Effect of the pressure difference over the screen basket on the performance of a pressure screen

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ABSTRACT

The effect of the pressure difference over the pressure screen basket on both energy consumption and the properties of the accepted and rejected pulp was investigated. Experiences with pressure screening were connected with the theory of filtration.

Application:

This study shows that the energy consumption of pressure screening depends mostly on the rotor frequency, while throughput rate and feed consistency are less important factors. The study also proves that a low pressure difference supports fractionation of long fibers.

PRESSURE SCREENS ARE COMMON equipment used to clean and fractionate fiber suspensions in pulpmaking and papermaking. A modern pressure screen is based on a cylindrical screen plate through which the accepted pulp fibers pass while the remaining particles are rejected. The radial flow velocity in the screen basket is typically much greater than the velocity in the axial direction. This means that material fed to the pressure screen is moved onto the screen surface soon after the feed point. Therefore, oversized and flocculated materials accumulate on the screen surface to form the thickening fiber mat until it is rejected from the end of the cylinder. Some particles may also lodge in the screen apertures and therefore reduce the open area of the screen basket, lowering the capacity of the screen. The aim of this study was to clarify the effect of pressure difference over the screen plate on the performance of pressure screening and to determine how lodged particles in the screen apertures affect the pressure difference over the screen plate.

Hydrodynamic force is exerted on the fibers due to fluid flow, and this force moves fibers through the screen apertures to the accepts chamber. The fluid flow occurs because pressure is higher in the screen basket than in the accepts chamber. The quality of the accepted pulp and the pressure difference over the screen surface are thought to be codependent. A higher aperture velocity means a greater pressure difference over the screen basket, and the screening efficiency is often reported to be a function of aperture velocity *(1–4)*. The pressure difference over the screen plate mostly depends on the aperture velocity but also depends on the structural properties of the pressure screen. Gooding has reported that, although the effect of pressure pulsation on the pressure difference is small, the certain profile of the screen plate clearly decreases the slot pressure loss *(5)*.

We consider the effect of the pressure difference over the screen basket on energy consumption and on the properties of the accepted and rejected pulp, while at the same time connecting pressure screening with the theory of filtration and making observations on the effect of lodged particles in the apertures on the pressure difference over the screen plate. In addition to the scientific aspect, this paper gives practical information for planning the energy-effective operation of stock preparation plants.

MATERIALS AND METHODS

The experimental work was performed using a small industrial pressure screen apparatus, a Valmet TAP 25, designed to handle a pulp suspension at feed rates of up to 150 m^3/h. The pressure screen itself was equipped with a wedge wire screen basket, with a 0.15-mm slot width and a 0.82-mm profile height, into which the stock was fed axially. The screen plate had a total area of 0.25 m^2 with an open area of 6.1%. A 0.3-m-diam hydrofoil-type rotor was used. The gap between the foil and the screen surface was 3 mm. The pressure screen was connected to a pulp-screening pilot system (**Fig. 1**), constructed to circulate a total pulp volume of 6 m^3. The pilot system was equipped with the valves and instrumentation required for controlling pressures, flows, reject rate, and rotor speed.

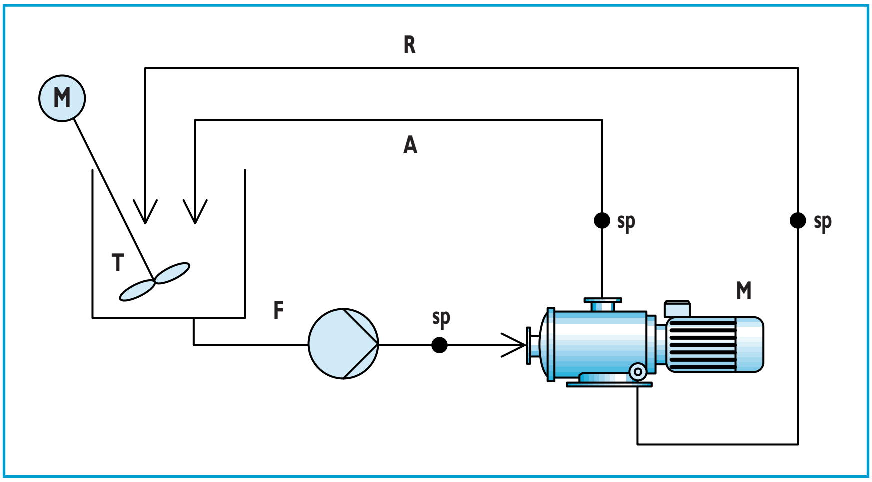
The pulp was sampled with automatic samplers connected to the feed, accept, and reject lines. Sampling took place during steady-state operation of the process. The drainability (Canadian Standard Freeness) and consistency of 6-L samples of pulp were analyzed according to SCAN standards. Error of drainability measurement was ±4%. The furnish for these experiments was spruce *(Picea abies)* groundwood pulp, and the stock temperature was near 20°C.

The locations of the pressure measurements with the axial midpoint of the screen basket and the corresponding position in the accepts chamber are illustrated in

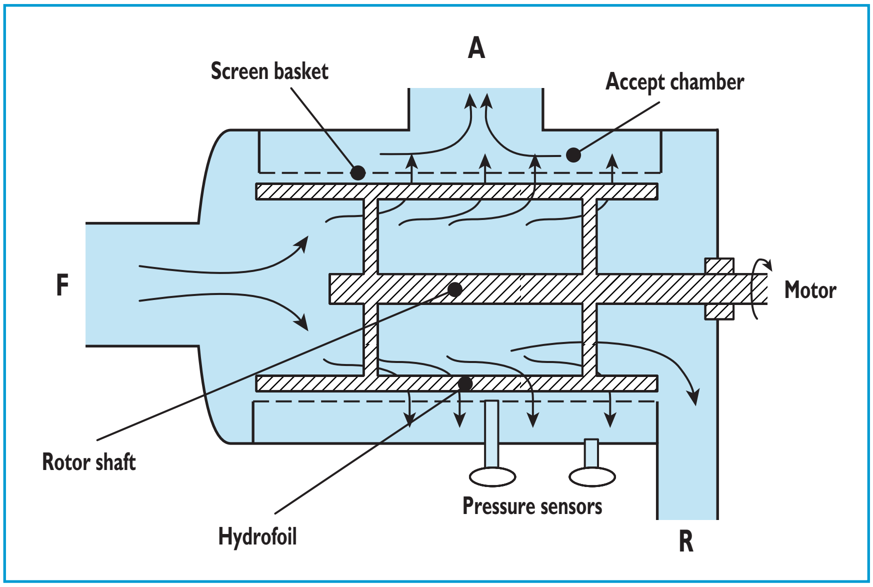
Fig. 2. The sensors used were capacitive pressure transducers (PMC MINI-EL 3070M), and they were protected against electrical disturbances. The time-averaging of pressure values was 1000 ms. The pressure difference over the screen basket was calculated as the difference between the pressures on the screen plate and in the accepts chamber. Average pressure differences were calculated from three pressure points measured at the same consistency and feed rate but at different rotational frequencies.

The power needed to propel the rotor of the pressure screen was obtained from the frequency converter, which was used as the power supply for the screen motor. *Power* refers to the total energy losses deriving from structures: friction in the screen bearings, motor windings, etc.

The experiments were carried out with pure water (referred to later as consistency=0%) and at feed consistencies of 0.87% and 1.15%. The pressure difference, energy consumption, and pulp properties (consistency and drainability) were measured as a function of the feed rate of the pressure screen. The volumetric reject rate was kept constant during the experiments at 20% of the feed flow.



1. The pressure-screening pilot system with sampling and measurement points. sp=sampling point, M=motor, T=stock chest, A=accept line, R=reject line, F=feed line.



2. Schematic of the pressure screen with pressure-measurement points. A=accept line, R=reject line, F=feed line.

RESULTS

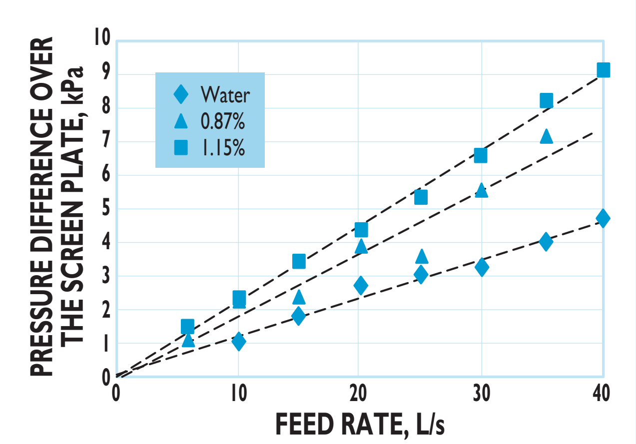
Figure 3 shows the average pressure difference over the screen basket as a function of feed rate for the three consistencies. The average pressure difference and feed rate appear linearly dependent at every consistency tested. Figure 3 also clearly indicates the increase in slope with increasing consistency. The net pressure differences over the screen basket at a feeding rate of 40 L/s were about 5.0, 7.5, and 9.0 kPa at consistencies of 0%, 0.87%, and 1.15%, respectively.

The power consumptions measured at different rotor speeds and pulp consistencies are presented as a function of feed rate in **Fig. 4.** This figure indicates a clear distinction between the rotor frequencies but only a small difference between the consistencies. **Figure 5** shows that in this situation, the relationship between average power consumption and rotor frequency can be described by Eq. 1:

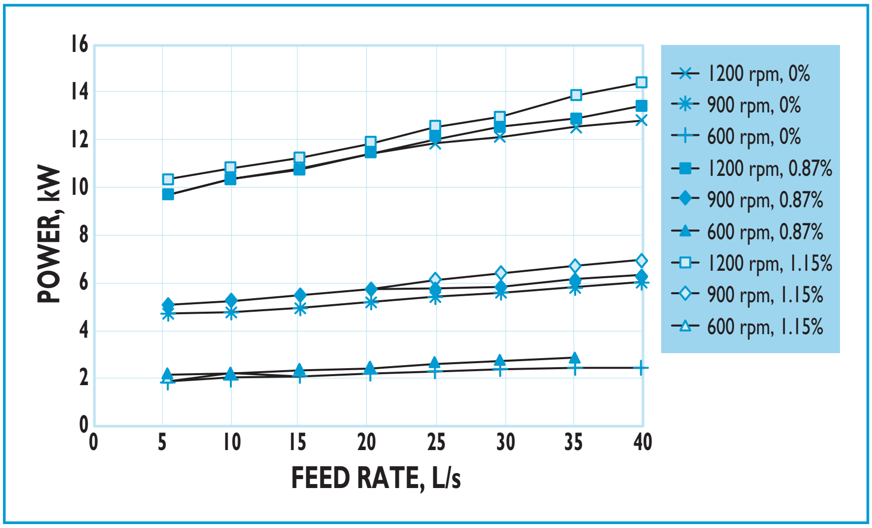
$$E = 0.0074 \cdot f_r^{2.448} \qquad (1)$$

where E is power (in kW) and f_r is the rotor frequency (in rpm).

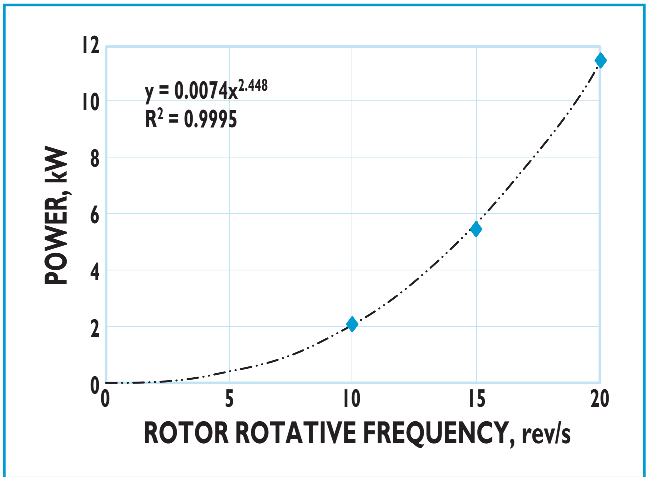
The properties of accepted and rejected pulp as a function of feed rate are presented in **Figs. 6 and 7** (feed consistency=0.87%, freeness=100 mL) and **Figs. 8 and 9** (feed consistency=1.15%, freeness=90 mL). The similarities between trends in consistency and freeness are indicated in both cases. At high feed rates, 30–40 L/s, reject consistencies and drainabilities decreased progressively with increasing rotor frequencies. Plugging of the screen occurred only at a rotor frequency of 600 rpm and a feed rate of about 30 L/s. In the midrange of feed rates, 20–30 L/s, minor differences in reject mass properties were observed when



3. Average pressure difference over the screen basket as a function of feed rate at different feed consistencies



4. Power consumption as a function of feed rate at different consistencies and rotor speeds



5. Power consumption of the pressure screen as a function of rotor frequency

changing the rotor frequency. In the range of feed rates less than 20 L/s, the reject consistencies and drainabilities increased markedly in the order of frequencies 900, 1200, and 600 rpm. The average drainability and consistency of the accepted pulp decreased with lower rotor frequencies, and increasing feed rate (i.e., a greater pressure difference) increased the consistency and drainability of the accepted pulp.

DISCUSSION

Flow conditions in the screen basket are dominated by the tangential flow field induced by the rotor. The other flow directions in the screen basket are the axial flow, induced by reject removal, and the radial movement toward the screen basket, caused by removal of the accepted pulp. In addition to these primary flows of fluid volumes, there may be also some relative movement between the solid matter and the water.

The higher concentration of pulp near the screen plate, referred to as the *fiber mat,* tends to form because the screen basket acts as a barrier that prevents shives and other oversized particles from passing through the screen apertures. In addition to individual oversized particles, fiber flocs can also accumulate on the screen plate if the flow conditions at the screen surface allow the flocs to remain coherent *(6).* Oversized particles and flocs are transferred to the screen plate by the influence of the flow field, and the resulting mat alters the properties of the screen surface and tends to blind the screen *(7).* Nevertheless, the rotating element inside the screen basket hinders the formation of a fiber mat by lifting the lodged particles away from apertures and by inducing turbulence on the screen surface. According to the function of the foil, it can be suggested that the rotor speed influences the resistance over the screen plate and thereby also influences the properties of the accept and reject streams *(8).* The contour of the screen plate is reported to greatly affect the fiber mat formation *(5),* and the pressure difference measured in this study was low because of the contouring of the screen plate *(9, 10).*

One focus of this study was to measure the pressure difference and to evaluate the effect of lodged particles on the flow resistance over the screen plate. This flow resistance can be examined with the following equation, which is derived from Darcy's law *(11)*:

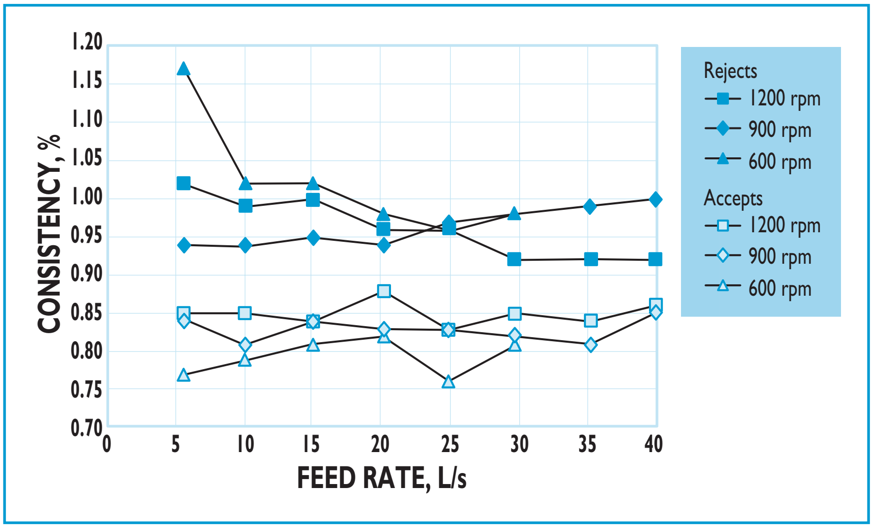
$$Q = \frac{A}{\mu(R + R_c)} \cdot \Delta p \qquad (2)$$

where

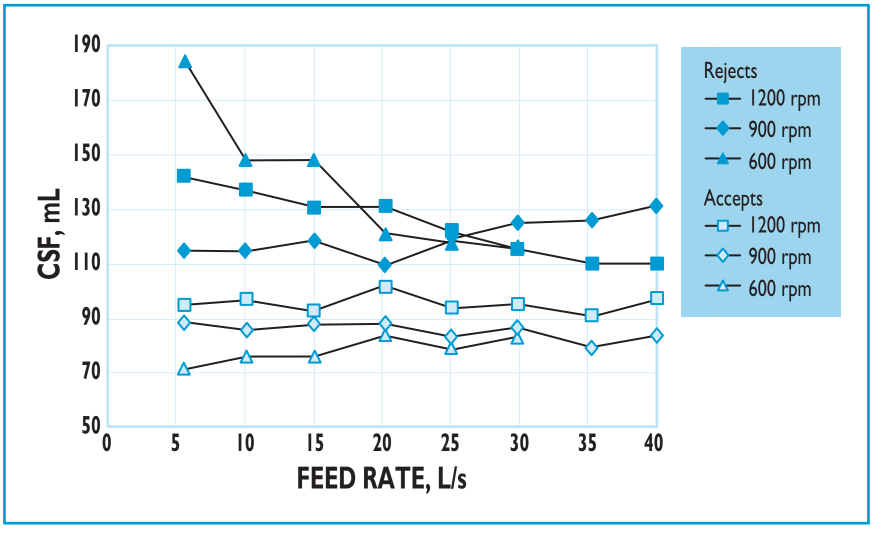
Q = flow rate
A = face area
μ = apparent viscosity
R = resistance of the screen plate
R_c = resistance due to fibers in the slots
Δp = driving pressure.

Equation 2 is valid *(11)* for this problem, because the laminar flow conditions prevail in the slots [i.e., the Reynolds number *(12)* was limited to 750].

The dependence between the feed rate and pressure difference is linear, as indicated in Fig. 3. Because the amount of lodged fibers in the slots can be assumed to change when the accepts throughput is increased, the linearity of the graphs suggests that very low resistance is induced by the lodged particles. That is because the term indicating the slope of curve is constant in the case of linearity, which means that R_c also stays constant during the change of flow rate. The increase in slope with increasing consistency suggests that the apparent viscosity *(13)* of the pulp was altered by an increase in consistency. Our results differed from studies of Gooding *(5)*, who found the pressure difference due to fiber accumulations to be more significant. Gooding found that the dimensioning of screen profile and local flow conditions has a marked effect on the pressure loss. The difference between the studies may be derived from the fact that the wedge wire screen basket with high profiles used in our study decreased the pressure difference over the screen more than the screen baskets used in Gooding's studies.

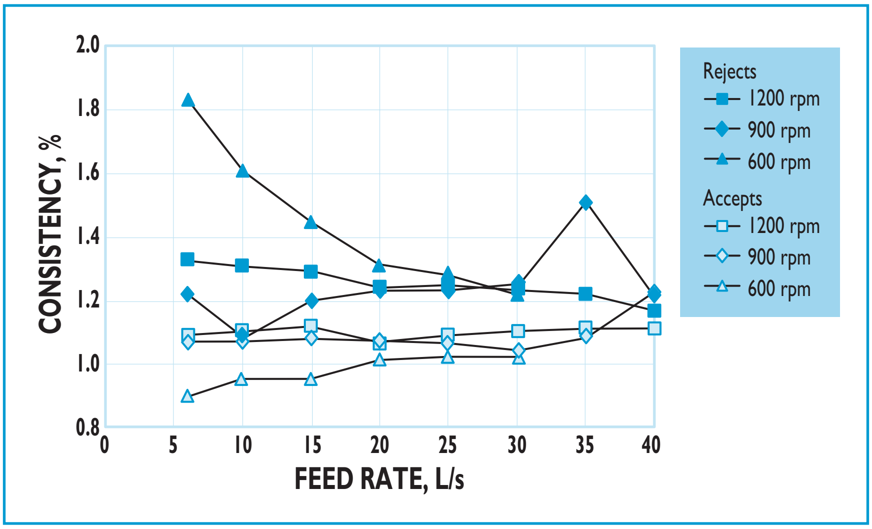


6. Consistencies of the accepted and rejected pulp as a function of feed rate of the pressure screen. The feeding consistency and freeness were 0.87% and 100 mL, respectively.

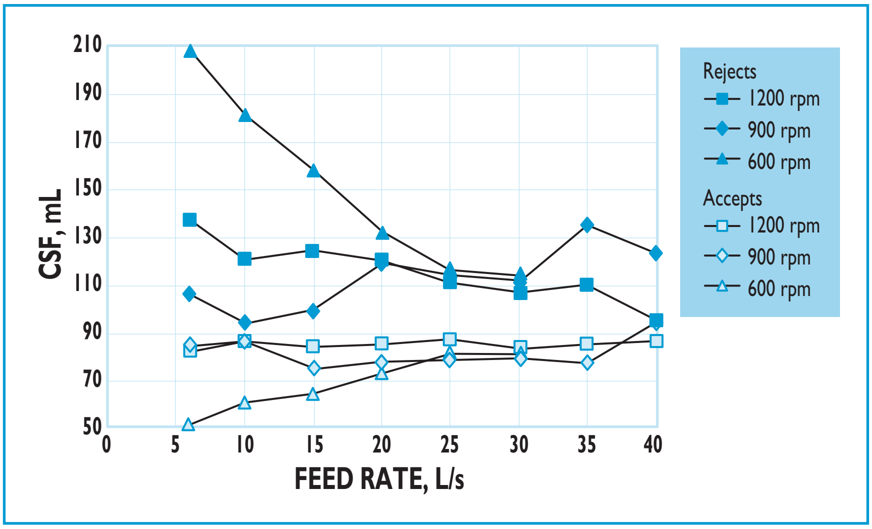


7. Freeness of the accepted and rejected pulp as a function of feed rate of the pressure screen. The feeding consistency and freeness were 0.87% and 100 mL, respectively.

A decrease in accepts velocity (i.e., a lower pressure difference over the screen surface) will decrease the hydrodynamic force exerted against fibers on the screen surface. Longer and more rigid particles will not follow the flow into the accepts chamber under conditions of low pressure differential, and this will increase the drainability and consistency of the reject material. The impact of hydrodynamic force is thus at its minimum in the lowest range of flow rates, as seen in Figs. 6–9. The highest drainability in the rejects is detected at the lowest rotor speed, which is logical in view of higher flocculation propensity of long fibers under low-turbulence conditions. The rotor speeds of 900 rpm and 1200 rpm did not follow the expected sequence because the drainability in the low range of feed rates was higher at 1200 rpm than at 900 rpm. This effect may be related to relative movement between water and solid material, which might be emphasized with a high tangential velocity and a low feed rate leading to a long retention time in the screen basket.



8. Consistencies of the accepted and rejected pulp as a function of feed rate of the pressure screen. The feeding consistency and freeness were 1.15% and 90 mL, respectively.



9. Freeness of the accepted and rejected pulp as a function of feed rate of the pressure screen. The feeding consistency and freeness were 1.15% and 90 mL, respectively.

CONCLUSIONS

The lower accepts flow rate through screen plate decreases the force exerted against fibers on the screen surface. The low force causes a marked decrease in acceptance of long fibers. The fibers and debris particles tend to lodge in the screen apertures during the passage of pulp. However, this lodging phenomenon causes very low pressure loss only, while the pressure difference over the screen plate mostly depends on the properties of the screen plate. The energy consumption of the pressure screen unit depends on the feed rate, consistency, and rotor frequency. However, this consumption is primarily determined by the rotor frequency; the influence of feed rate and consistency is relatively small. **TJ**

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