# Multistage fiber fractionation of softwood chemical pulp through smooth-hole screen cylinders and its effects on paper properties

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**ABSTRACT:** Pressure screens are used to fractionate fibers on the basis of aspect ratio to obtain high value long-fiber rejects and less desirable fines-rich accepts. Fiber fractionation is more practical and of maximum economic and commercial benefits when a mill can make use of all obtained fractions. We have demonstrated the potential of upgrading the reject fraction through a multistage fractionation process of a northern bleached softwood kraft pulp while isolating the remaining low-value pulp to be used as a raw material for a novel fiber-based product. The optimum operating conditions such as volumetric reject ratio, $R_v$; aperture velocity, $V_s$; and screen aperture size to carry out efficient fractionation were determined for the screens with 0.5-mm, 0.8-mm, and 1.0-mm apertures. This work shows that a high fines percentage in the accept fraction and increased fiber length in the reject fraction can be obtained when operating the pressure screen at a higher $R_v$ and lower $V_s$ using the screen cylinder with the small aperture size (0.5 mm). Feed and fractionated streams of pulp were used to study the effects on the physical properties of paper. Handsheets were made for strength properties of the unfractionated and fractionated pulps for comparisons. Significant improvements in the physical properties were observed after the removal of fines.

***Application:*** Multistage fiber fractionation of softwood chemical pulp can boost the quality of rejects to maximize economic and commercial benefits. Accepts could be a low-cost feed for nanocrystalline cellulose production.

There is a considerable natural variation in fiber dimensions within a tree and also between species. Fiber fractionation processes can overcome this variation by splitting a pulp stream into several fractions. Commonly, fractionation of pulp fibers produces higher-value long-fiber rejects and lower-value short-fiber accepts. It is more practical and of greater economic benefit if the industry can use all pulp fractions by upgrading the reject fraction through multiple stages of fractionation and using the accepts for fiber-based products.

Fractionation has been used for many years, especially in mechanical pulping and fiber recycling. For chemical pulp producers, fractionation is a tool to optimize the properties of chemical softwood pulp fibers combined with refining [1,2]. When pulp and paper grades are already established, fractionation allows for upgrading an inferior pulp [3]. Long-fiber fractions could be directed to a separate stream for the production of a high-value reinforcing pulp to be used with a relatively weak pulp. The short-fiber fraction could be directed to the surface of a multilayer paper product that requires smooth exterior and good optical properties with the core containing long fibers for strength [4]. Long-fiber softwood pulps are desirable in papermaking, especially when strength properties are important. Removal of the undesired fines has been commercially practiced in chemical pulps (e.g., during production of high-performance sack kraft paper) so that the remaining long-fiber pulp could be refined to higher strength while preserving high porosity [5]. Fines are usually under 0.2 mm in length and typically are considered to be a low-value stream of the pulp. They can affect the physical properties of the paper and are also associated with diminished drainage and porosity.

Fractionation can be carried out using a pressure screen through the use of mechanical barriers for separate handling of the resulting fractions. These screens separate the fibers primarily by their length, which is well established in the literature [5-8]. Traditionally, pressure screens are used in pulping processes to remove undesirable materials such as shives, sand, plastic debris, and other large contaminants from pulp before it reaches paper machines. Regardless of the applications, fundamentals of screening or fractionation are similar. A pressure screen consists of two principal components: (1) a rotor and (2) a perforated cylinder located inside the pressure screen housing. Since the introduction of pressure screens, numerous screen cylinder and rotor designs have been made available. Smooth-hole screen cylinders have been found to fractionate pulp by length better than contour-slotted screens [5]. During fractionation, pulp is directed to the inside of the perforated cylinder. Accepted materials that mainly consist of water, fines, and short-fiber pulp are pushed outward radially through the screen apertures by turbulence created by the rotor motion. The remaining long fibers and oversized materials are retained on the screen and continued along the screen cylinder toward the reject stream. Bow screens are also studied for the removal of fines but they are less commonly used for pulp fractionation [9].

Degree of fiber fractionation is characterized statistically by the pulp passing probability, referred to as pulp passage ratio, P. The P of fibers in a length interval i, $P(l_i)$, is described in Eq. (1), where subscripts f and a refer to feed and accept, respectively; cn is the average number concentration per unit volume of a specific fraction; and $p(l_i)$ is the fiber length distribution of length fraction i [6]:

$$P(l_i) = \frac{c_{na} p_a(l_i)}{c_{nf} p_f(l_i)} \quad (1)$$

The length dependency on the probability of fiber passage through screen apertures has been extensively studied [5-8]. Fiber passage decreases from 1 to 0 as fiber length increases; P=1 means no restrictions to fiber and P=0 indicates that all the fibers retain on the screen (rejects). Fiber passage ratio, P, can be characterized using a single parameter, λ, shown in Eq. (2).

$$P(l_i) = e^{-\left(\frac{l_i}{\lambda}\right)} \quad (2)$$

The performance of a pressure screen depends on the interaction among various design and operating parameters. These parameters include screen cylinder's aperture size; average fluid velocity through the apertures or aperture velocity, $V_s$; and volumetric reject ratio, $R_v$, which is the volumetric reject flow rate divided by the feed flow. These parameters have shown significant effects on fractionation. Decrease in the pulp fractionation efficiency has been reported at increased $V_s$ using smooth-hole screen cylinders [10]. High $V_s$ has been linked to a high pressure drop over the screen cylinder, which implies that a higher force is exerted on particles on the screen surface; therefore, more large particles are accepted, resulting in reduced fractionation efficiency [10].

Olson et al. have extensively studied the effects of operating parameters at a pilot scale for the fractionation of mechanical pulp and removal of shives [5-8,11]. In terms of design parameters for the smooth-hole screen cylinder, fractionation efficiency was found to be dependent on the diameter of the holes for thermomechanical pulp (TMP) [6]. For the contour-slotted screen cylinders, it was found that the aperture velocity, $V_s$ and the aperture width greatly affect the fractionation results [5]. Increasing the slot width provides an easier passage for pulp. Smooth-hole screen cylinders were found to provide better size separation than the contour-slotted screens. Another fiber length fractionation study of TMP using smooth-hole screen cylinders and profile-slotted screen cylinders showed improvement in fractionation by reducing the aperture size, rotor tip speed, $V_t$, and $V_s$ [12]. Varied response to $V_t$ with slotted and holed screen cylinders were found using both chemical and mechanical pulps; fractionation efficiency increases for some cylinder and pulp combinations but decreases in others [10,13,14]. However, in general, fractionation efficiency decreases with an increase in $V_t$, $V_s$, and aperture size.

Mass reject ratio, $R_m$, describes the split between feed and reject. Mass reject ratio is directly related to the volumetric reject ratio, $R_v$, and reject thickening factor, T, whereas T is a ratio between reject consistency to the feed consistency. One can estimate mass reject ratio when the consistencies of the fractions and the volumetric reject ratio are known. The reject thickening factor can also be predicted using passage ratio from Eq. (3):

$$T = R_v^{\ P-1} \quad (3)$$

where $R_v$ is volumetric reject ratio and P is passage ratio.

The main goal of the research presented in this article is to use all the pulp fractions to maximize economic and commercial benefits. This study determined the quality of the pulp after the removal of fines to estimate the economic potential of the quality boost in rejects and simultaneously evaluate accepts as a low-cost feed for nanocrystalline cellulose (CNC) production. We have experimentally investigated the effects of varying operating parameters (e.g., $R_v$, $V_s$, and $V_t$) using smooth-hole pressure screens with a range of apertures. Series of experiments were performed to determine the best possible combination of the operating parameters using certain aperture sizes. This paper describes the details of the experiment to optimize fractionation efficiency. Apart from fractionation, the quality of the rejects is discussed briefly in comparisons of the handsheet properties. Accept and low-cost fines fractions were successfully investigated for the production of CNC, which potentially could replace the use of high-quality pulp. The study regarding CNC will be presented in the second article of this series.

## MATERIALS AND METHODS

### *Feed pulp and experimental setup*

Dried sheets of northern bleached softwood kraft pulp were soaked overnight and reslurried before use. Feed pulp with consistency 1%±0.2% was prepared in a 1-m³ feed tank. The pulp had a length-weighted average fiber length, $L_w$, of 2.48 mm and a fines (<0.02 mm) percentage of 2.90 wt%. The freeness value was approximately 660 mL CSF.

All fractionation trials were carried out using a Beloit MR8 small industrial pressure screen and several 8-in. diameter smooth-hole screen cylinders. Pulp was fed tangentially from the feed tank to the screening annulus where it is accelerated


***1. Photograph of the fractionation loop, screens, and rotor that were used for the study.***

to a high tangential velocity by a rotor. An AFT EP rotor (Aikawa Fiber Technologies; Sherbrooke, QC, Canada) with two foils was used in all trials, and it was driven by a variable frequency drive (VFD). The feed pressure can be adjusted using the VFD, attached to a centrifugal pump. The pressure screen loop is fully automated and controlled by a computer program. Accept and reject lines are equipped with pneumatic control valves and magnetic flow transmitters for testing a wide range of flow rates. The screen is also equipped with electronic pressure transducers to monitor and control pressures of the feed, accept, and reject lines. Photographs of the setup, screen, and rotor are shown in **Fig. 1**.

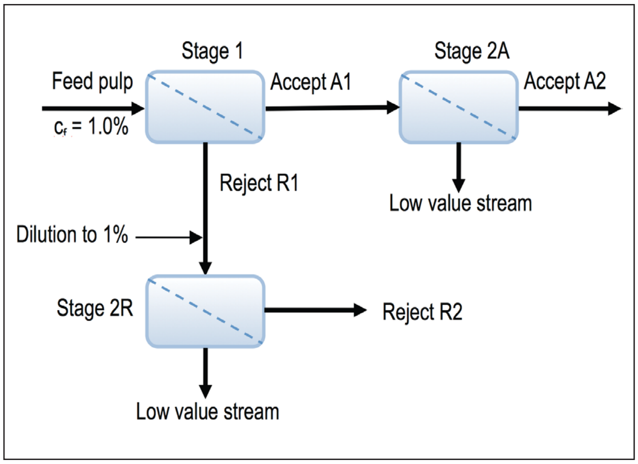
### *Multistage fractionation*

The multistage fractionation process is schematically illustrated in **Fig. 2**. The fractionation trials were carried out in three separate phases.

Stage 1

During this stage, operating parameters for efficient fractionation were determined. Feed consistency was maintained at approximately 1% and rejects were recirculated to the feed tank. Small samples were collected from the sampling valve for characterization, which does not affect the overall characteristics of the feed.

A range of aperture velocities from 0.3 $ms^{-1}$ to 1.0 $ms^{-1}$ was




***2. Schematic of multistage fractionation: stage 1 to determine best operating parameters for efficient fractionation; stage 2R, second stage fractionation of reject, R1, from stage 1; and stage 2A, second stage fractionation of accept, A1, from stage 1.***

achieved for the smooth-hole screens with aperture diameters of 0.5 mm, 0.8 mm, and 1.0 mm. Experiments were performed for volumetric reject ratio, $R_{v(1)}$, 0.3, 0.4, 0.5, 0.6, and 0.7 to obtain the efficient operating conditions. For all experiments, rotor tip speed, $V_{t(1)}$, was kept constant at 16 $ms^{-1}$ to compare the effects of varying $R_{v(1)}$, $V_{s(1)}$, and aperture diameter on fractionation. Maximum fractionation efficiency was achieved from the rotor with aperture diameter of 0.5 mm at $V_{s(1)}$= 0.3 $ms^{-1}$, $R_{v(1)}$=0.6, and $V_{t(1)}$=16 $ms^{-1}$. Rejects and accepts were collected using these parameters for the subsequent fractionation stages.

Stage 2R

In this stage, the reject from stage 1 (R1) was fed to the pressure screen. Consistency of the collected R1 was maintained to approximately 1% with addition of water at this stage. Only the screen cylinders with 0.5-mm apertures were used for the second stage. Experiments were conducted at $V_{s(2R)}$= 1.6 $ms^{-1}$, $R_{v(2R)}$=0.6, and $V_{t(2R)}$=16 $ms^{-1}$.

Stage 2A

During stage 2A, accepts from the first stage (A1) were refractionated using screens with an aperture diameter of 0.5 mm to concentrate the fines in the final accept stream (A2). The consistency of the feed A1 was about 0.11%. The following operating parameters were used for this stage: $V_{s(2A)}$=0.3 $ms^{-1}$, $R_{v(2A)}$=0.6, and $V_{t(2A)}$= 4 $ms^{-1}$.

In the current studies, pulp streams named as low value streams in stages 2R and 2A were not evaluated. It was even difficult to estimate their consistency as they contain very small amounts of material. At large-scale industrial fractionation processes, these low-value streams could consist of significant amounts of material that potentially can be used as a raw material for CNC.

The reject and accept fractions of interest are R1, R2, A1, and A2. Estimated mass of the accept fractions was approximately 4% of the feed pulp and estimated mass of the reject fractions was approximately 96% of the feed pulp. All the low-value streams along with accepts could be used for the nanocellulose-based products.

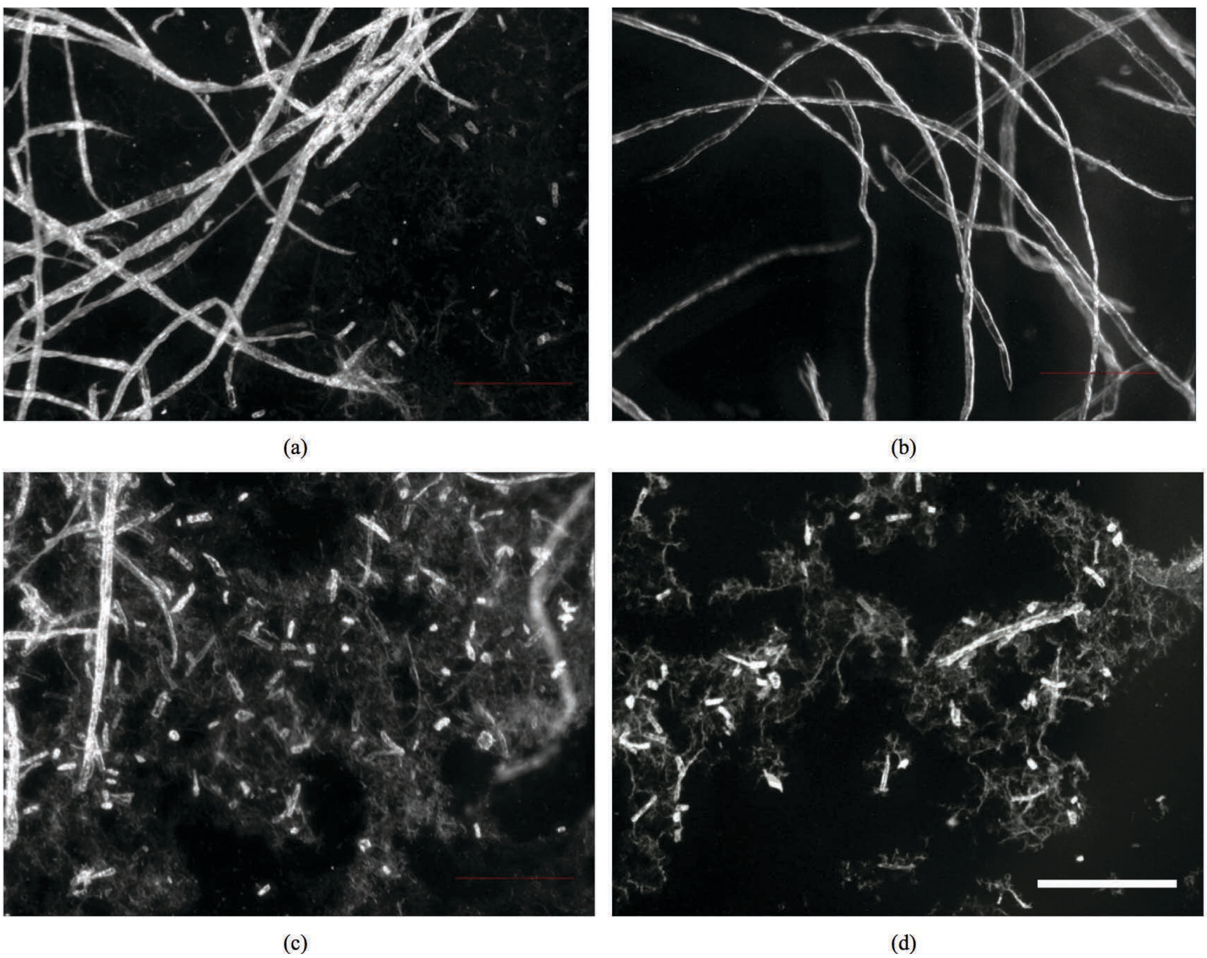
### *Pulp evaluation*

Samples of 2-3 L were obtained from the manual sampling valves located immediately after the screening area. All pulp samples were evaluated for consistency. This information is required when evaluating passage ratios. The fiber length distribution and fines content of the feed, accept, and reject fractions were measured using a fiber quality analyzer (FQA) (OpTest Equipment; Hawkesbury, ON, Canada). For the FQA analysis, each sample was diluted to a very low consistency before running it through the instrument. The FQA projects images of single fibers in the sample using circular polarized light as the fiber suspension passes through an optic box, and a digital camera takes pictures of the fiber projections [15]. Light microscope images of the feed pulp and all obtained fractions were recorded using a digital camera attached to an Optiphot microscope (Nikon; Tokyo, Japan). Handsheets were prepared from the pulp fractions and then their physical properties were tested.

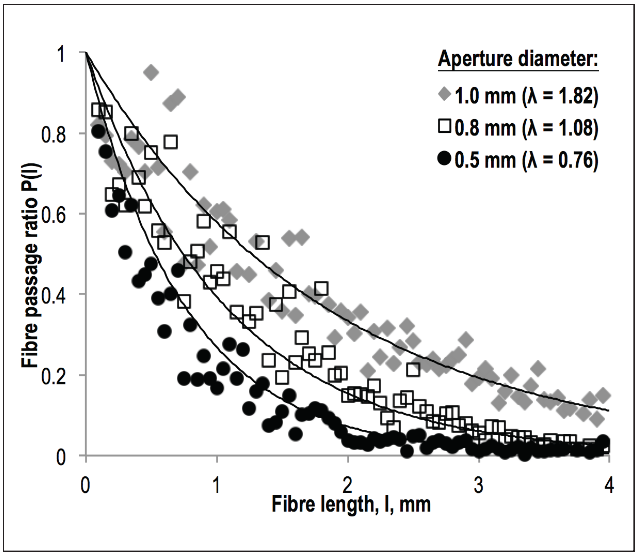
## RESULTS AND DISCUSSION

### *Optical microscope of the pulp fractions*

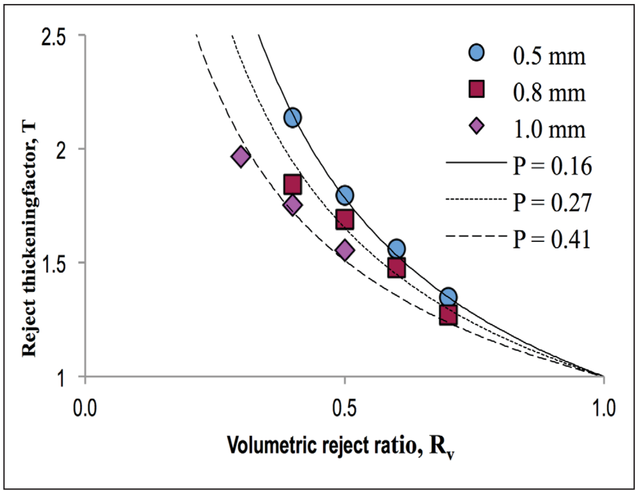
The reject and accept fractions were initially analyzed using a light microscope, as shown in **Fig. 3**. In Fig. 3a, R1 shows a small amount of fiber fragments and fines in the sample. Some fine fibrils can also be observed. On the other hand, the R2 sample comprises mostly fibers and no other small particles. Most fines have been successfully removed from R2. For accepts A1 and A2 in Fig. 3c and Fig. 3d, respectively, the A1 fraction contains some long fibers while the A2 fraction contains only very short fibers and fines. Accept fractions A1 and A2 contain a variety of different types of small particles. Chunky fines materials and clusters of cellulose fibrils (thread-like structures) are visible in both samples. Compared to the



***3. Microscope images of the reject fraction (a) R1 obtained after the first stage of fractionation and (b) R2 obtained after the second stage of reject fractionation. Microscope images of the accept fraction (c) A1 from the first stage of fractionation and (d) A2 from the second stage of accept fractionation. Bar is 400 μM.***




***4. Fiber passage ratio, P, plotted against fiber length for three aperture diameters at a constant $R_v$ of 0.6 and $V_s$ of 0.3 $ms^{-1}$. Data show that screens with 0.5-mm apertures removed fines more efficiently.***




***5. Calculated reject thickening factor, T, as a function of volumetric reject ratio, $R_v$, for several aperture diameters at constant $V_s$ of 0.3 $ms^{-1}$. Smooth and dotted lines show predicted reject thickening calculated using Eq. (3).***

rejects, accepts contain a higher amount of fibrils. For chemical pulp, the fines materials could be primary fines (coarser ray-cell rich fines) or secondary fines (finer fibril-rich fines generated during further refining stages) [16].

### *Operating parameters to obtain efficient fractionation*

Passage ratio

Passage ratios for all the collected samples were calculated using Eq. (1) as shown in **Fig. 4** (data were collected using the best operating parameters for each screen). Data are fitted using Eq. (2), giving the value of λ, which decreases from 1.821 to 1.075 and finally to 0.760 for the screen cylinders with 1.0-mm, 0.8-mm, and 0.5-mm apertures, respectively. Olson et al. have reported that the fiber with length 0.61 λ will have a passage ratio of 0.5 [7]. Figure 4 shows that with decrease in λ, the passage ratio of the long fibers dropped with decreasing aperture diameter. The average or bulk passage ratio, P, for the screens was estimated to be 0.41, 0.27, and 0.16 from the data in Fig. 4. Screens with an aperture diameter of 0.5 mm are more effective at removing the fines from the feed pulp. This is not unexpected given that with bigger aperture size more long fibers are able to pass through the apertures, resulting in more short-fiber fractions along with fines in the accept.

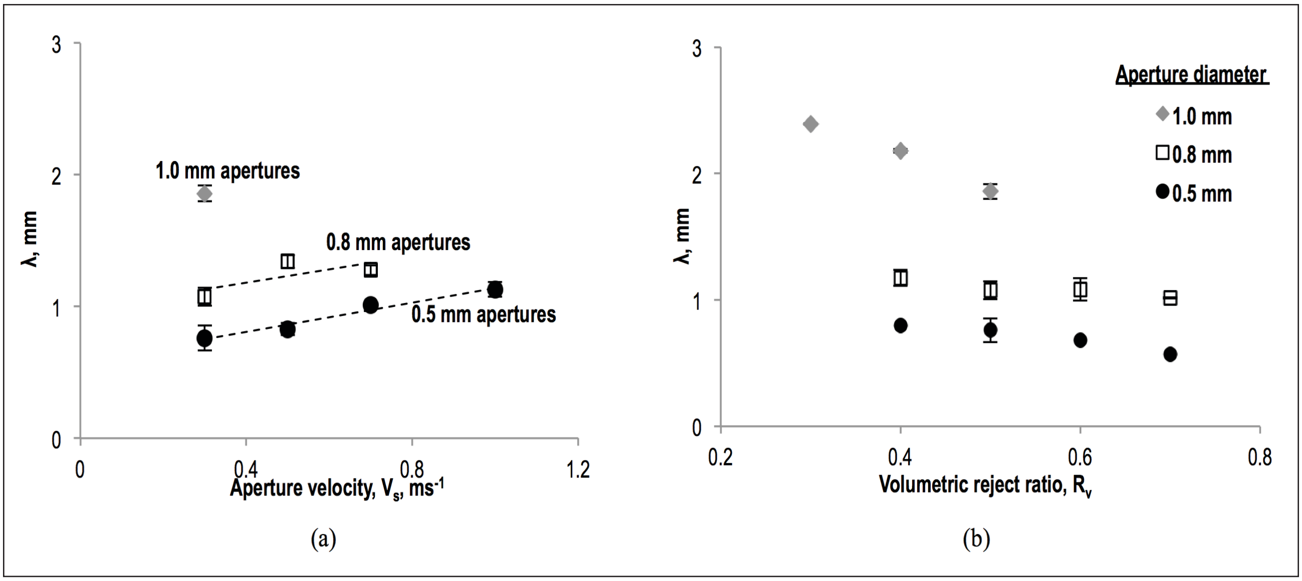
Using the bulk passage ratios, one can predict the value of the thickening factor for each value of $R_v$. In **Fig. 5** the reject thickening factor, T, is plotted against the volumetric reject ratio for the three cylindrical screens, for comparison, at constant $V_s$ of 0.3 $ms^{-1}$. Thickening factor was predicted using bulk passage ratios in Eq. (3). The continuous and dotted lines in Fig. 5 are the predicted values of T, which demonstrate good agreement with experimental results.

Thickening increases exponentially with decreasing $R_v$ as more water is removed from the feed to the accept side with a smaller $R_v$. Also, T increases with decreasing probability of overall fiber passage, P. Operating the pressure screen at a low $R_v$ poses a risk of plugging the reject line due to high reject thickening. Therefore, it is desirable to minimize the thickening for better screen runability. As shown in Fig. 5, at constant $V_s$ (0.3$ms^{-1}$) and $R_v$, reject thickening increased with decreasing aperture diameter because fewer fibers are accepted with smaller apertures. In other words, rejects of the screen cylinders with 0.5-mm apertures experience a greater level of thickening due to a higher number of long fibers that are not able to pass through as easily as during the fractionation using the screen with 1.0-mm apertures. This difficulty for long fibers using 0.5-mm apertures resulted in better separation of long and short fibers and fines, and thus better fractionation.

Aperture velocity and volumetric reject ratio

**Figure 6a** shows λ plotted at a constant $R_v$ of 0.6 with the aperture velocity, $V_s$, from 0.3 $ms^{-1}$ to 1.0 $ms^{-1}$ for the screen cylinder with 0.5-mm apertures. No trials were conducted for $V_s$ above 0.3 ms-1 and 0.7 $ms^{-1}$ for the screen cylinders with 1.0-mm and 0.8-mm apertures, respectively. This is because the holes in the cylinders were plugged at the beginning of the trials; hence, higher rotor speed would be required to prevent this plugging. The plot shows that increase in $V_s$ leads to increase in λ. High $V_s$ causes long fibers to pass through the apertures. This increase in the fiber passage is associated with greater fluid drag at a higher aperture velocity that forces the long fibers through the apertures more than the short fibers that decrease fractionation efficiency [12]. Olson et al. found no dependence of fractionation efficiency on aperture velocity using smooth-hole screen cylinders with 1.0-mm, 1.75-mm, and 2.1-mm apertures using a TMP pulp [7].

Comparison of the effect of volumetric reject ratio, $R_v$, on




***6. (a) λ versus aperture velocity at a constant $R_v$ of 0.6 for the three aperture diameters and (b) λ is plotted against volumetric reject ratio, $R_v$, at constant $V_s$= 0.3 $ms^{-1}$. Increasing $R_v$ appears to reduce λ. Error bars represent standard deviations.***

passage ratio is shown in Fig. 6b. In the figure, $R_v$ and λ seem to display a roughly negative linear relationship unlike that previously shown for TMP pulp where fiber passage and fractionation efficiency are wholly dependent on aperture size [7]. In addition, λ and consequently P were found to have greater dependency on $R_v$ for the screen cylinders with 1.0-mm apertures compared to screen cylinders with 0.5-mm and 0.8-mm apertures.

### Pulp quality at fractionation stages

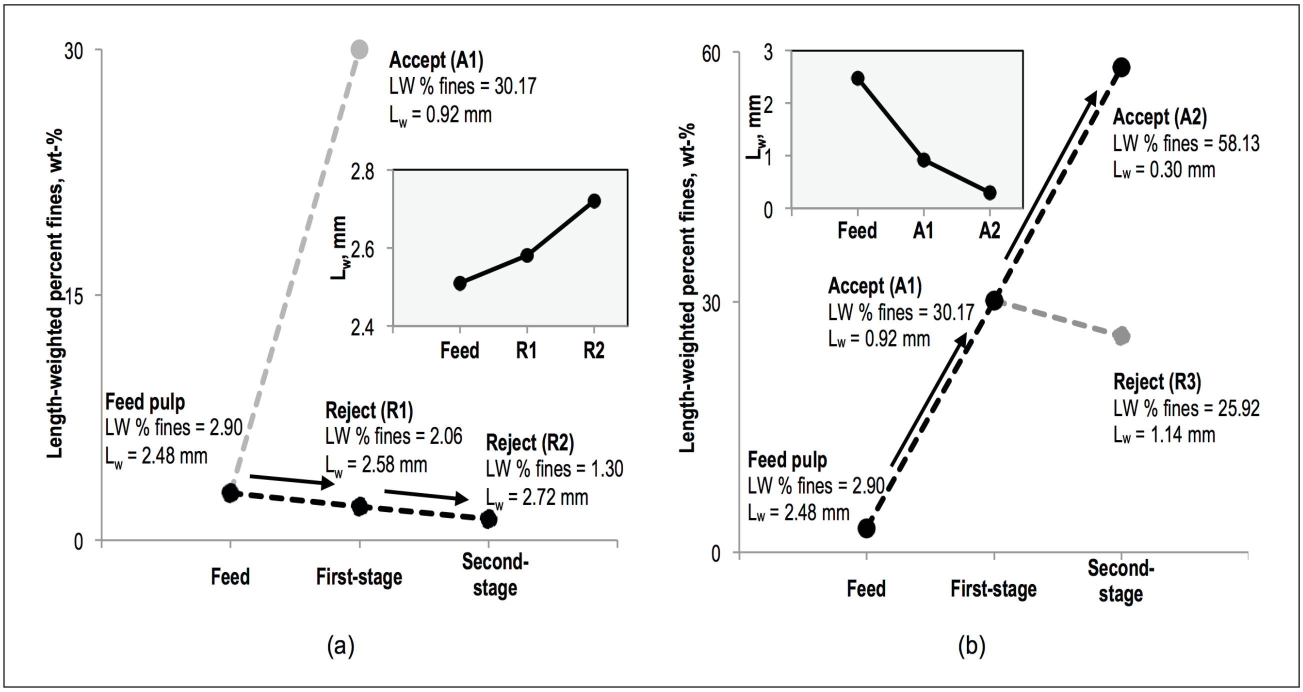
After determining the operating parameters for efficient fractionation, experiments were conducted using 0.5-mm screens, and the fractionated pulp streams were evaluated. Results are summarized in **Fig 7**. Figure 7a shows that the increase in average fiber length in the reject can be achieved at each fractionation as with the removal of fines. Fines percentage decreases to 1.3% in R2 whereas the weighted length of the fibers increases to 2.72 mm, which gives the pulp fraction with longer fibers. The final reject, R2, had an average length almost 10% higher than the original pulp. Fines content was reduced from 2.90% to 1.30%. The freeness of the R2 pulp also increased from 667 mL CSF to 701 mL CSF as a result of the removal of fines. A freeness value has a direct relation to the fines content in a pulp suspension. Reducing the fines content in a pulp suspension can provide a more open network in a pulp; therefore, water is able to drain through the suspension more readily. Figure 7b shows the accept fractions at the different stages of fractionation. In the final stage, fine-rich accept fraction A2 was obtained under the conditions summarized in the experimental section using 0.5-mm screens. The accept fractionation successfully generated a final accept fraction (A2) that mostly contains fines (micrographs in Fig. 3). There is also a clear distinction of accepts and rejects in terms of the average fiber length as the pressure screen fractionates mainly on the basis of length.

### Handsheet properties

Handsheets were prepared from the feed pulp and reject streams and the following properties were tested: tensile breaking (TAPPI Standard Test Method T 494 “Tensile properties of paper and paperboard [using constant rate of elongation apparatus]”); tearing strength (TAPPI Standard Test Method T 414 “Internal tearing resistance of paper [Elmendorf-type method]”); bursting strength (TAPPI Standard Test Method T403 “Bursting strength of paper”); and air resistance (TAPPI Standard Test Method T 460 “Air resistance of paper [Gurley method]”). Considerable improvements in the physical properties of the handsheets made from the reject fractions R1 and R2 were observed when compared to the handsheets made from the feed pulp. Also, R1 and R2 handsheets are less bulky than the feed handsheets with the removal of fines.

A pulp with longer fibers could have significant effect on the tensile index [2,17], which is expected to have a higher value. Long fibers create paper with higher tensile, tearing resistance, and a range of other strength-related properties due to their ability to be in contact and bond with more fibers compared to short fibers. As summarized in **Table I**, the highest tensile index, approximately 40%, was achieved with sheets made from the reject (R2) that has the highest average fiber length. This also suggests the similar increase in the breaking length. A decrease in the fines content in the final reject fraction also contributed to the increase in the tensile index.

A low Gurley air resistance value means a high porosity. Northern bleached softwood kraft pulp is quite porous to begin with, but the removal of fines further increase the air permeability or porosity of the handsheets. The fines content in a pulp is known to relate to the dewatering tendency of a pulp suspension, as well as the porosity of the resulting paper [18]. Feed pulp is the least porous handsheet; this is most




***7. (a) Changes in fines percentage of rejects R1 and R2 after the first and second stages of reject fractionation. Inset plot shows the change in the average fiber length, $L_w$. (b) Changes in fines percentage and average fiber length of accept stream after the first and second stages of accept fractionation. Inset graph shows the changes in the average fiber length, $L_w$. Fines percentage was increased significantly in the final accept, A2, after the second fractionation stage.***

| Handsheet Property | Feed Pulp | R1 | R2 | Percent Change |
|---|---|---|---|---|
| TEA index, Jkg$^{-1}$ | 363.33 | 520.37 | 560.90 | +54% |
| Tensile index, Nmg$^{-1}$ | 31.55 | 39.04 | 44.15 | +40% |
| Burst index, kPam2g$^{-1}$ | 1.99 | 2.29 | 2.76 | +39% |
| Tear Index, mNm2g$^{-1}$ | 19.24 | 24.72 | 26.45 | +37% |
| Stretch, % | 1.63 | 1.75 | 2.06 | +26% |
| Gurley air resistance, s | 4.25 | 2.78 | 2.28 | -46% |
| Bulk, cm$^3$g$^{-1}$ | 1.90 | 1.71 | 1.68 | -12% |

***I. Handsheet properties of feed and reject R1 and R2 fractions. Percent changes of the final R2 properties with respect to the properties of handsheets made from the original pulp are shown.***

likely due to a higher amount of fines filling the voids between the fiber networks compared to that in the rejects. Porosity was decreased as much 46% compared to the feed handsheets. Removal of fines by means of fiber fractionation has also been found to increase the porosity in another study [19].

## SUMMARY AND CONCLUSIONS

Northern bleached softwood kraft pulp was used for the multiple stage fractionation study to create long-fiber reject fraction and fines-rich accept fraction. This multistage fractionation process has effectively changed the fiber length distribution at each stage and successfully created a final reject fraction, R2, that is up to 10% longer than the original feed pulp. Significant decrease in the fines content was also obtained, from 2.90 wt% to 1.30 wt%. Pulp with fines materials removed evidently leads to a pulp with enhanced strength. Reject R2 has shown significant improvements in the handsheet strength properties. Tensile strength has increased up to 40% compared to the handsheets made from the feed pulp whereas TEA index (as measured by TAPPI Standard Test Method T 494 "Tensile properties of paper and paperboard [using constant rate of elongation apparatus]") has shown a 54% increase, burst index a 39% increase, and tear index a 37% increase. Gurley air resistance was 46%

reduced. An increase in freeness was also observed, from 667 mL CSF to 701 mL CSF, due to the removal of fines.

Influence of the primary fines on the strength properties can also be considered for never-dried or dried pulp. During the drying process, the primary fines could bind to the surface of the fiber. The fines with the higher bonding capability may not be able to release easily from the fiber when the pulp sheet is pulped at a later stage. Only the fines with low bonding capability would release relatively easy. This attachment of fines to the fibers could significantly affect the overall surface area and could have effects on the bonding during handsheet making. Such attached very small fines are hard to image using light microscopes, and need high resolution instruments such as scanning electron microscopes. It could also be helpful to study the properties of paper in comparison with the change in surface area for different fractions. Andersson has summarized the effects of fines on the physical properties of paper in detail [20].

Using smooth-hole pressure screens and multiple stages, fractionation efficiency of the pulp can be optimized by varying the operating parameters. Pressure screens with smaller hole diameters of 0.5 mm have effectively separated most of the fines from the feed pulp at $R_v$ of 0.6 and aperture velocity $V_s$ of 0.3 $ms^{-1}$. Most of the fines from the original feed pulp were separated into the second stage of the accept fraction, A2, that was successfully evaluated for potential use as a raw material for a novel fiber-based product such as CNC. Using the accept fractions for the production of CNC in next-generation CNC-based products could have significant economic benefits as they are excellent low-cost sources. In the industrial process, they comprise a huge amount of pulp, and using all fractionation most effectively will definitely save much money and resources. **TJ**

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## ABOUT THE AUTHORS

In paper mills, a significant portion of the pulp is discarded in the low-value streams. We selected this research topic to use the low-value streams of pulp for CNC production, along with improving the quality of reject fractions. Small, 0.5-mm cylindrical screens have not been used previously. Such screens can be used on a large-scale industrial level to give a quality boost to the pulp streams.

Collecting fines from the pilot plant was a challenge because of its very low consistency. We did several trials to collect sufficient fines for this purpose. In our research, we discovered that better fractionation can be achieved using small-holed screens, thus significantly improving the physical properties of the paper after removing fines that can be used for CNC production.

Mills can use the small-hole screens to improve the pulp quality in the reject streams for the production of strong and lighter packing material. At an industrial scale, a huge amount of low-value fines can be used for the economic production of CNC.

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The next step is to make slotted screens with hole sizes smaller than 0.5 mm (say 0.2 mm and 0.3 mm) to compare the fractionation efficiency with smooth-hole screen cylinders.

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