Recovering fibers from fine-prescreening reject at deinking mills

LIISA MÄKINEN, MIKA KÖRKKÖ, ARI ÄMMÄLÄ, ANTTI HAAPALA, TERHI SUOPAJÄRVI, AND JOUKO NIINIMÄKI

ABSTRACT: The yield of recycled paper production can be as low as 75%. The reject losses at deinked pulp mills are high compared to the small amount of ink applied to paper during printing. Thus, plenty of sufficiently clean fibers, fiber fines, and fillers are also rejected. This study provided proof of concept for recovery of long fibers from fine-prescreening rejects that contain a considerable amount of contaminants, such as stickies and dirt specks. The recovery of long fibers was studied by means of laboratory flotation experiments for untreated (fine-prescreening reject without dispersing) and dispersed (fine-prescreening reject after low-consistency dispersing) rejects. The possibility of recycling dispersed fine-prescreening rejects directly back into the preflotation feed also was considered; however, this technique was found to be unworkable. Instead, these results showed that low-consistency dispersion before flotation enabled a high level of contaminant removal at the separate flotation unit. Thus, there seems to be an opportunity to purify fine-prescreening rejects to a level that enabled reuse of the long-fiber fraction without degrading the quality of the end product.

Application: Deinked pulp mills can increase yield, and thus profits, by recovering fibers from fine-screening rejects.

Recovered paper is currently the most important raw material in the paper and board industry, with a 52% share [1]. Deinked pulp (DIP) manufacturing generates a great number of residues through removal of printing inks, stickies, and other contaminants. The rejected streams also contain some valuable and reusable components [2–5] that are lost during disposal. As much as 25% of the raw material can end up as process rejects [6]. Material recovery from the reject streams would be desirable from an economic and environmental viewpoint, if the means to do so were available.

Macrostickies are removed from pulp through screening, cleaning, and flotation; of these removal techniques, low-consistency (LC) screening is the most important [5,7]. Screening is performed in several stages. The avoidance of fiber losses during screening is impossible [8]; fiber loss is on the order of 1%–2 % of the production rate of a DIP mill. Fibers in fine-screening rejects were shown to have high brightness levels with low residual ink content [3]; therefore, their potential for reuse is strong. Consequently, fine-screening rejects are perhaps the most appealing material to recover at DIP mills.

For the recovery of fibers from fine-screening rejects, macrostickies and dirt specks must be separated from the fibers. One possible method to achieve this separation is to add a screening stage; however, in practice, investment and operation costs limit the number of screening stages to two or three. Because of the hydrophobic nature of stickies and ink-derived dirt specks, flotation was considered to be a more selective separation process, and its use in this purpose had not been studied previously. Good removal of stickies and waxes by flotation of pulp from old corrugated containers was reported by Ben et al. [9,10]. However, larger macrostickies do not float as well [5,9,11], resulting in an optimal size distribution in the 10 μm–250 μm range [8,12,13]. Therefore, from an industrial point of view, size reduction of contaminants is a precondition that would preferably be performed at a low consistency. For this reason, high-intensity dispersion at low consistency (i.e., LC dispersing) was used to reduce the size of stickies and dirt specks in this study. Low consistency would also be preferable for flotation because it has been suggested that at higher consistencies (above 1%) [14], fibers tend to form networks and floc, causing ink aggregates to detach from gas bubbles and thus lowering the flotation efficiency [15,16].

The objective of this work was to perform a proof-of-concept study for the recovery of long fibers from fine-prescreening reject that contain a considerable amount of contaminants, such as stickies and dirt specks, among high-quality fibers. Experiments were performed with fine-prescreening reject from an industrial DIP mill. Three flotation approaches were studied: (1) a separate flotation phase for the fine-prescreening reject without dispersing, (2) a separate flotation phase for the fine-prescreening reject after LC dispersing, and (3) the flotation of LC-dispersed fine-prescreening reject mixed into a preflotation feed.

MATERIALS AND METHODS

LC dispersion

Dispersion was performed using a laboratory-scale high-frequency dispergator (ZRI-homogenizer, Haarla Oy; Tampere, Finland) that does not damage fibers [17]. The device consists of a stator, which forms a series of concentric rings that contain slots. Embedded between the stator rings is a rotor with a frequency of

300 Hz (18000 rpm). Before dispersion, the pulp was heated to 45°C, and its consistency was adjusted to 0.9%. The pulp was dispersed as 225 g (o.d.) batches, which were fed into the center of the stator and (at a pressure of 10 bars) forced to flow outwards through the concentric rings. During the operation of the dispergator, the gap between the stator and rotor was on the order of 1 mm. A manual valve was used to control the throughflow and the pressure, which was set to 1 bar.

Flotation

A Voith Delta25 batch laboratory flotation cell (Voith GmbH; Heidenheim, Germany) was used for these flotation experiments. The batch size was 21 L, and the airflow was kept constant (7.4 L/min) for all the experiments. Samples were preheated to 45°C. No additional chemicals were used because the samples already contained the flotation chemical residue. However, the hardness was measured and adjusted to 18°dH with calcium chloride (German hardness, equivalent to 128 mg Ca^{2+}/L). Each batch, as well as the removed froth, was weighed, and samples were taken before and after flotation for analysis.

Samples

The fine-prescreening reject (final reject after the third stage of screening) and accept samples were obtained from a Scandinavian deinking mill that produced newsprint using a mixture of old newsprint and magazines as raw material (60/40 share). Three types of pressure screening processes were used at the mill: coarse screening, fine prescreening, and fine screening. Coarse screening was performed at the beginning of the deinking process with 2-mm holes. The fine prescreening, which was used as a sampling point for these experiments, was performed before preflotation with 0.20-mm slots. Fine screening was performed after the preflotation with 0.15-mm slots. Approximately 1% of the raw material at the deinking mill was rejected during the fine prescreening.

The fine-prescreening accept sample was used to indicate the reference level of contaminants in the pulp, as well as to perform a reference flotation and mixed-flotation experiment with the dispersed reject. **Table I** presents the characteristics of the studied samples. It is noteworthy that fine-prescreening reject consistency was low, which was a result of the deinking mill process and possibly the dilution wash at the screening stage that decontaminates the screen basket.

Flotation experiments

The proof-of-concept study was conducted by carrying out flotation experiments that were performed in two series (**Fig. 1**): separate flotation of the untreated or dispersed fine-prescreening reject (test series 1) and mixed fine-prescreening reject and accept flotation (test series 2). The contaminant levels of the separate untreated and dispersed-reject flotation experiments were compared to the fine-prescreening accept sample from the deinking mill. These levels were used to indicate the reference level of the contaminants in the pulp. The fine-prescreening accept was floated to obtain reference values for the removal efficiencies of the contaminants during the deinking-line flotation for comparison with the mixed-flotation experiment. Because the composition of the fine-prescreening reject was very different from that of the accept (Table I), rather than the same total consistency, the same fiber consistency was chosen for each flotation experiment. The flotation experiments were performed as follows.

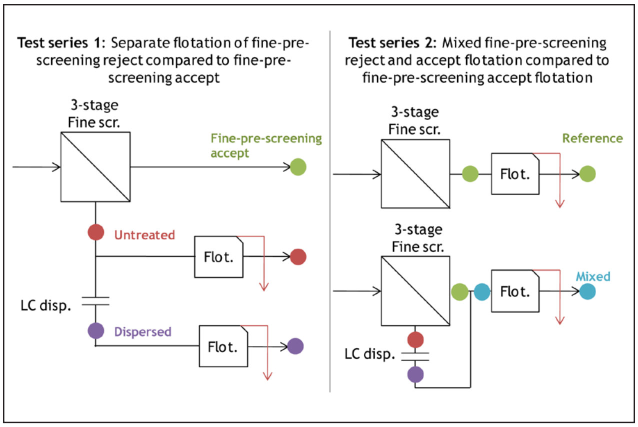
Untreated

The fine-prescreening reject sample was used in this flotation experiment. The flotation for the untreated reject was performed at 45°C with 0.8% total consistency, which corresponds to 0.63% fiber consistency. Flotation was performed to achieve hyperflotation (i.e., all of the contaminants that

	Ash 525°C [%] (a)	Fiber Content [%] (b)	Total Consistency [%] (c)	Fiber Consistency [%] (d)	Dirt Specks [mm²/m²] (e)	Macrostickies [mm²/kg] (f)	ERIC700 [ppm] (g)	ISO Brightness [%] (g)
Fine-prescreening reject	12.9	78.6	1.0	0.8	10 180	103 340	400	54.4
Fine-prescreening accept	23.6	53.6	2.3	1.2	1870	4540	1000	51.8

(a) ISO 1769:2001 "Paper, board and pulps–determination of residue (ash) on ignition at 525°C."
(b) TAPPI T 275 sp-02 "Screening of pulp (Sommerville-type equipment)," except 150-mesh wire screen was used.
(c) EN ISO 4119:1996 "Pulps. Determination of stock concentration."
(d) Fiber content multiplied by total consistency.
(e) DOMAS image analysis system.
(f) INGEDE Method 4:2011 "Analysis of macrostickies in pulps.
(g) Test medium preparation in accordance with [18].

I. Characteristics of the fine-prescreening reject compared to the fine-prescreening accept.



1. The laboratory flotation experiments. (Colored sample points refer to the colors used to present the results.)

floated were removed), which resulted in a reject rate of 18% by weight.

Dispersed

The fine-prescreening reject sample was preheated to 45°C and dispersed with a laboratory-scale high-frequency dispergator at 0.9% consistency. The total consistency was then adjusted to 0.8%, which corresponds to a 0.63% fiber consistency, with warm tap water to maintain the temperature level (45°C). The goal was to achieve the same mass reject rate as the untreated flotation experiment; thus, flotation was performed to achieve hyperflotation, which resulted in a reject rate of 20% by weight.

Reference

Reference values for the removal efficiencies of contaminants at the deinking-line flotation were obtained by floating the fine-prescreening accept sample. A total consistency of 1.2% was selected for fine-prescreening accept flotation experiments because this value is widely used as the flotation consistency for deinking processes [7,8,19]. The total consistency of 1.2% resulted in a 0.64% fiber consistency for the fine-prescreening accept. The temperature during flotation was 45°C, and the reject rate was limited to 14% by weight.

Mixed

A mixture of the dispersed fine-prescreening reject (10%) and the untreated fine-prescreening accept (90%) was preheated to 45°C and floated to determine whether the dispersed fine-prescreening reject could be fed back into the preflotation feed of the deinking process. To emphasize a possible difference in the removal of contaminants between the flotation arrangements, a ratio of 10/90 for the dispersed reject and fine-prescreening accept was chosen instead of a 1/99 ratio. Mixed flotation was performed at 1.2% consistency, which resulted in a 0.67% fiber consistency with a reject rate of 14% by weight.

Analyses

The consistency of the pulp samples was analyzed by filtering the pulp suspensions through ashless filter paper; the value was calculated as the ratio of the dry residue weight to the suspension weight (EN ISO 4119 "Pulps. Determination of stock concentration"). For ash content analyses, the filter papers for the consistency measurement were incinerated at 525°C (ISO 1769:2001 "Paper, board and pulps–determination of residue [ash] on ignition at 525°C"). The fiber content was analyzed with a Somerville screening apparatus (TAPPI T 275 sp-02 "Screening of pulp [Sommerville-type equipment]"), which was equipped with a 150-mesh wire screen having a nominal aperture size of 105 µm. The retained solids were collected and used for dirt-speck analyses, whereby the dirt specks were analyzed from hyperwashed pulp. Five sheets with grammage of 70 g/m² were prepared. From these sheets, the area of black particles was measured against the total area using a DOMAS image analysis system commercially available from PTS (Papiertechnische Stiftung; Munich, Germany) with an Epson 1680 Pro scanner. During the analysis, a constant threshold setting (182) was applied that was 15% lower than the mean grey level of the darkest sample. The dirt-speck results are presented as mean values determined from five sheets. Assuming normally distributed data, the confidence intervals for the 95% confidence level are presented.

For the macrostickies analysis, 10 g of pulp (o.d.) was screened with a Somerville screen using a 100-µm slotted aperture. The retained sample was filtered on filter paper and dyed with water-based ink. Finally, the hydrophobic particles were contrasted with aluminum oxide powder. The white-particle area on the prepared sheet was then analyzed and converted to the area of the macrostickies with respect to the amount of pulp. Three parallel sheets were analyzed for all cases reported as mean and with confidence intervals (INGEDE Method 4 "Analysis of macrostickies in deinked pulp").

For the brightness and $ERIC_{700}$ measurements, low-grammage sheets (35–40 g/m²) were prepared by filtering the suspension onto a filter paper with a porosity of 1–2 µm. This method was used to achieve a high rate of retention and to determinate the scattering coefficient [18]. The $ERIC_{700}$ was assessed from the reflectance and light scattering coefficient (ISO 22754 "Pulp and paper—determination of the effective residual ink concentration [ERIC number] by infrared reflectance measurement") and TAPPI T 567 ("Determination of effective residual ink concentration [ERIC] by infrared reflectance measurement"); however, the reflectance was recorded at 700 nm, which is not included in the aforementioned standards but it is commonly used. Brightness was measured from the stack of test media in accordance with SFS-ISO 2470 ("Paper, board and pulps—measurement of diffuse blue reflectance factor").

Calculations

The mass reject rate (RR_m) was calculated as the proportion of rejected material to the flotation feed using Eq. (1). The component removal efficiency (E_r) calculation for macrostickies and dirt specks was based on the component content in the feed and accept samples (Eq. [2]). The feed, accept, and reject are abbreviated as F, A, and R, respectively.

$$RR_m = \frac{V_R \cdot cs_R}{V_F \cdot cs_F} \cdot 100\% \qquad (1)$$

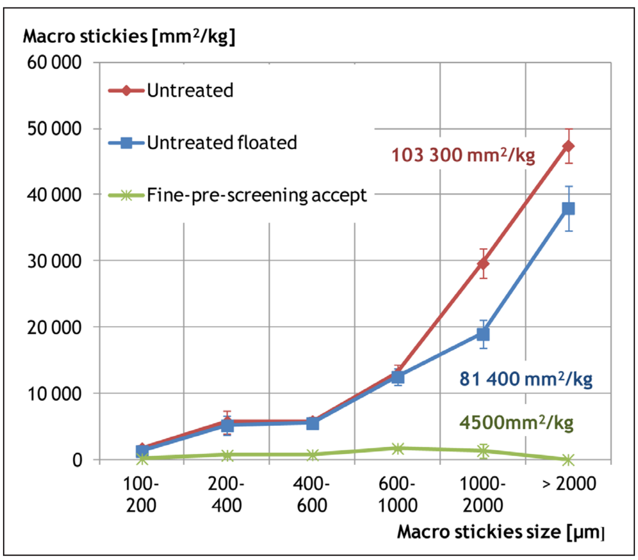
$$E_r = \left[1 - \left(1 - \frac{RR_m}{100}\right) \cdot \frac{X_A}{X_F}\right] \cdot 100\% \qquad (2)$$

Where RR_m is the mass reject rate [%], V_i is the volume of the sample [L], cs_i is the consistency of the sample [%], E_r is the removal efficiency [%], and X_i is the content of the studied component in the sample [mm²/kg or mm²/m²].

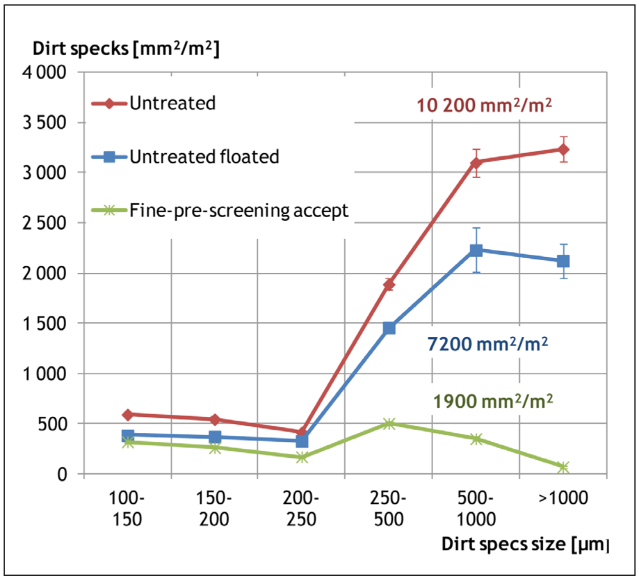
RESULTS

Test series 1: flotation of untreated fine-prescreening reject

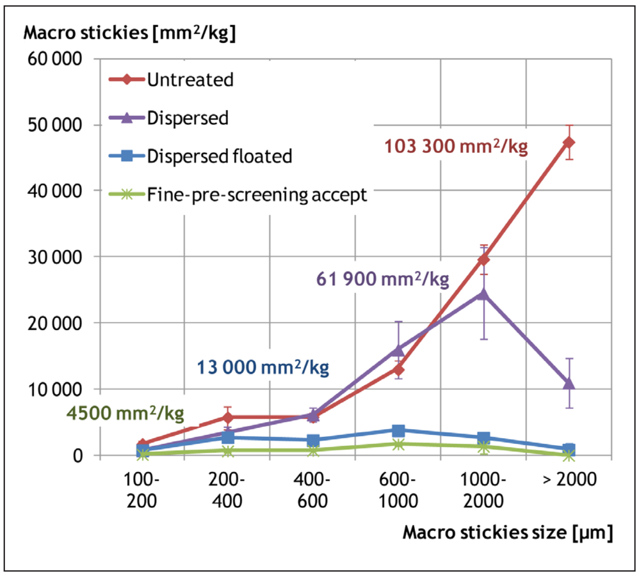
Figure 2 presents the quantities of different-sized macrostickies for the untreated reject (fine-prescreening reject without dispersing) before and after flotation. The quantities of different-sized macrostickies for the fine-prescreening accept are also presented to indicate the reference level of macrostickies in the pulp. During the flotation, only a minor decrease was observed for the large macrostickies (>600 µm). Even after flotation, the total quantity of macrostickies was 18 times larger than that of the fine-prescreening accept.



2. Macrostickies in the untreated reject before and after flotation. (The numerical values refer to the total quantity of macrostickies in the samples.)

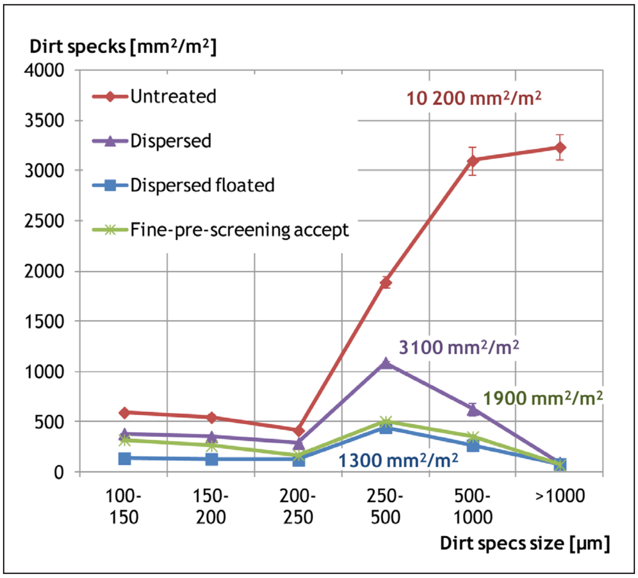


3. Dirt specks in the untreated reject before and after flotation. (The numerical values refer to the total quantity of dirt specks in the samples.)

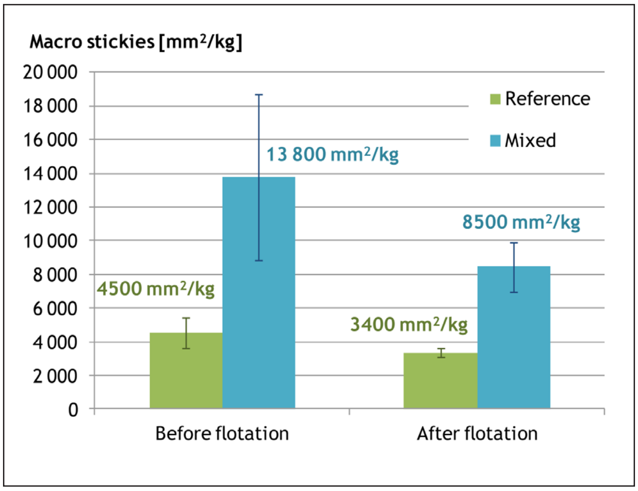


4. Macrostickies in the dispersed reject before and after flotation. (The numerical values refer to the total quantity of macrostickies in the samples.)

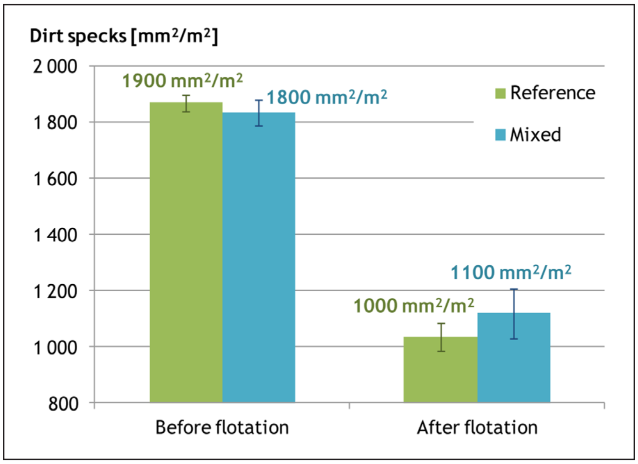
Figure 3 presents the quantities of different-sized dirt specks for the untreated reject before and after flotation. The quantities of different-sized dirt specks for the fine-prescreening accept are also presented to indicate the reference level of dirt specks in the pulp. During the flotation, similar to the macrostickies, only a minor decrease was observed for the large dirt specks (>250 µm). The total quantity of dirt specks was still four times larger than that of the fine-prescreening accept after flotation.



5. Dirt specks in the dispersed reject before and after flotation. (The numerical values refer to the total quantity of dirt specks in the samples.)



6. Macrostickies in the mixed sample before and after flotation. (The numerical values refer to the total quantity of macrostickies in the samples.)



7. Dirt specks in the mixed sample before and after flotation. (The numerical values refer to the total quantity of dirt specks in the samples.)

Test series 1: flotation of LC-dispersed fine-prescreening reject

Figure 4 presents the quantities of different-sized macrostickies for the dispersed reject (fine-prescreening reject after LC dispersing) before and after flotation. The quantities of different-sized macrostickies for the fine-prescreening accept are also presented to indicate the reference level of macrostickies in the pulp. The dispersion reduced the quantity of macrostickies with particle sizes of 2000 µm or larger and it slightly increased the quantity of 400- to 1000-µm stickies, yet the difference was less than error bars. After flotation, the total quantity of macrostickies was clearly less than before flotation, but it remained three times higher than in the fine-prescreening accept.

Figure 5 presents the quantities of different-sized dirt specks for the dispersed reject before and after flotation. The quantities of different-sized dirt specks for the fine-prescreening accept are also presented to indicate the reference level of dirt specks in the pulp. Dirt specks, especially large dirt specks (>250 µm), were fragmented into smaller-sized particles with dispersion, allowing flotation to remove the dirt specks so efficiently that the total quantity of dirt specks was even less than in the fine-prescreening accept.

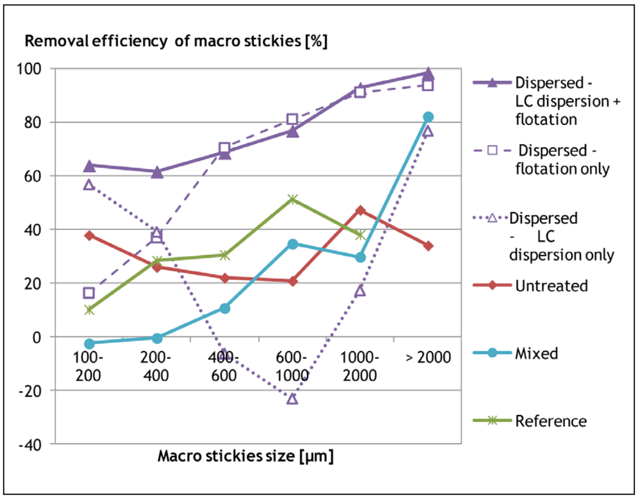
Test series 2: flotation of LC-dispersed fine-prescreening reject mixed into preflotation feed

Figure 6 presents the total quantities of macrostickies for the reference (fine-prescreening accept) and mixed sample (10% dispersed reject, 90% accept) before and after flotation. The total quantities of macrostickies were three times higher for the mixed sample than the reference before flotation. Even after flotation, the quantity of macrostickies was 2.5 times higher than the reference.

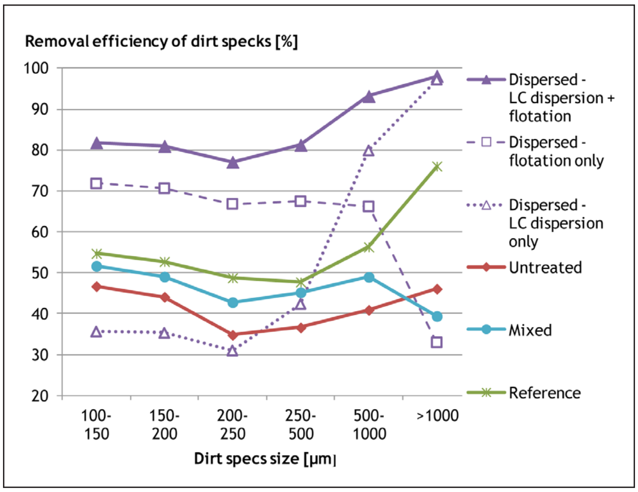
Figure 7 presents the total quantities of dirt specks for the reference (fine-prescreening accept) and mixed sample before and after flotation. The total quantity of dirt specs was slightly lower (by 100 mm^2/m^2) for the mixed sample than the reference before flotation. There were no significant differences in dirt-speck removal in the mixed and reference flotation experiments; flotation removed nearly half of the amount of dirt specks, resulting in similar values when error bars were accounted.

Removal efficiencies of the flotation experiments

Figure 8 presents the removal efficiencies of the different-sized macrostickies by means of the flotation experiments.



8. Removal efficiencies of macrostickies.



9. Removal efficiencies of dirt specks.

For the dispersed reject, the total removal efficiency (LC dispersion + flotation) as well as the removal efficiencies separately for the dispersion and flotation stages (dashed lines) are presented. Negative removal efficiency was observed for the macrostickies in the 400–1000 µm size range over the LC-dispersion stage because the amount of stickies in this size range increased slightly from the dispersion. The removal efficiency of the macrostickies (>200 µm) during the flotation stage for the dispersed reject was greatest, and the combined removal efficiency of the dispersion and flotation stages was high for all macrostickies sizes. A higher removal efficiency was achieved for larger stickies (>400 µm) than for smaller stickies (<400 µm). The same trend can be observed for the reference and mixed samples. The larger macrostickies had greater removal efficiency and the smaller stickies had smaller removal efficiencies. For the reference flotation experiment, the removal efficiency of the macrostickies >2000 µm could not be calculated due to their absence. The removal efficiency of the smallest macrostickies (100–200 µm) by means of flotation was greatest among the untreated reject (nearly 40%). For other samples, the removal efficiency of the smallest macrostickies with flotation was below 20%. In addition, the removal efficiency of the macrostickies by flotation with untreated reject varied between 20% and 50%.

Figure 9 presents the removal efficiencies of the different-sized dirt specks by means of flotation experiments. For the dispersed reject, the total removal efficiency (LC dispersion + flotation) and the removal efficiencies separately for the dispersion and flotation stages (dashed lines) are presented. The removal efficiency of the largest dirt specks (>1000 µm) by flotation of the dispersed reject was the lowest. However, large dirt specks were already removed in the dispersion stage, which effectively dispersed dirt specks that were >500 µm, and the removal efficiency over the LC-dispersion and flotation stages together was high. Thus, the removal efficiency of the dirt specks was greatest for the dispersed reject, followed by the reference, then the mixed sample, and finally the untreated reject, which had the lowest removal efficiency. The removal efficiency of dirt specks remained relatively constant in each flotation experiment. Only a slight variation in the removal efficiencies of the largest dirt specks could be observed between the flotation experiments.

Table II summarizes the total removal efficiencies of the macrostickies and dirt specks in the flotation experiments. The removal efficiencies were calculated for macrostickies of all sizes (>100 µm), as well as for macrostickies from 100–2000 µm. In accordance, the removal efficiencies for dirt specks of all sizes (>100 µm) were calculated, and dirt specks from 100–1000 µm (i.e., the largest contaminants) were excluded from the calculations. This exclusion was performed because the accuracy of the analysis of the contaminants in the largest size class might have been affected by the lack of a representative population and the removal efficiencies for all sizes of contaminants may be misleading. The best removal efficiencies were seen with the dispersed reject and the worst removal efficiencies were obtained with the untreated reject. The total removal efficiency of the macrostickies was better for the mixed sample compared to the reference, whereas these conditions were reversed for the dirt specks.

Ash balance in flotation experiments

Table III summarizes the ash contents of the flotation feed, accept, and reject for each flotation experiment. In addition, reject rates and removal efficiencies of ash over flotation are presented. The ash contents in test series 1 (untreated and dispersed) and in test series 2 (mixed and reference) were respectively similar. The ash contents in test series 1 were smaller than in test series 2. Altogether, the ash contents of the flotation feeds and accepts were small, and the mass balances were good.

Flotation Experiment	Removal Efficiency [%]				RR_m [%]
	Macrostickies (>100 µm)	Macrostickies (100–2000 µm)*	Dirt Specks (>100 µm)	Dirt Specks (100–1000 µm)*	
Untreated	35	36	42	40	18.0
Dispersed	90	83	81	92	20.0
Flotation only	83	81	67	68	20.0
Dispersion only	40	9	70	57	0.0**
Mixed	47	27	47	48	14.0
Reference	37	40	52	52	14.0

*Largest size class of contaminants excluded from the calculation.
**No mass loss over the dispersion stage.

II. Total removal efficiencies of the contaminants and mass reject rates in the flotation experiments.

		Ash Content [%]			RRm [%]	Removal Efficiency [%]
		Feed	Accept	Reject		
Test series 1	Untreated	14.2	5.5	47.1	18.0	68.2
	Dispersed	14.5	4.6	46.9	20.0	74.6
Test series 2	Mixed	24.5	15.6	65.2	14.0	45.2
	Reference	25.3	15.6	64.6	14.0	47.0

III. Ash contents of the flotation feed, accept, and reject, as well as reject rates and removal efficiencies of ash in flotation experiments for each flotation experiment.

DISCUSSION

The proof-of-concept study conducted here included three different approaches to recover fibers from fine-prescreening reject in a DIP mill. The approaches are discussed below.

1. Flotation of untreated fine-prescreening reject

First, the removal of macrostickies and dirt specks from untreated reject (fine-prescreening reject without dispersion) in a separate flotation unit was studied. Expectedly, this approach was ineffective due to the high concentration of large contaminants, which are known to be poorly removed by flotation [5,9,11]. This experiment was performed as a reference for the dispersed flotation experiment. Poor removal of contaminants from the untreated reject was also found in a previous investigation by Noda et al. [20]. Due to their large size, the contaminants easily detached from the rising air bubbles.

2. Flotation of the LC-dispersed fine-prescreening reject

Second, the removal of macrostickies and dirt specks from the dispersed reject (fine-prescreening reject after LC dispersing) in a separate flotation unit was studied. On the basis of the results, the dispersion effectively broke the large contaminants into smaller sizes. The optimal size distribution of ink and stickies for flotation has been reported to be in the range of 10–150 µm [12,13] or 10–250 µm [8]. However, in this study, the optimal flotation removal size for stickies and dirt specks was found to be larger. Because the size of the macrostickies was measured as the stickies were flattened, the diameter of the stickies (400–1000 µm) would be equivalent to 190–350 µm in spherical form [21], which was still larger than the optimal size range for flotation. The current study suggested that the reason for the better removal of large contaminants in flotation may be the newly formed or cleaned surface produced by dispersion. In addition to size reduction, dispersion may possibly clean and activate the surfaces of the contaminants so that they become more floatable [8]. The results obtained in this study indicated the important role of clean hydrophobic particle surfaces for selective separation during flotation, which is a less-reported effect of dispersion. After dispersion, the removal efficiency of each size class of contaminants during flotation was found to be greater than that of the untreated reject (except for the smallest-size class of macrostickies and the largest-size class of dirt specks, which may be due to the already low concentration of these sized contaminants in the flotation feed). We assumed that the surfaces of the large stickies were modified more than those of the smaller ones by dispersion, and the surfaces of the smaller stickies remained coated with debris; thus, the smaller stickies were less active and unable to attach to the air bubbles.

The positive effect of the dispersion on the flotation removal efficiency of the contaminants had previously been attributed to the size reduction [22] or shape change [5] of the contaminants in dispersion. It can be considered that kneading applies a rubbing action to the stickies, modifying their shape and causing them to become more spherical, while the high-speed dispersers produce more impacts leading to breakup of the particles [23]. In this case, we can assume that the high-intensity disperser cuts the contaminants rather than modifies their shape, generating a new surface; this is beneficial because newly formed surfaces are free of contaminants and tend to adhere well on bubble surfaces.

The dispersion decreased the amounts of macrostickies in the largest and smallest size classes; thus, dispersion evidently produced an increased amount of microstickies (<100 μm). The removal of microstickies by flotation was not studied. However, according to earlier studies [13,24], their removal efficiency was expected to be high; thus, microstickies will not be a problem when the reject is reused, although this must be validated in further studies. In addition, the shape of the contaminants and the bubble size distribution may have affected the separation; thus, these factors need to be studied further.

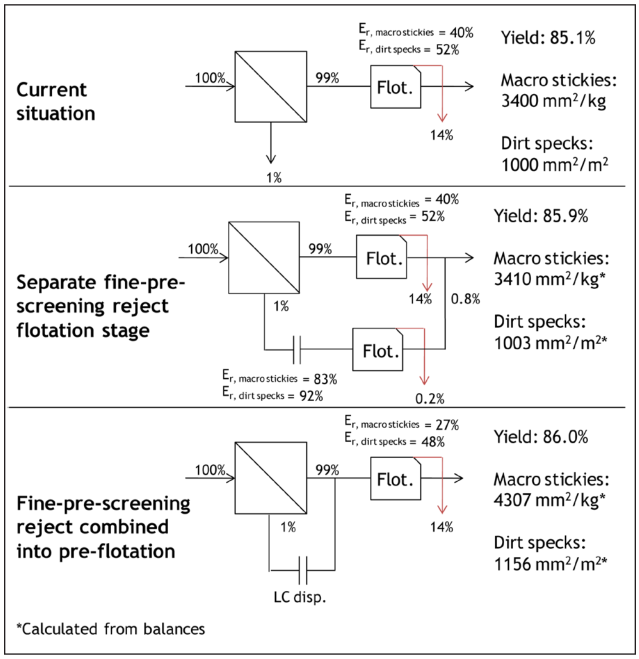
3. Flotation of LC-dispersed fine-prescreening reject mixed into preflotation feed

Third, the flotation arrangement of the dispersed reject was studied to determine whether the reject could be recirculated directly into the preflotation (i.e., mixed with the fine-prescreening accept before preflotation). To emphasize a possible difference in the removal of contaminants between the flotation arrangements, a ratio of 10/90 for dispersed reject and fine-prescreening accept was chosen instead of a 1/99 ratio. Comparison between the mixed and reference flotation experiments could not be done based on the final quantities of the contaminants. As expected, the final values were higher for the mixed flotation than for the reference when the 10/90 ratio was used; however, the removal efficiencies should be comparable.

With the 10/90 ratio, the total removal efficiency of the macrostickies was slightly better in the mixed flotation than in the reference flotation, while with the opposite was true for dirt specks. However, from Fig. 8, it can be seen that the removal efficiency of the macrostickies for the reference flotation was better in every other size class than in the largest size class. When the removal efficiencies were calculated for the macrostickies between 100 μm and 2000 μm, the removal efficiencies were 27% and 40% for the mixed and reference flotation experiments, respectively. These efficiencies may be more reliable because the accuracy of the largest size class analysis of the macrostickies might have been affected by the lack of a representative population. Accordingly, compared to the reference flotation, the mixed flotation did not work well.

Process concepts

Dispersion before flotation was found to be necessary. Two process options were presented in comparison with the current configuration, as shown in **Fig. 10**: separate flotation of the dispersed fine-prescreening reject and recirculation of the dispersed fine-prescreening reject into the preflotation feed. In addition, the effects of these processes on the mill were summarized in terms of the total yield of the process, the final contaminant levels, and the removal efficiencies of the contaminants during the flotation stages. The removal efficiencies of the contaminants during flotation stages were calculated for the macrostickies ranging from 100–2000 μm and the dirt specks ranging from 100–1000 μm. The final contaminant values for the process concepts for the fine-prescreening reject recovery were calculated from mass balances, assuming the flotation removal efficiencies from experiments presented in this paper.



10. Comparison of processes to recover fibers from fine-prescreening reject. The removal efficiencies of the contaminants during the flotation stages were calculated for macrostickies sized 100–2000 μm and dirt specks sized 100–1000 μm.

From an industrial viewpoint, recirculation would be the most desirable option; however, this option seems to be an unworkable method due to contaminant removal. Fiber recovery from the fine-prescreening reject was found to be possible by means of LC dispersion and separate flotation. With this method, the contaminant levels were nearly the same as the reference, and the yield at the deinking mill could be increased by at least 0.8% by recovering the most valuable long fibers for the process.

A drawback of the separate flotation is the need for additional flotation stages in addition to the LC-dispersion stage. However, because the fine-prescreening reject stream only represents 1% of the total stock flow, the capacity of the flotation device would be much smaller than in the deinking process line. The dispersion performed at a low consistency was seen to be preferable because the dewatering of the reject to achieve a high consistency—typically used in the dispersion stage—may not be economically feasible. In these experiments, without optimizing flotation or dispersion, dirt specks and macrostickies were practically at the same level.

The general notion in industry has been that the flotation of mixed-screening rejects would not be an efficient process configuration. The scarcity of published results makes it difficult to compare our results with previous investigations; however, according to our analysis, the method functioned as expected. By using separate dispersing and flotation units that operate at a low consistency, low contaminant levels can be achieved and long fibers can be recovered for the process line. This proof-of-concept study shows promising initial results, but more thorough investigations are needed.

CONCLUSIONS

This proof-of-concept study indicated that it is possible to recover fibers from fine-screening rejects by removing contaminants with flotation. To achieve high separation efficiency during flotation, a certain level of size reduction is needed. However, it is at least equally important to increase the hydrophobicity of the contaminants by increasing their clean surface area with dispersion. The removal efficiency for all size classes of stickies and dirt specks was better after dispersion. Good removal efficiencies of contaminants were observed with a separate flotation unit operating at a low consistency (<1%) rather than returning the dispersed reject stream to preflotation. With this method, 80% of the high-quality long fibers from the fine-screening rejects could be recovered. **TJ**

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ABOUT THE AUTHORS

We chose this topic because the yield loss at deinked pulp mills is so great that improvements are needed to maintain deinked pulp production that is both environmentally and economically viable. Furthermore, the fibers in fine-screening rejects were previously shown to have high brightness with low level of printing ink and therefore strong potential for reuse. This study complements earlier studies by introducing a method to recover long fibers of sufficient quality from fine-screening rejects.

The most difficult aspect of this study was to modify the contaminants' size distribution and surfaces to promote their removal during subsequent flotation stages. It was interesting to observe that, in addition to reducing their size, it was equally important to increase the hydrophobicity of the contaminants by increasing their clean surface area with dispersion before flotation.

Deinked pulp producers can use this proof-of-concept study when they consider actions for improving the material efficiency of deinked pulp mills. With the method depicted, 80% of the high-quality long fibers from the fine-screening rejects could be recovered.

In our next study, we will concentrate on combined sludge dewatering properties at deinking mills and the effect of fiber content; fibers are considered to be essential for sludge press filtration.

Mäkinen, Körkkö, and Suopajärvi are reseachers; Ämmälä is education coordinator; Haapala is a postdoctoral research fellow; and Niinimäki is a professor at University of Oulu, Oulu, Finland. Email Mäkinen at Liisa.Makinen@oulu.fi.


Mäkinen


Körkkö


Ämmälä


Haapala


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