Fractionation by micro-hole pressure screening and hydrocyclone applied to deinking line rationalization and future manufacturing concept

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ABSTRACT: This study pursued two objectives related to deinking. The first objective deals with the application of fractionation for deinking operations rationalization, which requires all free ink separation in one fraction and treatment in ink removal operations. Following accomplishment of the first objective, the second objective was fractions generation for stratified sheet formation. The first objective requires separation based on length, and the second requires separation by development of surface characteristics. The experimental plan was focused on selective fines separation and further valorization of fiber and fines fractions.

It was shown that fractionation by a pressure screening system equipped with a smooth hole basket with 0.25 mm perforations was very selective towards fines (free ink, fillers, cellulosic fines) separation in the accepts. Long fibers, as well as specks, were retained in the rejects fraction. Due to the higher selectivity of the micro-hole screen, fibers are retained on the screen basket. Hence, they are not subjected to flotation operations, thereby effectively reducing their probability of being lost during flotation. This essentially translated into a fractionation-deinking concept. It was also shown that 1-stage micro-hole fractionation and fines flotation provided higher yield than conventional direct pulp flotation, though the final residual ink content was high. A multistage fractionation process would allow further reduction in long fiber residual ink.

The second objective was achieved by applying hydrocyclone fractionation on the fine and fiber fractions generated. Separation was based on fiber and fines development. This new fractionation strategy allowed production and characterization of four different fractions: well developed fibers/coarse fibers and fibrillar/flake type fines.

Application: This paper describes the potential of a new fractionation concept to rationalize deinking operations and better regulate final pulp and paper characteristics.

Paper recycling has spread worldwide over the past several decades, reaching a current recovery rate of over 70% in the European Union (EU) [1], leading to the positioning of recovered fibers as the major raw material for paper and board production, even over virgin fibers. About half of the recovered fibers are deinked, commonly by froth flotation, in order to remove ink and other contaminants. Deinking is a key process and a sustainable strategy for papermaking. Thus, it is necessary to increase its efficiency, while reducing costs and environmental impact at the same time.

Manufacture of pulp and paper from recovered fibers involves treatment of the fibrous suspension in various unit operations connected in series, one after another. These operations either treat the pulp flux for contaminant removal (screening, cleaning, deinking) or upgrade the pulp for more value-added final products, called up-gradation (dispersing, bleaching). However, an opportunity exists to further rationalize the manufacturing process by applying the right treatment to the right fraction. It signifies that ink removal operations should be applied only to ink containing fines fraction of the pulp. Similarly, the mechanical energy application should be done on specks fragmentation and ink detachment from fibers. In such a scenario, the fractionation operation would play a key role in separating pulp components according to the desired strategy. This would result in parallel processing instead of series processing and could lead to energy savings, as all the pulp will not be treated in all the unit operations.

Normally, paper has a single-layer structure (except for tissue grades), where all the pulp components are mixed together. An exciting concept of paper manufacture is stratified formation [2], which relates to a multi-layer sheet structure. In such a strategy, pulp constituents are separated and put into different layers. Thanks to this concept, paper properties could be tailored as per requirements of the end user. This would necessarily require fractions generation, and fractionation would play a pivotal role. An example of the possible gains in stratified paper manufacture from such a fractionation scheme has been reported by Huber et al. [3] and Carré et al. [4].

BACKGROUND AND EXPERIMENTAL

Fractionation in deinking operations

The manufacture of paper from deinking operations using a fractionation step is currently limited to simplification of a deinking line and selective treatment of fractions obtained. This strategy differs from the application of fractionation to high-yield mechanical pulps or multi-layer board manufacture, where fiber up-gradation is focused to enhance pulp characteristics in the final product.

In other words, the fractionation process applied in a deinking operation essentially relates to treating the right fiber type, as the whole pulp flux is not treated in the different unit operations. These unit operations treat the pulp suspension for ink removal (flotation or washing). Other process operations are dedicated to detaching ink from fibers by applying mechanical energy or by fragmenting the specks (high speed disperser or low speed kneader).

In recent years, researchers have studied deinking pulp fractionation and selective treatments of fractions in the area of deinking application. For some packaging recycling lines, it is already an industrial reality. Deinking lines are classically designed as a "single" line configuration, but increased energy costs and poor input quality of recycled fiber have led to parallel processing of fractionated streams while maintaining the normal final paper quality. The focus is on reduced equipment size and loops; or a lean [5] compact design [6] ink splitting approach [7]. This is achieved by using screens with narrow aperture dimensions [6-8]. The concept of deinking fractionation was also applied in 2005 to a full-scale industrial plant producing newsprint [9], which reported annual savings as well as improved operational stability.

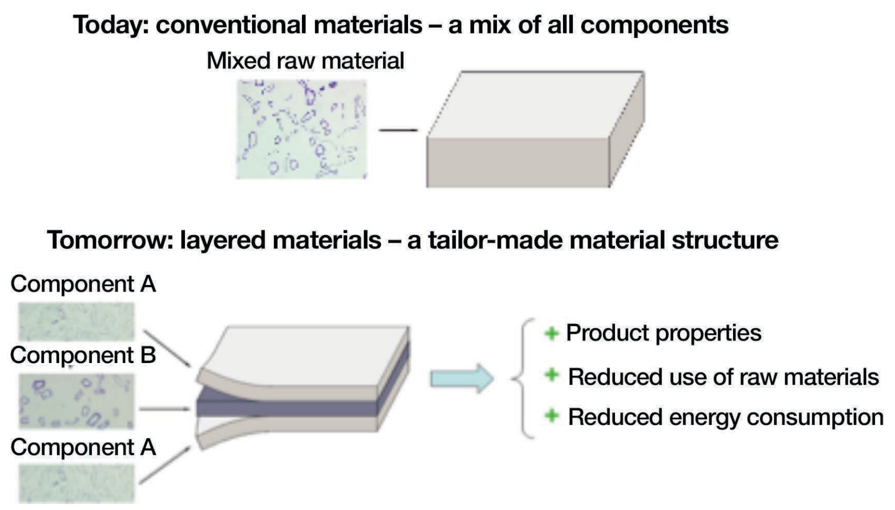
Fabry and Carré [10] mentioned that the perfect process running situation will be when mechanical energy is applied only on the fiber fraction and specks. It will hence reduce the pulp mass for mechanical energy application, and more importantly avoid detrimental fragmentation of the already detached ink.

Single-layer and stratified paper

Traditionally, paper is a single-layer structure. Controlled dewatering of a suspension of fibers, fines, additives, and inorganic fillers results in a single-layer paper sheet structure, where all the entities that are present in the final sheet are mixed. This differs from a stratified formation, which leads to a multi-layered structure.

Stratified forming with different pulp and/or pulp fractions is shown in **Fig. 1**. This has been investigated in the framework of the European Union EcoTarget project [11]. It considers a more environmentally friendly approach for production of paper using fewer raw materials with similar (reference) or better strength and sheet properties. This approach has been carried forward in another European project, BoostEff [12]. The project aims to develop new manufacturing concepts for wood fiber-based products giving a significant reduction in environmental footprint. A new patented headbox design stratification technology [2] offered new perspectives to develop improved resource-efficient papers by using the best pulp fractions in the right layers. This helped to achieve the best paper bulk and surface properties.

Actually, approximately 30%-45% of the whole deinking pulp is composed of the "fine fraction," defined as the pulp fraction containing particles smaller than 75 µm, mainly mineral fillers, cellulosic fines, and ink particles. Most of the ink that should be removed from a pulp (in order to improve the brightness) is present in the fines, in the form of isolated particles or linked to inorganic/organic surfaces [13]. Moreover, some particular types



1. Single- and multi-layer sheet structure concept [12].

of cellulosic fines elements have important significance to sheet property development. In particular, the thin, fibrillary fine-type category is more beneficial for mechanical property development than the blocky flake-type fraction. Fibrillar fines having a higher specific surface area improve the sheet consolidation-sheet density; have a pronounced positive effect on the strength properties; improve printing pick speed; and reduce sheet linting and sheet roughness [14-16].

Experimental approach

The experimental approach was linked to the objectives illustrated in **Fig. 2**. Hence, looking into the two objectives of deinking operations rationalization and production of fractions for tailor made stratified paper manufacture, two industrial grade fractionation technologies were studied: a pressure screening system and hydroclones.

This paper will discuss how a pressure screening system equipped with a micro-hole screen plate can be combined with fractionating hydrocyclones to attain the two objectives previously described.

Pressure screens fractionate primarily on the basis of fiber length, while flexibility and stiffness are secondary factors. Short fibers, fines, and mineral fillers having a higher probability of passage enrich the accept fraction, whereas long fibers are concentrated in the reject fraction [17-18]. In the case of hydrocyclones, density and fiber/fines development are the principal basis of fractionation. Well-developed, fibrillated/low-cell-wall-thickness fibers are preferentially separated into the accept stream (also known as the base fraction). Coarse fibers, fiber bundles/shives, and flake-type fines get concentrated into the reject fraction (also known as the apex fraction) [19-20].

It must be noted here that fractionation of a pulp suspension/fiber refers to fraction generation for selective treatment or usage, whereas screening/cleaning implies removal of unwanted, non-desirable material with minimum fiber loss to enhance the final product quality. Hence, in a fractionation system, the reject fraction is produced for specific treatment and not for its removal from the process streams.

Thanks to fundamental analysis of the separation process, it has been shown that a 0.25-mm micro-hole screen plate offers a higher degree of fractionation in comparison to conventional slot screens [21-22].

MATERIALS AND METHODS

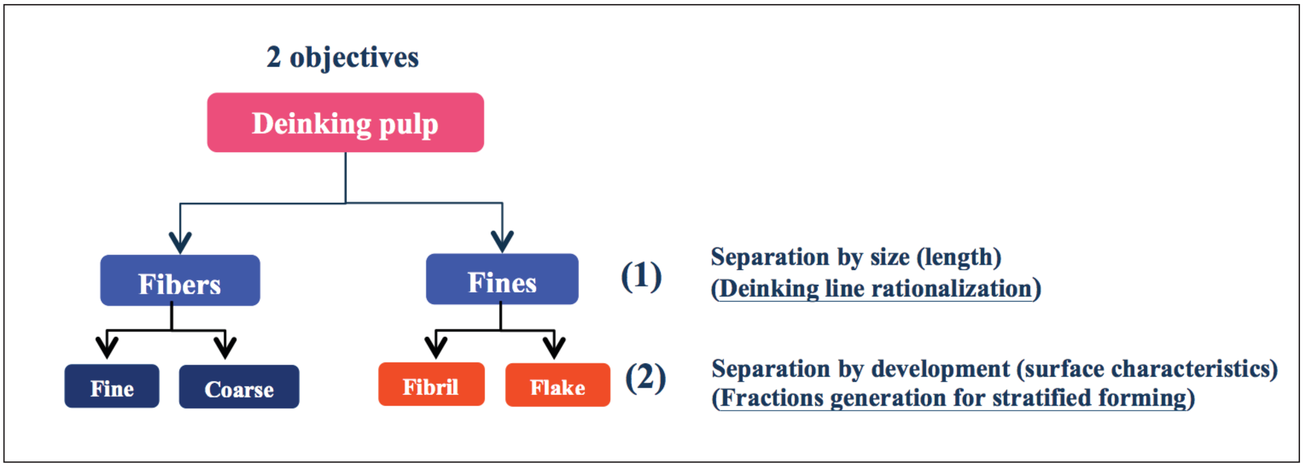
Two experimental trials were performed. The first series of experiments were dedicated to pilot plant pressure screening fractionation and laboratory flotation. The second series of trials were complete pilot plant operations consisting of the micro-hole fractionation (as done for the first trials), flotation, and finally hydrocyclone fractionation to generate different fractions for stratified paper manufacture in the laboratory. The results of the two trials are discussed separately, with the adoption of respective operating conditions and methodology.

Pulp fractionation by pressure screening was performed at the Centre Technique du Papier; Grenoble, France (CTP) recycled fibers pilot plant. Pilot plant equipment has been supplied by Kadant Lamort, Vitry Le François, France. The configuration of consisted of a 0.25-mm smooth hole screen basket and a solid core rotor with three hydrodynamic elements. The screen was fed from a 3 m³ tank. The inlet and reject lines were equipped with a flow transmitter, and the difference determined the flow in the accept line. Samples were taken from lines (fully open) that recirculated back the accepts and rejects into the feed tank. The pilot flotation cells were of Verticel type and the pilot hydrocylone was a Kadant-CT4 with a 65-mm head diameter. Laboratory flotation was performed in a Voith Delta 25L cell (Voith; Ravensburg, Germany).

For both the trials, the raw material consisted of a mixture of 75% old magazine (OMG) and 25% old newsprint (ONP), corresponding to Central European 1.11 grade according to EN 643 (The European List of Standard Grades of Recovered Paper and Board, version 2002).

As part of the trials, the following analyses were performed:

1. **Hyperwashing**: Performed with a high pressure water jet on a 90-µm wire opening. Controlled by visual in-



2. The two objectives of the experimental approach.

spection until filtrate was clear. The pulp fibers retained on the wire are called long fibers, while those passing through are short fibers, mineral filler, and fines. The technique allows rapid calculation of the ink detachment efficiency during the defibering (or dispersing) operation.

2. **Bauer McNett classification**: TAPPI Standard Test Method 233 cm-06 "Fiber length of pulp by classification" was followed.
3. **Optical properties**: Pulp pads made for pulp concentration were used to measure the optical properties brightness and effective residual ink concentration (ERIC) on a Technidyne spectrophotometer model: colour touch 2 (Technidyne; New Albany, IN, USA) with an ultraviolet (UV) filter.
4. **Fiber morphological properties**: MorFi fiber analyzer [23] (TECHPAP; Grenoble, France) was used to characterize whole pulp. The fiber length in this manuscript refers to the length-weighted fiber length.
5. **Ash content**: An oven-dried weighed sample concentration pad was subjected to 425°C in a furnace for 8 h.
6. **Specks content**: For only the deinking pulps, the specks content was measured by making handsheets of hyperwashed (to increase the contrast between the specks and fibers for image analysis and to remove all the microscopic ink particles) pulp, 1.2 g in weight, on Rapid Köthen sheet former (PTI Laboratory Equipment; Vorchdorf, Austria). The sheets were then analyzed for specks content using the SIMPATIC image analyzer (TECHPAP; Grenoble, France). This method allows measuring the "detached' free specks or those in the form of inked coating flakes fragments (>90 µm), as well as the attached specks on the fibers (>50 µm). However, this analysis does not differentiate between free and attached specks.

FIRST SERIES OF TRIALS: DEINKING LINE RATIONALIZATION

Operational parameters and methodology

The re-slushing of the raw material was done in the pilot Hélico pulper in neutral conditions at 45°C and 16% concentration.

The pressure screen operating conditions are reported in **Table I**. The screen was first run in recirculation mode (accepts and rejects recirculated back to the feed tank). This was done to understand the effect of volumetric reject ratio (or R_v, which is the ratio of reject to inlet flow) on the accept and reject fractions. At the lowest R_v of 20%, the streams were then directed into two separate tanks. The long fibers were diluted to 5 g/L for the 2nd pressure screening stage, where two different R_v were tested in recirculation mode, as was done for the 1st stage.

The accept fractions obtained and one reference pulp after pilot pulping (i.e., the inlet to 1st stage micro-hole screening) were subjected to laboratory batch flotation. The experiments were performed in absence of flotation chemistry; the operating conditions are reported in **Table II**.

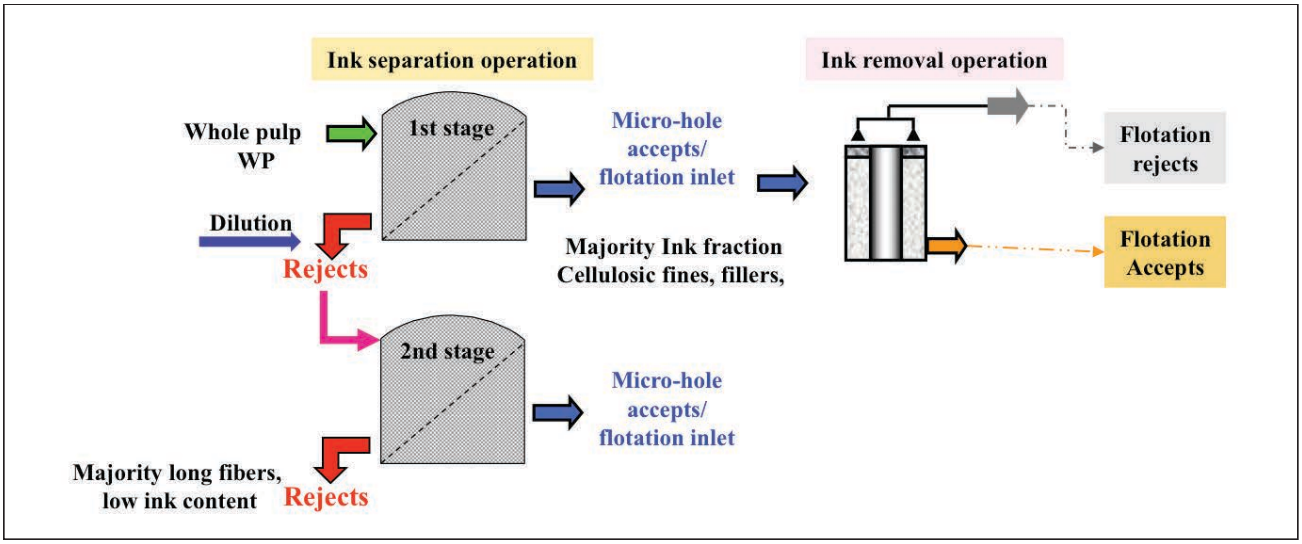
The complete experimental scheme is illustrated in **Fig. 3**. Though flotation has been used to understand the concept of selective treatment of fractions, this research

Stage	Inlet Concentration, g/L	Volumetric Reject Ratio, R_v, %
1	6	20, 30, 40
2	5	30, 40

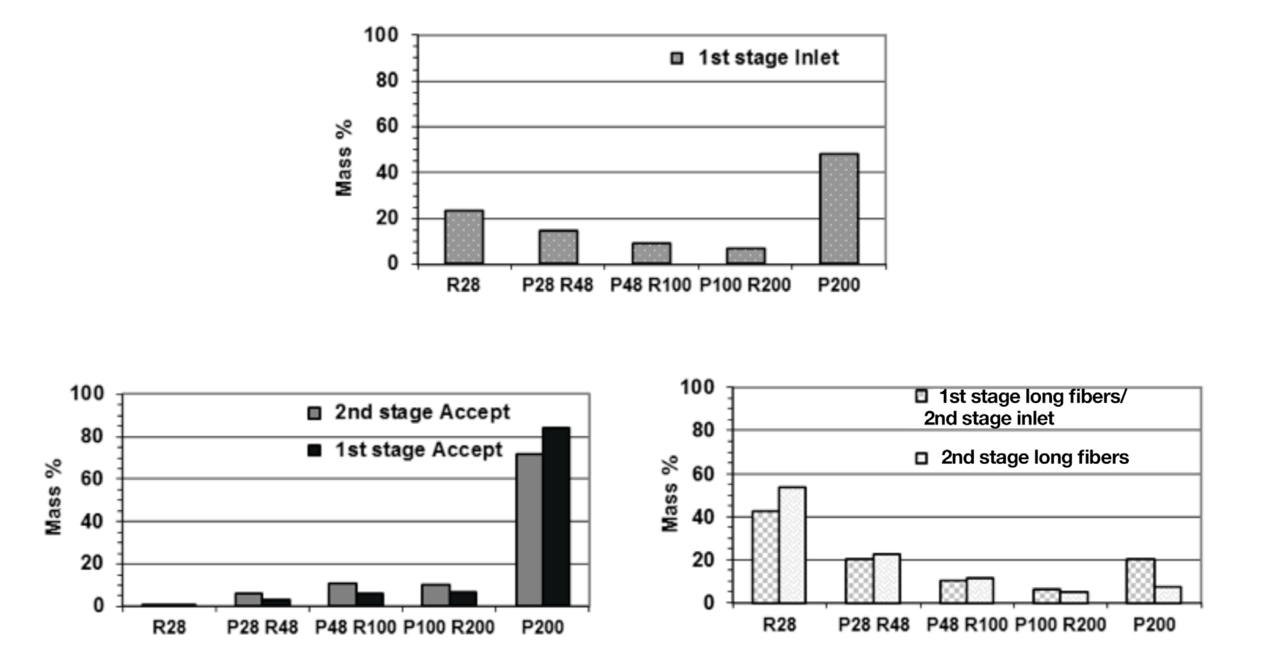
I. Pressure screen operating parameters

Suspension Volume for Each Test	22.5 L
Air introduced	7 L/min (200%)
Flotation time	7 min

II. Laboratory flotation conditions.



3. Micro-hole screening application in deinking pulp manufacture - feed forward setup.



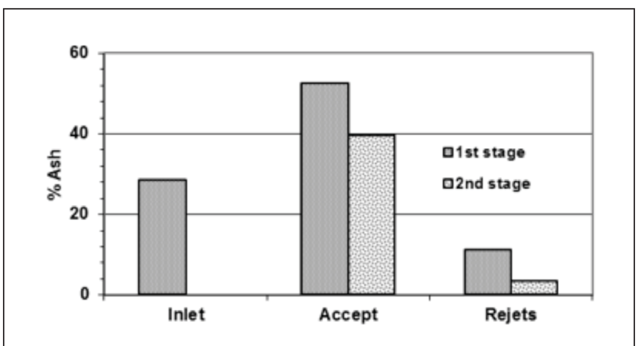
4. Bauer McNett evolution across the two stages of pressure screening trials.

focused on micro-hole fractionation and fractions generation. In fact, the ink rich fraction obtained from the pressure screen operation was subjected to standard flotation conditions and not studied critically with respect to flotation cell operational parameters.

Results and discussion

Bauer McNett results

Bauer McNett results reported in **Fig. 4** show the evolution of different fractions at the 2 stages of 0.25-mm hole screening (P indicates passing the mesh; R indicates retained on the mesh). The first stage inlet pulp is composed of a significant amount of 48% P200 fraction. First and 2nd stage accepts contain 84% and 72% of P200 fraction, respectively (values are reported for 20% R_v in 1st stage and 30% R_v in 2nd stage). As expected, the long fiber fraction gets depleted in fines. However, some residual fines still remain in the 2nd stage long fiber fraction, which would indicate the presence of ink. The results clearly highlight that the micro-hole screen is very selective in fines separation into the accepts and in retaining the long fibers, which get concentrated in the reject fraction.



5. Ash content values for the two stages.

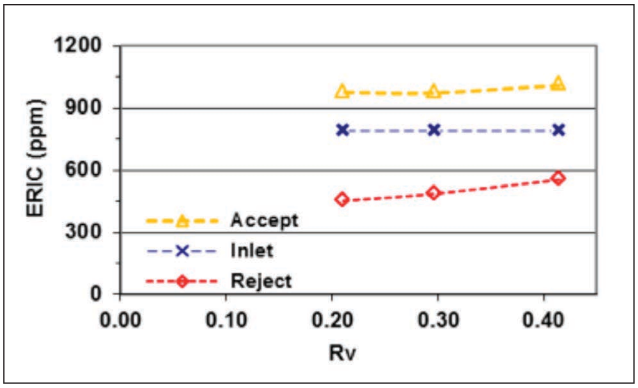
Ash content

Mineral fillers follow the flow split in the pressure screening system operation; the ash amount in accepts increases with respect to long fibers. The values are reported for lowest R_v (**Fig. 5**). As expected, the 2nd stage pressure screening operations further remove the fine fraction present, resulting in 3% ash content for the final long fibers.

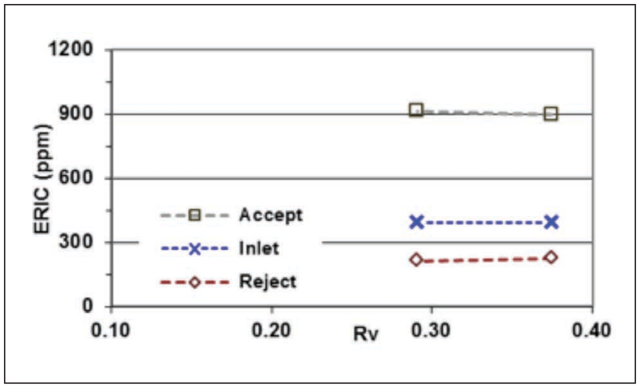
Optical properties

The fractionation trials showed that the long fibers in the reject fraction get depleted and accepts get enriched with the ink particles. The results obtained for each pressure screen's operating conditions are given in **Fig. 6** and **Fig. 7** for the ERIC, and in **Fig. 8** and **Fig. 9** for the brightness.

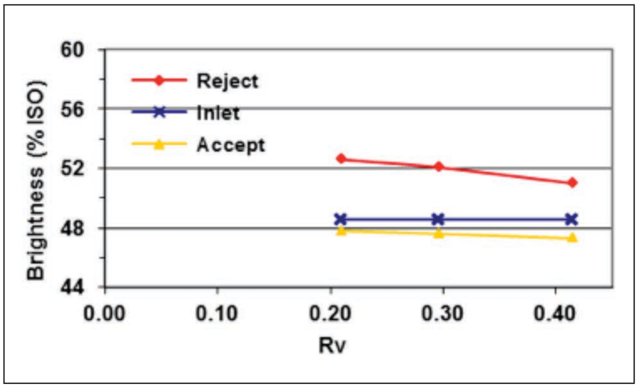
Fines containing ink particles and mineral filler follow the flow split; a lower volumetric reject ratio gives better results for long fibers ink content reduction. However, residual fines and ink particles still remain in the 1st stage long fiber fraction, even at the lowest tested R_v. Performing a 2nd stage micro-hole screening on this fraction improves the pulp brightness and further lowers the ERIC content to ~200 ppm, as fines are separated into the accept fraction. However, this is still not optimal, as the hyperwashed pulp brightness and ERIC values are 63% ISO and 51 ppm, respectively. This suggests that a further improvement of the final long fibers could be possible. Among the solutions that should be tested are operating the 2nd stage pressure screening at lower R_v and/or the implementation of a 3rd stage.



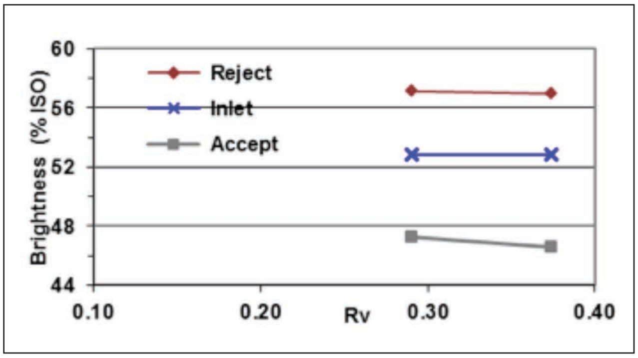
6. First stage ERIC evolution.



7. Second stage ERIC evolution.



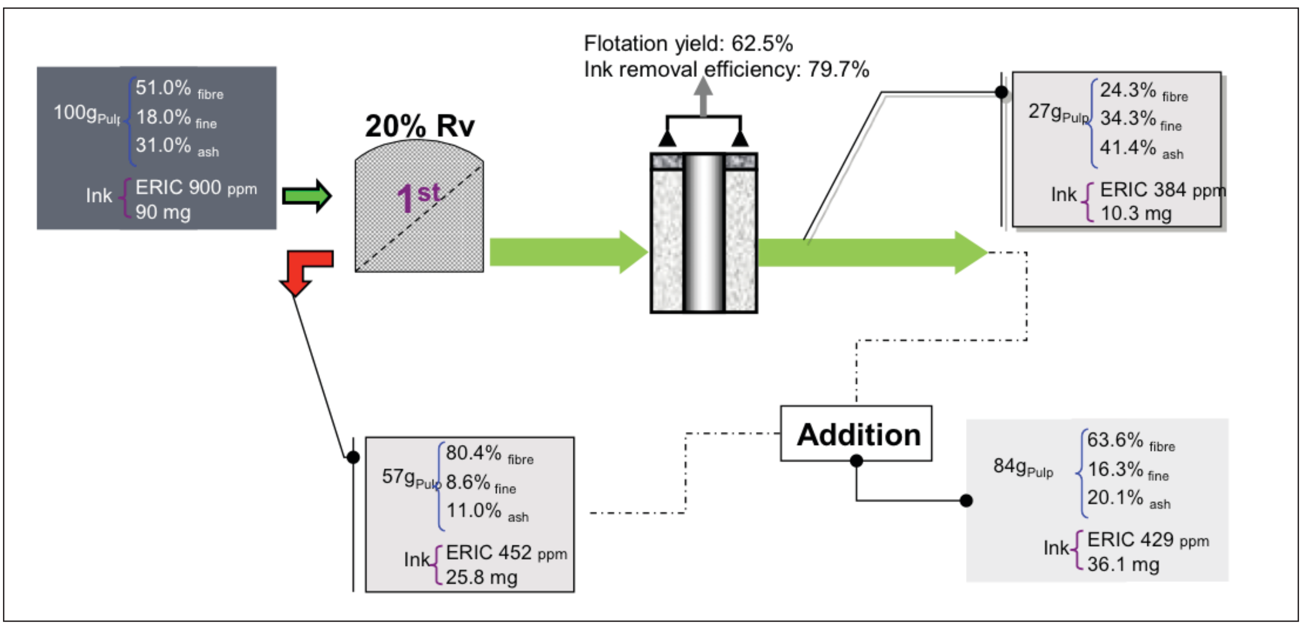
8. First stage brightness evolution.



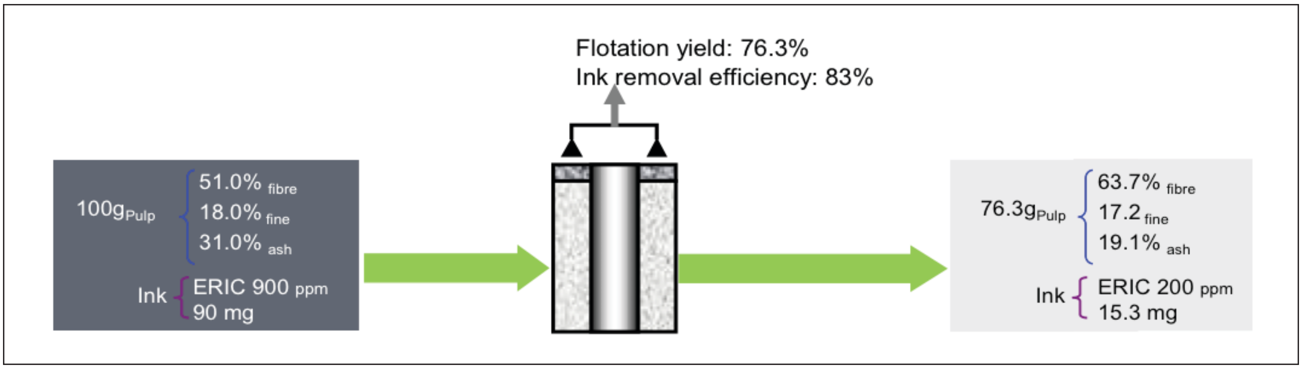
9. Second stage brightness evolution.

Flotation results

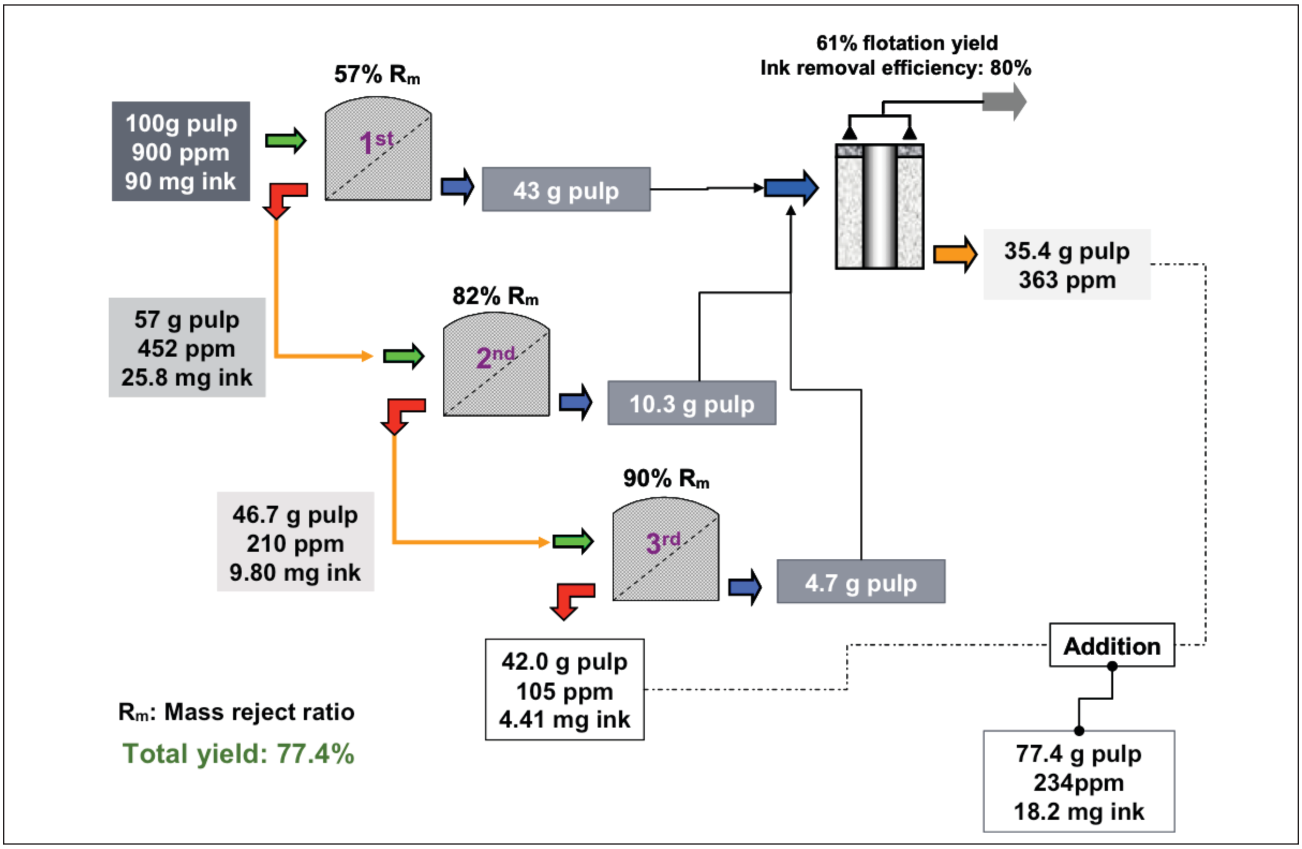
Fines and ink rich micro-hole accept fraction (at various R_v) were subjected to ink removal treatment in laboratory flotation cells. Rough calculations were done in order to verify if the new proposed process can potentially lead to the same pulp characteristics as for the conventional one (without screening and with whole pulp flotation). As can be seen in **Fig. 10**, the (screening + fine flotation) process has slightly higher yield on addition of the 2 pulp streams than the full stream flotation process reported in **Fig. 11**. If re-mixing the screening rejects and the screening accepts after their flotation, the final pulp has a similar composition as that of



10. Final pulp characteristics: 1-stage fractionation at 20% R_v and fine flotation.



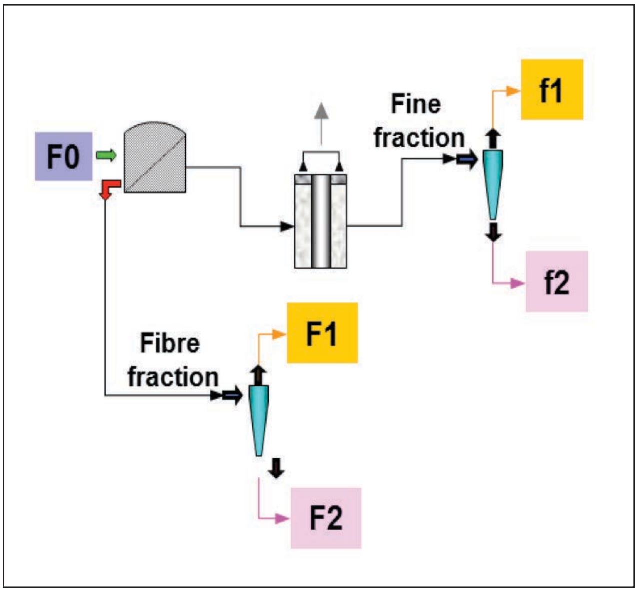
11. Pulp flotation without fractionation (reference).



12. Three-stage micro-hole fractionation and fines flotation.

the whole pulp treated by flotation, without prior screening, as shown in dotted lines in Fig. 10. The fiber concentration is calculated by hyperwashing; fines here refer to cellulosic fines, which have been calculated from total fiber and ash concentration. Ink removal efficiency refers to the ink mass removal. It has been calculated on pulp mass and the associated ERIC content in the inlet and accepts stream.

The major difference between the two scenarios is the final ink content, which is higher for that obtained with the new process involving only 1-stage fractionation in the present case. When considering each step, the main origin of this additional ink amount is its presence in the screening stage of long fibers that were not treated by flotation to remove the residual ink. For this reason, the addition to the screening of a 2nd stage, and even of a 3rd stage, could be beneficial. As analyzed in **Fig. 12**, the 3-stage screening with fines flotation could give approximately the same yield as the whole pulp flotation, and more importantly, with the same residual ink. The values of mass reject ratio, R_m, and ERIC for 1st and 2nd stages are from the experimental pilot trials at the lowest volumetric reject ratio. For the 3rd stage, a value of 90% R_m and 50% reduction in ERIC content has been assumed, considering a very high amount of long fiber at the 3rd stage inlet. Another hypothesis has been taken into consideration for flotation operations that will treat the combined flow of the 3 stages with the accepted pulp ERIC at the average



13. Fractionation deinking simplified schematic.

of the three micro-hole accept flotation (R_v) found experimentally. The average value of yield and accept pulp ERIC as obtained in the 1st stage experimental trial have been considered.

Though the schematic presented in **Fig. 12** depicts 3 separate pressure screening systems (batch) in feed forward mode, the same configuration can be applied in a single unit with 3-separate screening zones. Such systems already exist and are functioning at industrial scale. Operating the 1st stage at low volumetric reject rates removes the maximum amount of fines into the accept fraction. The 2nd and 3rd stage accepts can be fed backward for interstage dilution as they are diluted. This scenario could considerably reduce the pulp dilution requirements for 1st stage and 2nd stage. The major impact on energy consumption would come from energy application stages (high speed disperser, low speed kneader), where only a fraction of the pulp containing the majority of specks would be treated. In the previous scenario, this represents 42% of the whole pulp. Less amount of pulp flux could also signify either lower flotation capacity requirements or smaller design of equipment.

SECOND SERIES OF TRIALS: FRACTIONS GENERATION FOR STRATIFIED PAPER MANUFACTURE

Operational parameters and methodology

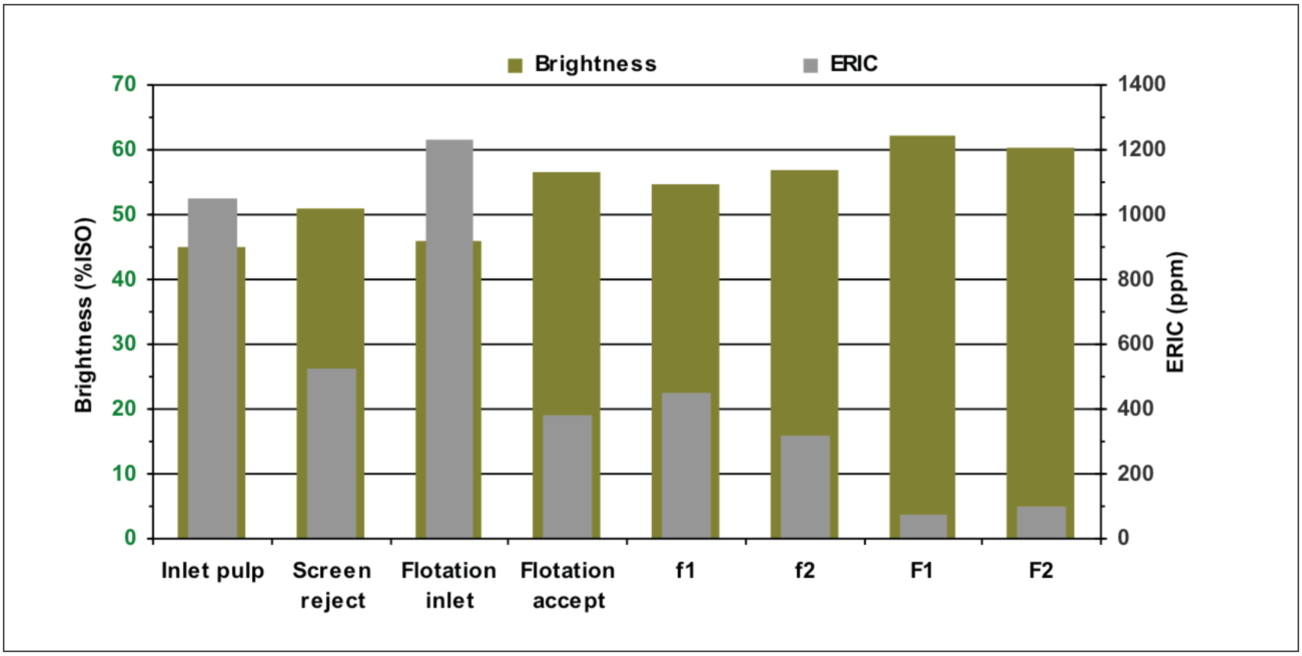
The approach of micro-hole fractionation and accepts flotation can be developed further if distinct fractions have to be produced for a multi-layer manufacturing process. The 2nd series of complete pilot plant experiments described in the following section illustrate the combined use of two different fractionation technologies and flotation operations to produce different fractions. The pilot operating conditions are reported in **Table III**. The 2nd and 3rd stages of micro-hole fractionation were substituted by washing stages.

The micro-hole accepts containing the majority of free ink were treated in flotation cells. The flotation accepts containing the majority of fines were stored and heated by direct steam injection for hydrocyclone fractionation. The long fibers obtained after 1-stage screening were diluted with tap water and treated on a Classiflux washer (a wire washing technology developed by CTP). The washing process takes place on an inclined open wire with a 355-µm opening. The fiber mat formed due to dewatering is continuously unclogged by counter current moving bars located under the wire. For hydrocyclone fractionation, the pulp was diluted with hot water to 5 g/L concentration. Accept and reject hydrocyclone fractions were again washed on a Classiflux washer. This was done to decrease the residual ERIC content of micro-hole rejects, as only a 1-stage pressure screening was performed. The trials led to production of 2 “fine” fractions, f1 and f2 (named as such because they contained the majority of fines), and 2 “fiber” fractions, F1 and F2, as they contained the majority of fibers.

The objective of this series of pilot plant trials was to obtain 2 fines and 2 fiber fractions. The results described hereafter provide an indication that the approach outlined in the experimental schematic illustrated in **Fig. 13** can be developed (optimized) further. A complete process configuration could include fine screening operations of the micro-hole screening rejects to remove macro-stickies followed by application of mechanical energy to fragment the specks and detach residual ink from the fibers.

	Remarks
Pulping	16% concentration, 50°C, 15 min pulping time, 0.4% of soap SERFAX MT90
Pressure screening	11 g/L inlet concentration, 20% volumetric reject rate
Pilot flotation	4.4 g/L inlet concentration, 50°C temperature
Hydrocyclone	~180kPa ΔP, 50°C • Fine fractionation: 2 g/L inlet concentration, ~48% mass reject ratio (R_m) • Fiber fractionation: 5 g/L inlet concentration, ~50% mass reject ratio

III. Operating conditions of various unit operations.



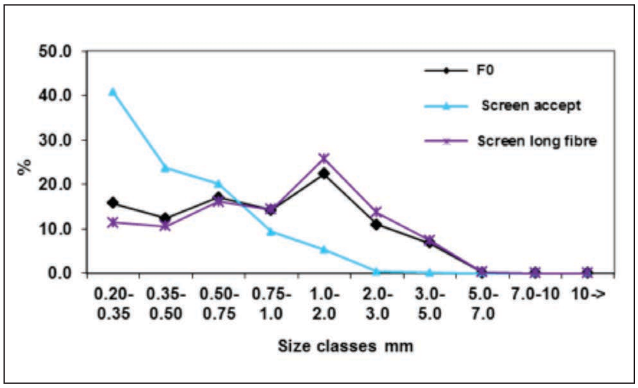
14. Brightness and ERIC values for various streams.

Results and discussion

Figure 14 shows the optical characteristics at selected positions of the experimental setup. The final fine fractions, f1 and f2, have a higher ink load in comparison to fiber fractions, F1 and F2, which reach almost the hyperwashed pulp characteristics.

The fractions f1 and f2 contain the majority of fines, short length and smaller width fibers, and filler/pigments (ash content), as reported in **Table IV**, in comparison to the fiber fractions F1 and F2, which are longer in length and have higher width. This is primarily due to efficient separation of fines and fiber fraction during micro-hole screening.

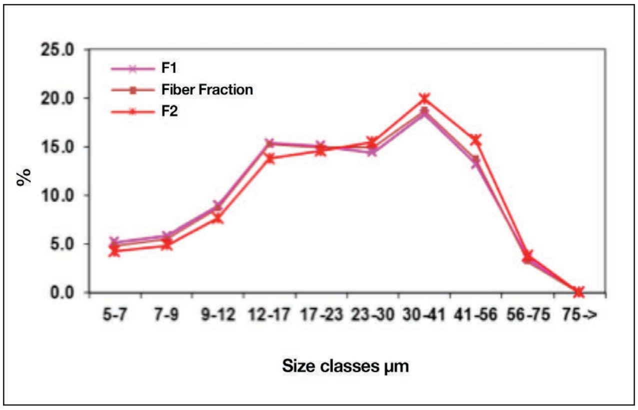
Figure 15 shows the fiber length distribution in various size classes after screen fractionation of the starting pulp: shorter fiber length in accepts and longer fiber length in rejects. Hydrocyclone fractionation of the flotation accepts or micro-hole screening long fibers provides 4 pulp streams that do not have the same morphological characteristics. Accepts (f1 or F1) contain fibers with small width diameters. This is explained further by examining the fiber width and length distributions of these fractions. Accept fractions have higher proportions of fibers in the smaller width class as shown in **Fig. 16** for fiber fraction and **Fig. 17** for fine fraction. High specific surface area fibrillar-type fines and fibrillated fibers get concentrated in the accept fraction.



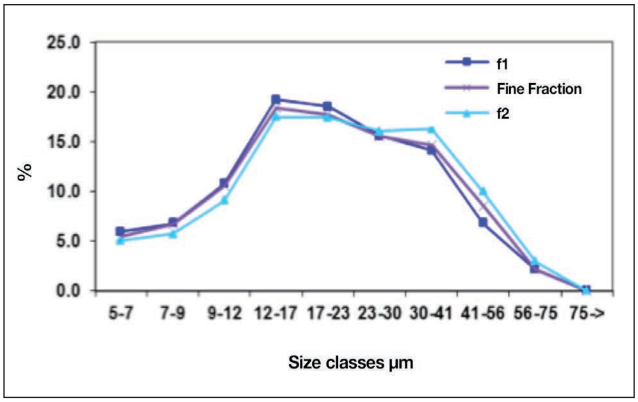
15. Screen fractions fiber length distribution.

	Intermediate Situation				4 Final Fractions Obtained			
	Inlet Pulp	Micro-hole Reject	Flotation Inlet	Flotation Accept	f1	f2	F1	F2
Ash, %	32.0	10.2	56.0	37.5	42.0	32.5	1.4	1.7
P200%, fines	52.5	23.8	88.1	78.0	84.5	72.6	10.4	6.6
Fiber length, mm	1.12	1.26	0.52	0.52	0.48	0.54	1.23	1.24
Fiber width, µm	24.4	26.0	22.2	23.0	22.0	24.3	25.4	26.8

IV. Pulp characteristics



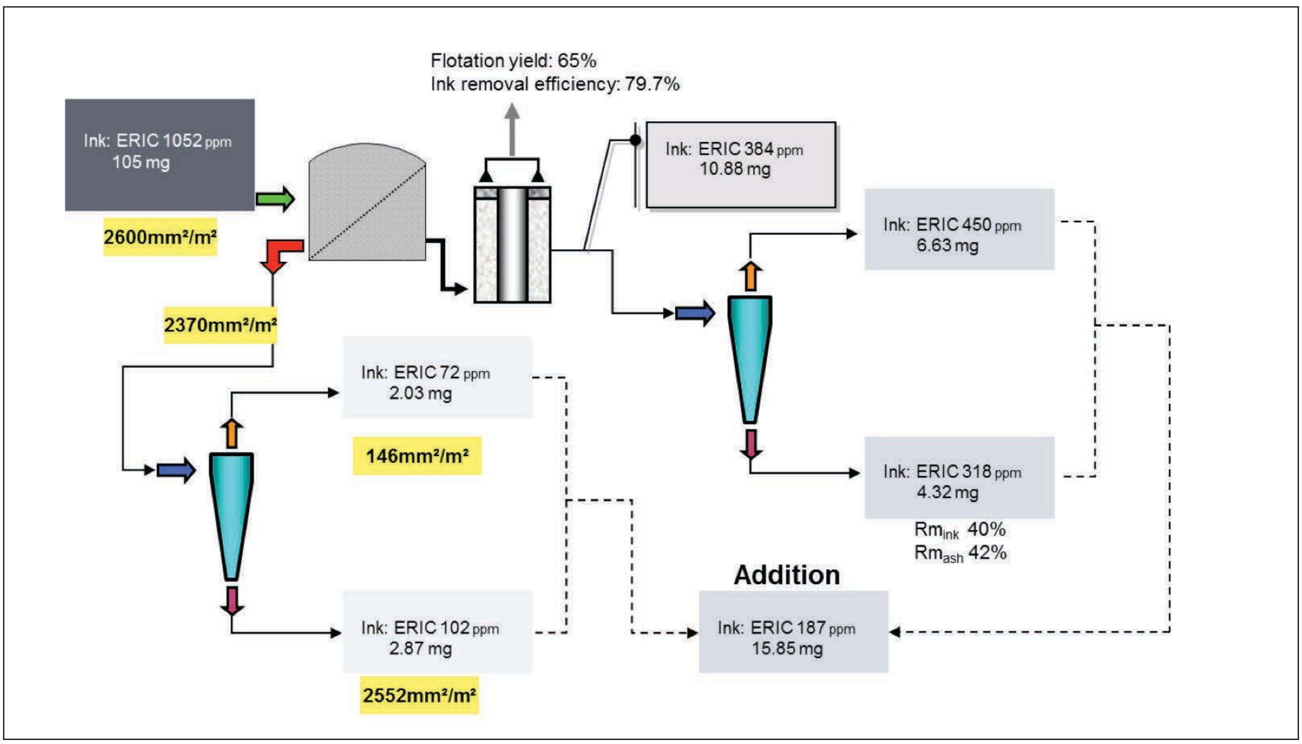
16. Deinking pulp hydrocyclone fiber fractions width distributions.



17. Deinking pulp hydrocyclone fine fractions width distributions.

Fractionation by hydrocyclone provides a very interesting scenario where the fractions produced could be put into different layers as envisaged in stratified paper manufacture. As an example, the accept fractions (f1 and F1), which have lower fiber width and more fibrillated fibers/fibrillated fines, will provide better strength properties and can be directed to surface layers, whereas the reject fractions (f2 and F2) could be directed to a middle layer (**Fig. 1**). In fact, from these four fractions, various combinations are possible, with different proportions of fractions in each layer. Additional benefits could also be achieved by performing separate bleaching treatment of the fractions. The bleaching costs could be reduced by studying the response of fractions to the bleaching dosage and chemicals.

Thanks to micro-hole fractionation, only 44% of the total pulp flow was treated in the flotation cells and 56% of the total pulp flow would be subjected to the screening stage (for macro-stickies removal with fine slots) and mechanical treatment. In the pilot plant flotation operations, the volume losses amounted to 18% with a yield of 65%. The ink removal efficiency at flotation stage was 80%, which is comparable to laboratory flotation trials described earlier. If all the 4 fractions are combined and considering no losses at washing and thickening stages (for example in industrial application, the corresponding flow would be mixed with micro-hole accepts) of screening rejects, the total yield would be 85%. Addition of all 4 fractions results in an ERIC content of 187 ppm, shown in a simplified schematic in **Fig. 18**. The schematic also shows



18. Combining all fractions leads to final ERIC of less than 200 ppm.

the specks flow (only done for fiber fraction and shown in yellow boxes, mm²/m²). Indeed, a major part of the specks are retained with the fiber fraction, as seen previously. And thanks to hydrocyclone fractionation (which also acts as a cleaner), the apex fraction gets enriched with specks content and the base fraction gets depleted. This also provides another scenario where different energy levels could be applied for specks fragmentation.

The analysis also indicates that during hydrocyclone fractionation of the flotation accepts, the free ink and mineral filler fraction follows the flow split, as R_{mink} and R_{mash} approximately equal R_v (42%). It is difficult to assume the same for fiber fractionation, as the ink is attached to the fibers and not free.

The results reported for series 2 trials show that the combined micro-hole and hydrocyclone fractionation methodology could be applied on a deinking line to achieve two distinct objectives: simplification of deinking operations and production of fractions for eventual multi-layer forming.

The trials showed the potential of micro-hole fractionation coupled with hydrocyclone fractionation, providing 4 different fractions that could be utilized in an optimized way for stratified sheet formation. First, the ink-containing fines fraction must be produced, and then treated in ink removal operations. Once treated, these fines could then be fractionated into high specific area fibrillar fines and low specific area flake-type fines. Separation based on cell wall characteristics could also be applied to the fiber fraction, leading to separation of fibrillated, thin cell wall fibers from coarse thick wall fibers in two different fractions. Such a strategy would lead to deinking line rationalization for energy efficiency and production of fractions for multi-layer sheet forming.

Sheet properties will depend on the type and quantity of fractions. With different optical and morphological characteristics, the fractions will provide a varying degree of property enhancement.

CONCLUSIONS

The objective of a series of experimental trials dedicated to fines fractionation obtained by using micro-hole pressure screening was twofold in the case of pulp manufacture from recovered fibers:

- Performing the right treatment for the right fiber type
- Producing fractions for possible multi-layer sheet structure

This was done by the application of pressure screening fractionation with a 0.25-mm micro-hole basket in deinking operations. This fractionation technology helped to produce two distinct fractions, which had different optical and morphological characteristics. The 2-stage pressure screening was very effective in separating fines and ink into accepts and in retaining the majority of specks, as well as clean long fibers with low ERIC content. This allowed performing dedicated treatment. One such treatment studied was ink removal operation in flotation cells. It was demonstrated by simple simulation that an additional pressure screening stage could further reduce the ink content in the long fibers. The total yield of 3-stage pressure screening and fine flotation would be equivalent or slightly better than whole pulp flotation.

In another test series, fractionation of the flotation accepts and micro-hole rejects based on fiber fibrillation state or fines specific surface area with hydrocylones lead to production of 4 fractions, which had different morphological characteristics. Accepts were enriched with low fiber width fibrillated fibers and high specific surface area fibrillar fines, whereas flake-type fines and less fibrillated fibers were concentrated in rejects. The major advantage of fractionation in a deinking line would first be dedicated treatment to the right fraction, and second, a possible energy savings in unit operations, as only a fraction of the whole pulp would be treated. **TJ**

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ABOUT THE AUTHORS

The continuous development of paper recycling over the last decades has strongly contributed to improved resource efficiency through saving of wood resources. Improving overall resource efficiency, including water and energy, was the objective of a large European project, Ecotarget "New and innovative processes for radical changes in the pulp & paper industry" (2004-2008), aimed at reducing energy; wood raw material and fresh water consumption; and waste and emissions.

Fractionation, i.e., the separation into different fractions of various pulp components, such as fibers with different morphological properties, cellulosic fines, minerals pigments, and inks, showed potential to save energy in the field of deinking, as the right treatments were limited to the right pulp fractions instead of the whole pulp in the conventional deinking process.

Another European project, BoostEff "Boosting raw material and energy efficiency using advanced sheet structure design and fiber modifications" (2010-2013), focused on developing new manufacturing concepts for wood-fiber based products giving a significant reduction in environmental footprint. The work reported in this paper has been carried out in the framework of the BoostEff project. The research has been focused on "fines fractionation," the separation of fine elements towards the optimization of the deinking process and the use of the pulp fractions in a layered paper sheet.

The work performed, namely the proposed rationalization of the deinking process with application of only the right treatment to the right fraction, offers perspectives for increasing competitiveness of the deinking process and the final pulp quality, with consequently, the possibility to increase recycled fiber usage in the graphic paper sector. The major part of this research was based on a new perforation-size basket of screening equipment. This was not considered before for deinking line rationalization. It was very interesting to evaluate the homogenous particles separation phenomenon and other fundamental aspects of this particular basket/rotor combination. A part of the research was devoted to observation of deinking pulp fines using light microscopy. A new technique to further fractionate the pulp fines was developed, and it was interesting to observe that some ink particles are preferentially attached to one group of cellulosic fine category.

The new fractionation strategy was developed to better valorize pulp fractions, which worked well in addressing the needs of a tailor made stratified sheet structure. Since the end of project BoostEff, the fractionation strategy work continues to be developed and applied in CTP research (in deinking as well as virgin fiber pulp). The work opens new stimulating possibilities reinforcing 40 years of CTP experience in the deinking research field.

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