-VIS light quenching by lignin explains the lower level of fluorescence from OBA additives. Wood-free coated grades of paper, with OBA added as a part of the coating formulation, are less affected as the integrity of the coating layer minimizes the impact of the lignin present in the base sheet[13].

Ni[14] discussed the effect of HYP on brightness stability in uncoated wood-free grades. Increasing PCC filler content not only increased immediate OBA performance levels but also sheet brightness stability. In a very elegant set of experiments, authors[13] demonstrated that combining the stabilizing effects of OBA and PCC allows for the production of papers with HYP and high UV brightness stability.

Interesting results were observed by Ni and Pruszynski[15] when studying the impact of surface size treatment with Nalco's EXTRA WHITE® (EW) brightness technology. Adding EW to the size press formulation increased the brightness ceiling by about 2 units and the CEI whiteness ceiling by about 6 units, Fig.5,6.

STRENGTH

In terms of strength, HYP occupy an intermediate position between typical mechanical pulps and chemical pulps. Gao [16] reviewed HYP fiber development strategies in terms of certain quality expectations. These strategies indicate a number of trade-offs between certain pulp properties such as tensile, strength, and bulk. Increased fiber rigidity, less external fibrillation, lignin content and higher fines content reduce the strength of HYP compared with kraft pulps. Some data indicate that increasing the content of HYP in a copy paper furnish from 0% to 20% decreased MD breaking length from 6.0 km to 5.7 km (5% drop) and CD breaking length from 3.3 km to 2.9 km (13% drop). The tear index remained practically unchanged. Other strength related issues need to be considered, including surface strength as related to offset printability issues, such as linting and dusting. The effect to which HYP impact paper strength depend on many factors and in some cases at low substitution levels (10-15%) it was observed that the synergy between HYP fines and HWK content led to strength improvement.

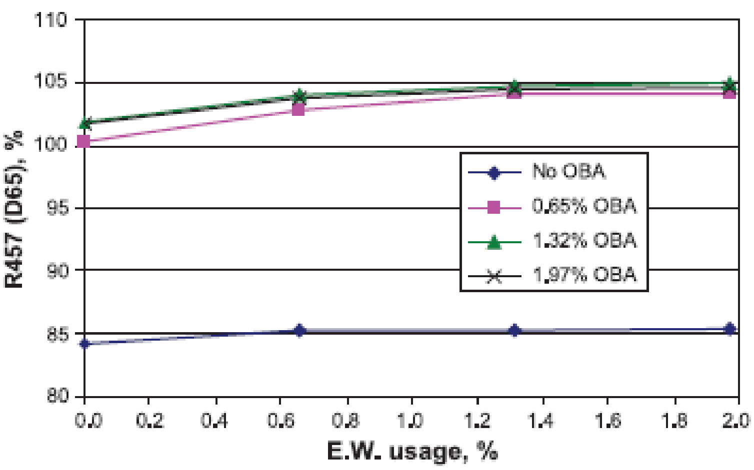

Fig. 5 - **Effect of EW on the brightness ceiling of HYP-containing sheets**

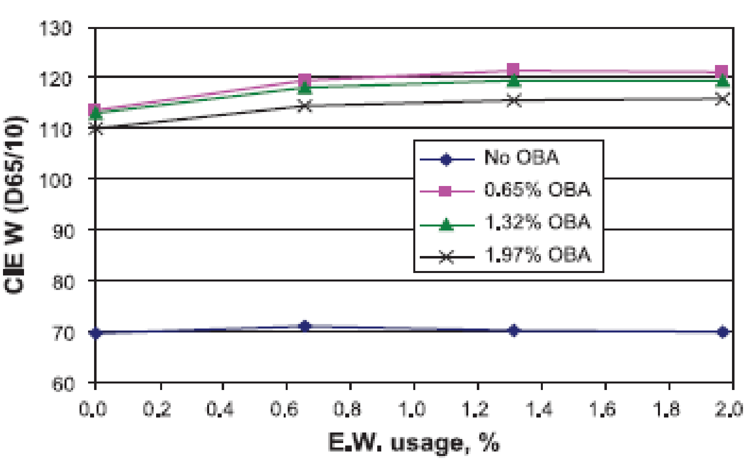

Fig. 6 - **Effect of EW on the CIE whiteness ceiling of HYP-containing sheets**

AVAILABLE STRATEGIES

- Optimize HYP grade selection to best meet goals in terms of cost and impact on quality. If possible, select HYP grade with least impact on strength properties.
- Select starch with higher degree of substitution at higher conductivity.
- Bearing in mind the saturation of the dosage-re sponse curve for starch application, consider the use of synthetic strength materials.
- Pre-treatment of HYP with proper coagulant typically results in improved cost effectiveness of starch and synthetic strength additives.

CONCLUSIONS

The successful introduction of HYP into typical wood-free furnish blends requires papermakers to take advantage of established best practices from mechanical grades in conjunction with new technology development. Remedies for potential issues such as increased levels of contamination and variability of wet-end conditions, extractives control, brightness, and strength optimization were discussed in this paper. The authors wish to emphasize that increased levels of cooperation between papermakers and specialty chemical suppliers will be required as the trend of increasing HYP continues. **PPI**

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