Process design optimization for deinking plants

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ABSTRACT: A simulation program of a deinking plant was used to find optimum filtrate recycle rates. The program calculated how changing the recycle rates would affect the yield, ink, ash and fines concentration, fresh water makeup, and effluent flow.

KEYWORDS: Deinking mills, design, filtrates, recycling, simulation.

The general objectives in designing a deinking plant are to remove contaminants from the pulp and achieve a desired brightness. Depending on the furnish used and the end-product quality requirements, there may be other issues to address, such as limits on the ash content of the deinked pulp and limits on suspended solids or chemicals in the white water. Other considerations can involve hardness levels or limited availability of raw water, and environmental regulations on wastewater discharge or on solid waste sent to landfills.

These and other questions were addressed in a recently designed facility intended to convert mixed office waste into a deinked market pulp for printing and writing papers. The process design included medium consistency batch pulping, screening and cleaning, flotation deinking, dispersion, post flotation, and washing. After the process equipment had been selected and configured, there remained one important design consideration: the white water system. Residual chemicals, ink, and suspended solids can accumulate in white water and create havoc with deinking operations.

For the following design, the white water system was split into two main water loops, the first for primary flotation and the second for post flotation. **Figure 1** is a simplified schematic of how these water loops fit into the deinking process. As part of the design, there was a white water clarifier for each water loop. This allowed for some flexibility in such parameters as pH and chemicals used in each loop.

Sludge for the plant consisted of foam from clarifiers 1 and 2 and liquid rejects from primary and post flotation, cleaners, and screens. These streams are collected and pumped to sludge thickening. Thickened sludge is removed for disposal. Heavy rejects from detrashing and screening are also dewatered and removed for disposal. Virtually all the effluent from the plant comes from filtrate from these two operations.

Yield for the deinking process was defined as oven-dry kg of pulp produced per oven-dry kg of recovered paper. To optimize yield, the design called for recycling a portion of both the dewatering screw press filtrate in the primary flotation loop and the washer filtrate in the post flotation loop. This article discusses how software balance calculations were used to determine the optimum recycle rates.

Discussion

A material balance for the entire deinking plant was originally performed using spreadsheet software. The dewatering press filtrate flow was in the range of 19 m^3/metric ton to 20 m^3/metric ton. Washer filtrate flow was in the range of 115 m^3/metric ton to 120 m^3/metric ton. Several recycle rates for press filtrate and washer filtrate were used to find the effect on yield. The minimum yield needed was 74%. Minimizing the rate of washer filtrate recycled was also desirable to limit carryover. Spreadsheet calculations were made for press filtrate recycle rates of 0–50%

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and washer filtrate recycle rates of 0–40%. A preliminary design was developed based on spreadsheet results which met both goals.

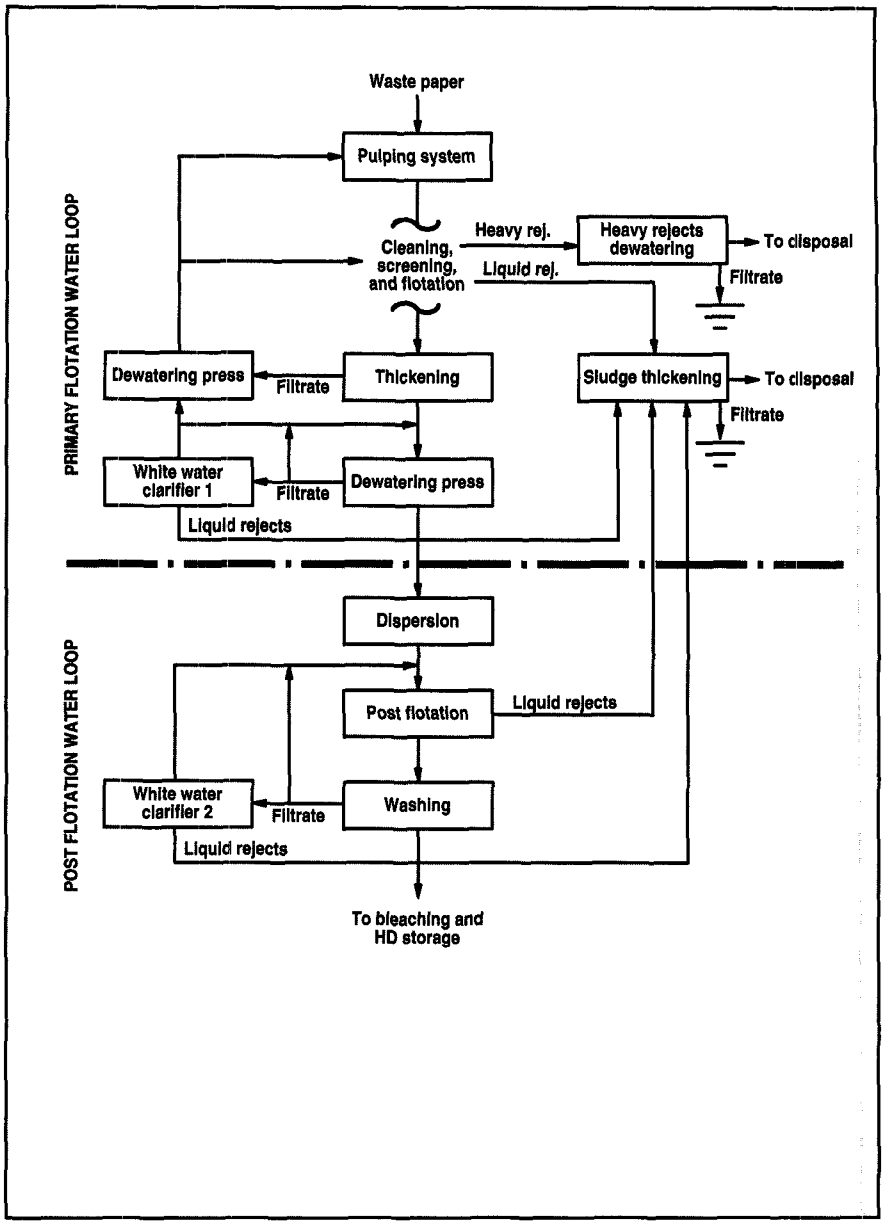
There were some concerns about using spreadsheet results as a design guide. The main concern was that there was no information on potential buildup of ink, ash, and fines in the white water. Buildup of these parameters could have a negative effect on final pulp quality. For this reason, a more thorough balance was made using MASSBAL® software. First, the program was developed to calculate just the fiber, water, and energy balances. The program was fine-tuned using the spreadsheet results as a guide. One benefit of using the program came unexpectedly. Calculations from the energy balance showed that a lot of heat would be lost with the effluent stream. Based on this information, a heat exchanger was added to the design to transfer heat from the effluent stream to the fresh water stream.

After the fiber and water balance was completed, the program was expanded to include balances for ink, ash, and fines. The balance around ink was split into three categories to reflect the operations used for removal. Ink particles under 50 µm would be mostly removed by washing. Ink particles in the 50–150 µm range would be mostly removed by flotation. Ink particles over 150 µm would be removed by screens and cleaners. Guidelines for the expanded balance are shown in **Tables I and II.**

The main product quality guidelines which would affect the calculations are shown in Table I. No method was chosen to correlate brightness, but an upper limit of 100 ppm in product pulp was placed on ink particles of less than 50 µm. There was also no attempt to correlate the effect that fines content in the product pulp would have on freeness.

Table II lists the assumptions made for the calculations. These included assumptions on product pulp, recovered paper, and the process equipment. Some of the assumptions were intentionally conservative estimates of removal efficiencies. Other assumptions were based on removal efficiencies stated by vendors. The post flotation ink removal capacity was purposely set lower than primary flotation for two reasons. The concentration of ink was expected to be lower in post flotation, and the fraction of ink bound to fiber relative to total ink was expected to be somewhat higher.

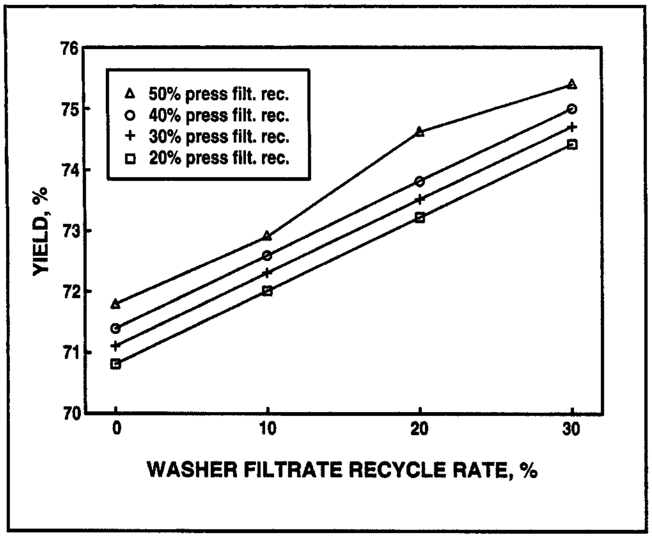
1. Deinking plant: printing and writing grades



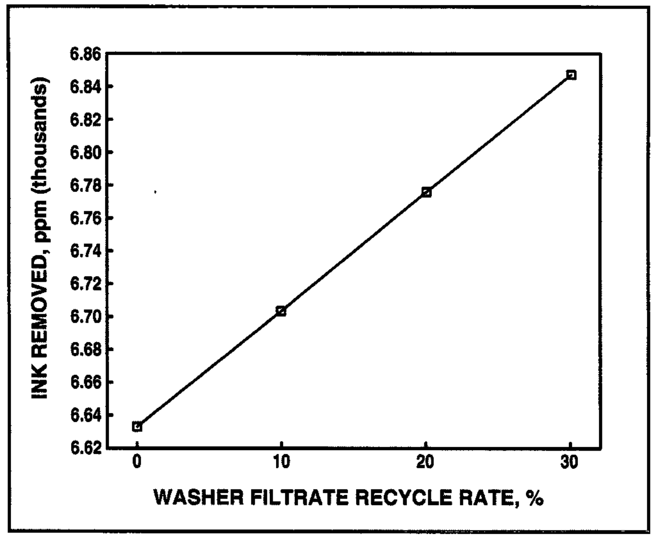
I. Product quality guidelines

TAPPI Brightness	80-83%
TAPPI Dirt Count	15-20 ppm
Ash Content	2.0-2.5%
Canadian Standard Freeness	350-450 mL

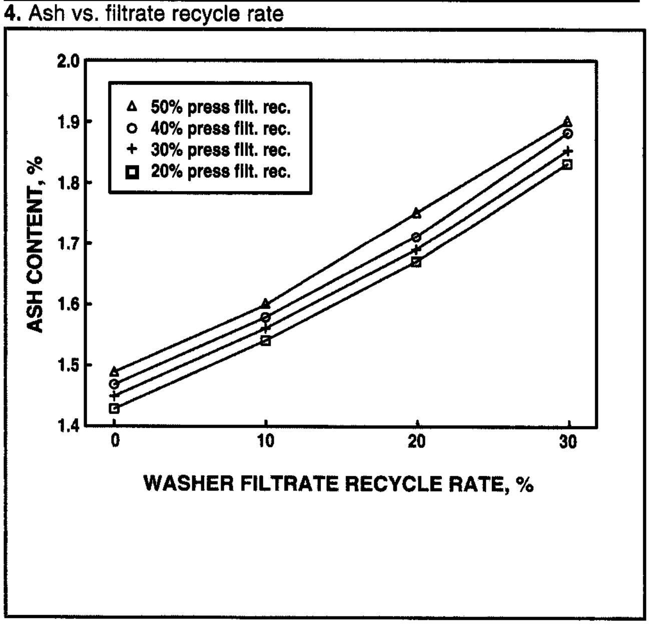
2. Yield vs. filtrate recycle rate



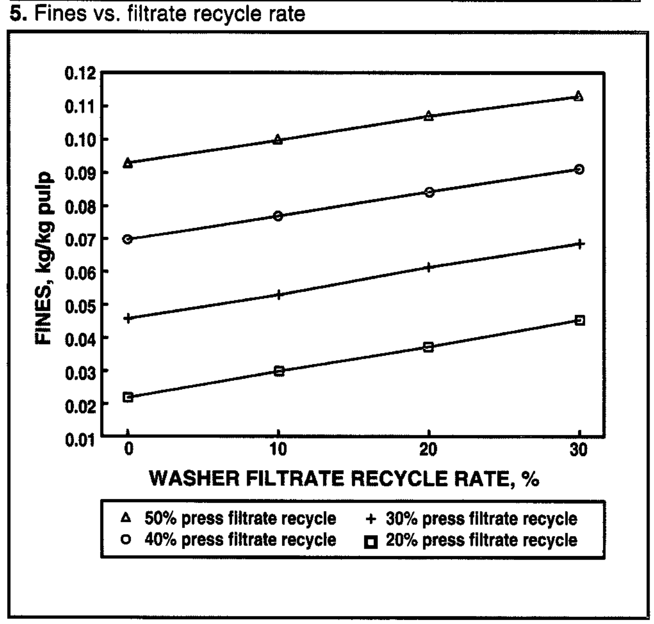
3. Ink removed vs. filtrate recycle rate



4. Ash vs. filtrate recycle rate



5. Fines vs. filtrate recycle rate

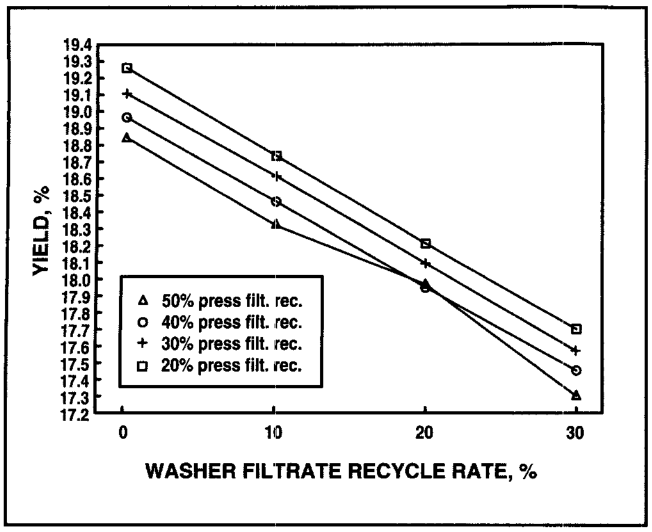


The program was run for press filtrate recycle rates from 20% to 50% and washer filtrate recycle rates of 0–30%. The increment for each recycle rate was 10%. The program calculated the yield, incoming ink and product ash and fines concentrations, effluent flow, fresh water makeup, and sludge produced for each set of recycle rates. The main interest in the program results was to see the trends in these variables. Specific numerical results would depend on the accuracy of the input assumptions. At the time this paper was written, there was no way to verify specific results; the program was run in autumn 1992 and there would be no empirical data until late 1993.

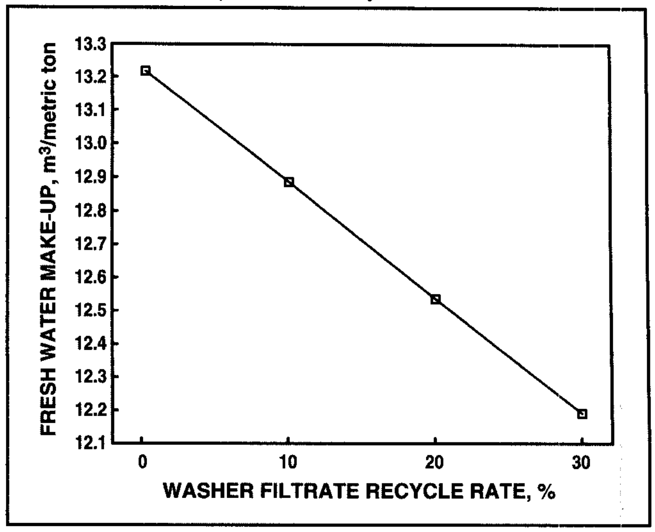
Figure 2 shows the effect of filtrate recycling on yield. As expected, the yield increased for increasing the percentage recycle of both press filtrate and washer filtrate. The yield increase was significantly higher on a percentage basis for increased recycling of washer filtrate. There was a small gain in yield for increased recycling of press filtrate at constant washer filtrate recycle.

Figure 3 shows the effect of filtrate recycling on the amount of ink removed from the recovered paper. The expected result would be that increased filtrate recycling would decrease the amount of ink removed due to ink buildup in the white water. Calculations showed that increased filtrate recycle rates allowed more ink to be removed, and that recycling press filtrate had a negli-

6. Effluent vs. filtrate recycle rate



7. Fresh water makeup vs. filtrate recycle rate



gible effect on ink removal. This might mean that the ink removal capacity limit, particularly for post flotation, was not reached for the chosen recycle rates. The maximum calculated amount of ink removed was 6853 ppm, using the highest recycle rates. Allowing for ink concentrations in the product, this means that the most ink which could be removed from the recovered paper feed is just under 7000 ppm, or 0.7% by weight. The assumption that the ink density is the same as fiber may slightly reduce the calculated value. Published accounts list that the amount of ink on mixed office waste is in the 1–2% range. However, it is not clear in these accounts if the ink is entirely ash-free.

Figure 4 shows the effect of filtrate recycling on ash in the product pulp. As expected, ash content increased with increased filtrate recycling, particularly for increases in washer filtrate recycling. However, calculations for 30% washer filtrate recycle showed ash levels in the pulp that were still below the lower target guideline of 2.0%.

Figure 5 shows the effect of filtrate recycling on fines content in the product pulp. As expected, fines content increased with increased filtrate recycling. Fines in product pulp were calculated to be 7–38% of the amount in the inlet recovered paper, depending on the filtrate recycle rates. The calculations showed that the press filtrate recycle rate had a greater effect on fines than the washer filtrate recycle rate. This result is somewhat surprising and may be due to an inaccurate assumption on fines removal in washing.

Figure 6 shows the effect of filtrate recycling on the amount of effluent produced. As expected, effluent flow decreased with increased filtrate recycling, with the washer filtrate recycle rate having the greater effect.

Figure 7 shows the effect of filtrate recycling on the amount of fresh water makeup needed. Fresh water makeup depended only on the washer filtrate recycle rate. The specific figures would be lower for an integrated and well-closed mill, since this mill was designed so all dilution used after the washing operation was fresh water. This design decision was made to optimize product cleanliness.

The results for sludge were not graphed since the effect of filtrate recycling was not as significant. Calculations did show minor decreases in sludge generation as filtrate recycling increased. The calculated amount of sludge generated was about 0.40 kg per kg pulp produced. The largest variation was within 10% of this value.

The calculations indicated that neither ink nor ash would build up in the white water to a troublesome extent. Recycle rates were selected which would optimize yield without pumping too much filtrate.

The mill using the process for which this model was developed started operations late in the third quarter of 1993. Steady state operation at the target production rate was achieved early in the fourth quarter of 1993. There are plans to use mill data to test the assumptions used for the calculations and fine-tune the program.

This program can easily be applied to other process arrangements. Given a set of quality requirements and removal parameters, or mill data, one can model any configuration. The program can also be used to optimize for quality and operating cost by adding cost data for the furnish, effluent treatment, and sludge disposal. Information from this program can prove as useful for fine-tuning an existing mill as for designing a new mill.

Conclusions

Using process simulation allows the deinking plant designer to balance the flows of ink, ash, and fines, as well as stock and water. These vari-

II. Assumptions for program calculations

Product ink concentration, 50-150 µm	20 ppm
Product ink concentration, size >150 µm	2 ppm
Recovered paper ash content	12%
Recovered paper fines content	0.3%

Dispersion decreases 90% by weight of ink >150 µm to the next lower range (50-150 µm). Dispersion decreases 90% by weight of ink in the 50-150 µm range to the <50 µm range.

Ash removed by washing follows the water split (i.e., the weight percentage of ash removed due to washing is the same as the weight percentage of water removed).

Primary flotation removes 95% by weight of the ink particles in the 50-150 µm range.

Post flotation removes 70% by weight of the ink particles in the 50-150 µm range.

Ink and ash removed by cleaning and screening follow the fiber split specified by the vendor.

Ash removed by primary and post flotation follows the water split (i.e., no preferential removal of ash in flotation).

Sludge thickening removes 94% by weight of the ink and 93% by weight of the ash in the feed stream.

Ink density is roughly equal to fiber density.

Fines carryover is 30%.

ables can have a significant effect on plant design, particularly for plants which must meet strict quality standards.

The program results showed that ash and fines content in product pulp and yield increased as the filtrate recycle rates were increased, as expected. The results showed that effluent flow, fresh water makeup, and sludge production decreased as the filtrate recycle rates were increased, also as expected.

The only unexpected result was that the amount of ink removed increased slightly as filtrate recycle rates were increased. This might mean that the ink removal capacity limit of the process equipment was not reached, particularly for post flotation. The assumptions used for the program should also be checked against actual operating data.

Program results were used to select filtrate recycle rates which would optimize yield while minimizing the pumping of filtrate. There are plans to verify the program assumptions and results in 1994 using mill data. TJ

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