Deinking plant optimization using image analysis

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Results showed that ink removal could be improved and the effect of residual ink on paper quality minimized by maintaining a narrow range of particle sizes in the pulper.

The history of deinking at the Newberg mill of the Smurfit Newsprint Corp. began in 1979 when the "A"-line washing circuit was installed. It was capable of handling 100 air-dry tons/day out of a total newsprint production of 420 tons/day. The No. 6 paper machine started up in 1980, increasing production to 900 tons/day. A second expansion of the deinking plant in 1982 ("B" line) increased its capacity to 275 air-dry tons/day or 30% of the furnish. In 1984, a third expansion ("C" line) brought the capacity to 525 air-dry tons/day. In addition, further refinements to the washing process through upgraded screening and cleaning processes have raised quality and production to 600 air-dry tons/day. The furnish on the No. 5 paper machine typically contains 75-80% deinked pulp while the furnish to the No. 6 paper machine contains 35-40% deinked pulp. The balance of the furnish is thermomechanical pulp (TMP) and semibleached kraft. To maintain machine brightness targets, the deinked pulp brightness is maintained at 57% after bleaching.

The optimization project aimed at making improvements in three areas: brightness, yield, and chemical cost reduction.

Smurfit Newsprint Corp.'s sales personnel saw a need in the marketplace to improve sheet brightness from the historical 54-55% to a new target of 56% or better. At the same time, the mill was committed to maximizing the deinking plant production and quality.

Yield was seen as another area where improvement was needed, not only from the obvious standpoint of process economics but also from a desire to reduce effluent volume through more complete recirculation within the various water circuits.

Thirdly, the use of as little chemical as possible was desirable not only because of overall cost but also as a means of controlling detrimental downstream effects. For instance, excessive foam generated by the deinking surfactant was making it impossible to effectively operate a reclaim flotation process and was hindering formation on the paper machines because of entrained air.

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Objectives

The objective of any deinking operation can be summed up as the removal of sufficient ink to make the required paper quality at minimum cost. Since residual ink, which is not removed by the process, will inevitably go forward to the paper machine, it is critical that the particle size distribution is such that it minimizes the impact on critical paper qualities, namely brightness and smear, the latter being a qualitative test for large ink particles employed at the Newberg mill as a measure of process performance.

Required paper quality for the Newberg mill involves a target paper machine brightness of 56%, which must be maintained while the proportion of deinked stock increases to reduce the dependence on availability of wood logs and chips. To do this, it has been necessary to improve the brightness achieved in the deinking plant.

Minimum cost in terms of chemical consumption has been achieved through the use of deinking reagents with improved performance characteristics. Newberg and Hart Chemical personnel have actively pursued this objective over the last two years, during which the consumption of the deinking reagent has been reduced to 45% of previous levels and has reduced deinking chemical costs by 20% per ton of pulp produced.

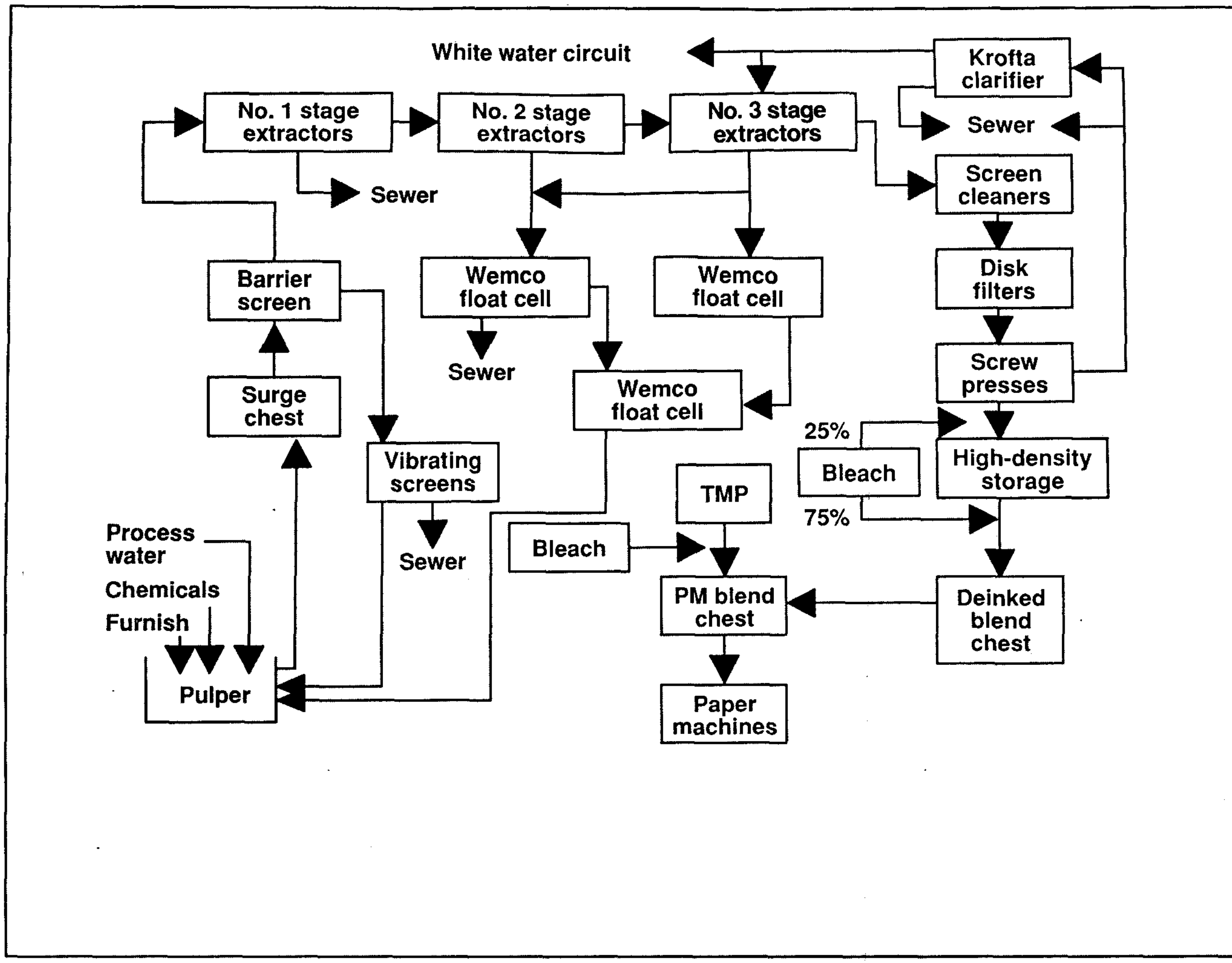
Process description

Ink removal is achieved in a five-stage washing system consisting of three stages of extractors, a Thune press, and the paper machines themselves. The process circuit for the "C" Line is shown in **Fig. 1**.

Waste newsprint is pulped at 4-5% consistency at 120-150°F with separate chemical additions to maintain pH in the range 8.0 to 8.2, disperse the ink, and chelate heavy-metal ions present. Two pulpers operate on a continuous basis and supply pulp into a common surge tank. Barrier and vibrating screens are used to remove trash from the process before the pulp is fed to three stages of extractors. The effluent from the first extractor is sewered, the second- and third-stage effluents are treated by flotation to remove the bulk of the ink before the water is returned to the pulping operation.

The washed pulp then passes through screens and

1. Newberg deinking circuit



reverse cleaners before disc filtration. Consistency is further increased through the Thune press before going to high-density storage where bleach is added. Part of the Thune press effluent is treated in a Krofta clarifier before being returned to the white water or dilution water systems.

The pulp is drawn from the high-density storage in the deinking plant to the deinked blend chest situated in the stock preparation area of the paper machine building. From here it is pumped to either machine blend chest to be blended with TMP, kraft, and broke.

The installation of the Thune press is a comparatively recent event. The thickening to 20-25% consistency has improved water separation between the deinking plant and the paper machines. The results show an improvement of 0.8% of brightness.

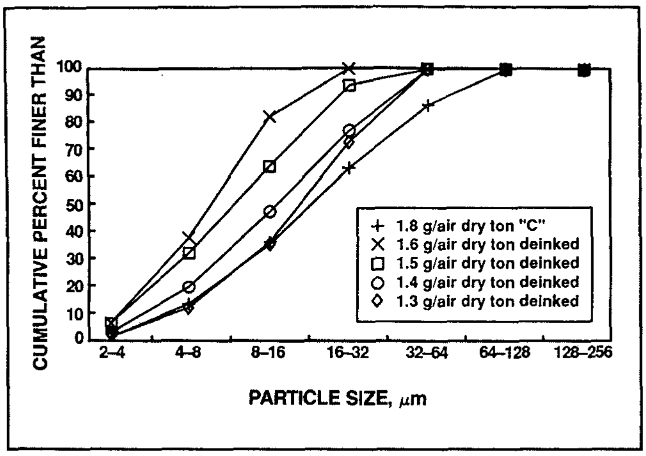
White-water circuit modifications to date have been aimed at producing two separate loops, the first being for the deinking plant up to and including the Thune press and the second for thick stock dilution and the paper machines. In an earlier circuit configuration, No. 5 paper machine white water was used as process makeup in the deinking plant and refiner white water was used on the machines. This led to a problem with small-particle ink concentration building up as a recirculating load. Current practice uses refiner white water for high-density dilution, and available excess is used to make-up in the pulping stage; the bulk of the water load, however, is recovered from the recycle through the inky water chest.

Wash water modifications have been aimed at producing counter-current flow from the Thune press back through to the first stage of extraction. The inclusion of the Wemco circuit was a step in this direction, but prior to using Hartasperse reagents this benefit was largely negated by the excessive foam produced when using an alcohol ethoxylate as the deinking surfactant.

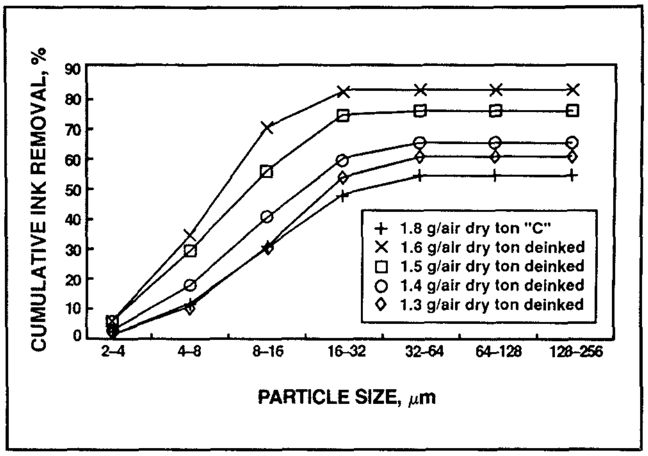
Plant trials

The cooperation between Hart Chemical and Smurfit Newsprint Corp. started late in 1988 when Hart personnel were invited to test alternative deinking reagents. Through the use of image analysis, both during laboratory testing and a series of plant surveys, it was shown that deinked brightness could be improved by more than 1% of brightness by changing to a different deinking reagent. The chemical change reduced the mean ink particle diameter in the pulper from 13 μm to 7 μm, which meant that mechanical efficiency was increased from 50% ink removal to 75% removal. Examination of laboratory and

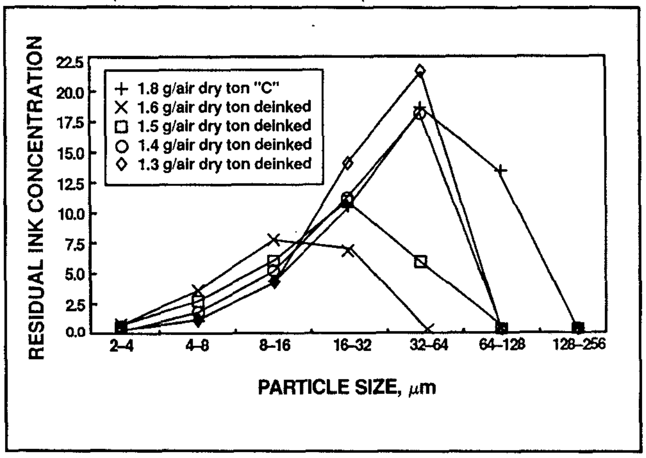
2. Particle size distribution in pulper as function of chemical type and dosage



3. Cumulative percent ink removal as function of particle size



4. Residual percent ink as a function of particle size



I. Percentage of ink eliminated

Deinking reagent	*Dosage*	*Percent ink removal*
Chemical "C"	1.8	54.18
Hartasperse	1.6	82.11
Hartasperse	1.5	75.51
Hartasperse	1.4	64.97
Hartasperse	1.3	60.24

plant data showed that separation of ink particles in any particular size range could be evaluated in terms of a probability distribution. In other words, a constant proportion of ink would report in the effluent and a corresponding amount would appear in the accepts. The concentration in the product streams varied according to the amount of ink in the feed, but the proportional ratio of each size range in the product streams remained constant.

During a subsequent plant trial, the benefit of lower particle size on deinked brightness was confirmed, but no corresponding improvement in paper machine brightness was achieved on a lasting basis. Detailed examination of results showed that the reason for this was a buildup of small ink particles in the white water circuit, which at that stage was being returned to the pulper. Although rejection of particles in the 2-μm to 4-μm size range was 92%, the residual concentration that went forward was not retained in the paper; therefore the concentration in the circulating load built up until a new dynamic equilibrium was achieved at a higher concentration throughout the entire circuit. The ink concentration in the surge tank increased by 20-50% as a result. Under these conditions, no increase in paper brightness was apparent even though the total amount of ink had been substantially reduced.

The differences in particle size distribution in the pulper for the alcohol ethoxylate (at 1.8 gal/air-dry ton) and Hartasperse DI-4777-006 (at 1.3-1.6 gal/air-dry ton) are shown in **Fig. 2.**

Figure 2 shows that Hartasperse gave a smaller average particle size than the alcohol ethoxylate material even at reduced dosage. As dosage is reduced, the particle size increases. Hartasperse at 1.3 g/air-dry ton gives approximately the same distribution as the alcohol ethoxylate at 1.8 g/air-dry ton. Since the efficiency of ink removal as a function of particle size is known, it is easy to calculate the percent ink removal as shown in **Fig. 3.**

The percentage of ink eliminated in overall terms is shown in **Table I.**

The reason for there being no increase in brightness despite the fact that more ink has been removed can be seen in **Fig. 4,** which shows the particle size distribution for the residual ink in the pulp. The residual ink is concentrated in smaller particle size ranges as the efficiency of removal increases. It is well known that smaller particle sizes have much more effect on brightness.[1] Although there is less total ink, the fact that it is

[1]Scott, J. and McCool, M. A., TAPPI 1989 Pulping Conference Proceedings, TAPPI PRESS, Atlanta, p. 373.

concentrated at smaller mean diameter negates the benefit.

The image analysis techniques used during this investigation had a lower detection limit of 2 μm. Hence, at smaller particle sizes there are additional particles that have not been counted. It is reasonable to assume that these increase as the particle size within the measured range is reduced.

Image analysis technique

As previously stated, one of the limitations of image analysis is its inability to measure equipment. For particles within the operational range, several important points relating to sample preparation and data handling should be noted.

First, it is important to be careful during dilution of pulp during the sample preparation procedure. This is critical from the standpoint that the orifice of sampling syringes must be large in comparison to the effect being measured.

Next, some segregation will occur when using small-diameter pads, i.e., wall effects are significant. To overcome these problems, a pad with a diameter of at least 10 cm should be used and a constant mass of fiber deposited in each instance. For routine work, the mass of fiber plus ink is typically 4 mg. Natural drainage is preferred over vacuum filtration to deposit a mono-layer on the sample pad.

During measurement, it is necessary to complete at least one linear traverse and to add further traverses until the total ink particle count exceeds 2000. By this means, the standard error will generally be maintained below 5%. In terms of data representation, it is beneficial to adopt a root 2 logarithmic interval for particle size ranges since this makes the data approximate to a normal distribution and is therefore amenable to mathematical representation.

Discussion of image analysis data is best described in terms of ink area per view as a function of particle size range. By this means, we are in fact comparing a numerical "quality" measurement for all samples, and relative information is easily assessed. To use the image analysis data in a meaningful way, it is necessary to distinguish between preparation problems (mostly chemical) and separation problems (mostly equipment related). This approach to optimization has been comprehensively reviewed elsewhere,[2] but the procedure can be summed up in the following sequence of operations:

1. Establish the operational size range for the circuit being examined and quantify the effect of particles outside this range.
2. Change the process chemistry to maximize liberated ink in the process size range and minimize the effect of particles outside this range.
3. Change the parameters for the separation process to improve the efficiency within the process size range.
4. Modify the separation process to extend the process size range up or down as far as possible.

[2]Leighton, G. and Licht, B., 1990 Technical Section Annual Meeting Proceedings, CPPA, Montreal, p. B373.

II. Smaller particle sizes reporting to the reject stream

Size range, μm	*Percent in rejects*
64-128	2
32-64	6
16-32	64
8-16	83
4-8	89
2-4	92

From a series of plant surveys at the Newberg mill, we found that particles greater than 32 μm were predominantly sent forward with the accepts. The percentage of smaller particle sizes reporting to the reject stream is listed in **Table II.**

These efficiencies were confirmed several times using data collected from the plant during a three-month period late in 1989. Mass balances for ink and fiber across the deinking process during this period were within ± 5% centered on a zero unaccounted loss.

It has also been shown that deinking reagent dosage could be reduced from 1.8 gal/air-dry ton to 1.3 gal/air-dry ton without detrimental effects. Accompanying this reduced dosage, the mean ink particle size increased from 8 μm to 21 μm. This showed that it was not the smaller particle size per se that was giving improved brightness but the tighter distribution of particle size ranges, which in turn gave a higher proportion of particles in the size intervals that could be separated with highest efficiency.

This led to an improved operating concept in that low brightness did not automatically mean that the surfactant dosage should be increased. The additional information provided by image analysis allowed the operator to judge whether low brightness had been caused by too much or too little ink dispersion. It took some time to overcome the psychological barrier that under defined circumstances a reduction in surfactant dosage would raise brightness and hence improve plant performance.

Conclusions

Image analysis has proved to be an important source of additional information which has improved the extent of process knowledge for the operating staff at the Newberg deinking plant. Having seen these benefits, the mill has purchased and installed its own image analysis equipment to give faster data turnaround, testimony to the fact that they are fully convinced of its usefulness.

Deinking reagent dosage has been successfully reduced to 45% of its historical value, and a 20% reduction in overall chemical costs per ton of pulp produced has been achieved.

From a quality standpoint, the plant has moved from 54-55 brightness to the point where a target brightness of 56 is regularly achieved using an ever higher proportion of deinked stock. At the same time, paper formation and water drop have improved as a result of the change to a low-foaming reagent. Much work remains to be done, namely increasing the yield from current levels of 85-87%. There is also a need for further development and mechanical improvement plus configuration changes in the circuit. The current objective in this area is to raise ink removal efficiency from the current level of 70% to 84%, while at the same time limiting residual ink to larger size ranges.

In conclusion, we would like to quote James B. Malloy, president and CEO of Jefferson Smurfit Corp. and Container Corp. of America, when addressing what to expect by the year 2000 and beyond: "Research and development represent a powerful tool designed to revitalize the near term and shape the future. The keyword for keeping pace with the demand for innovation will be cooperation, a heightened dialogue among allies in our industry, and the development of partnerships that build strengths and alleviate weaknesses."

The work described in this article is testimony to the fact that such partnerships really work for the benefit of all concerned.□

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