Saimaa University of Applied Sciences
Technology, Imatra
Paper Technology

Loan Dinh

Development of the Pressure Screen Foil

Bachelor’s Thesis 2012

Abstract

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Development of the Pressure Screen foil, 60 pages, 12 appendices
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The purpose of the research was to develop new foils model for headbox screen on higher consistency level of the feed flow than foil that is used today with target feed/accept consistency being approximately 2.0%. However, energy consumption and pulsation level should be in same range as today's foil type has. The study was commissioned by Andritz.

The study was carried out at Fiber-Laboratory in Savonlinna. The work was divided into four parts. First part was the test of Dolphin D foil and Bump foil. Second part was the test of new foil with different position on the rotor. Third part was the test of three new foils which were designed from new original foil. Last part was the test of new HB foil. The purpose was to find out which one has the best condition for using in headbox screen of the paper machine. The data for this thesis were collected from the control room of the laboratory. The information was gathered from literature, newspapers, journal, theses and the internet.

The final result of this thesis was that Bump had the most suitable condition for working in headbox screen. However, if concentrating on the results of new foil, new designed foils and HB foil, No8 (new designed foil with two cutting edges) had the most suitable condition with low pulsation, good runnability, low thickening factor and low power consumption.

Keywords: pressure screen, headbox screen, pressure pulsation, power consumption, screening, foil

Contents

1 Introduction

Pressure screening is the key process in pulp and paper production and is used to enhance the quality of a wide range of pulp and paper products. While the usual goal of screening is to remove oversize contaminants from the pulp with minimal fiber loss and acceptable cost, screening is finding increased use for fiber fractionation which means that the pulp can be split into fiber classes, which differ in their average properties. For these reasons, pressure screen are an increasingly important unit operation in pulping, recycling and papermaking.

In approach flow applications, pressure screening is the final stock cleaning stage before the headbox, and the machine is called headbox screen or machine screen. It is used to protect the headbox and paper machine from foreign material, to remove debris and dirt, to deflocculate the stock and to improve formation.

The purpose of this study is to develop new foils and new HB foil model for headbox screen for Andritz on higher consistency level of the feed flow than foil that is used today with target feed/accept consistency of approximately 2.0%. However, energy consumption and pulsation level should be in the same range as today’s foil type has.

Theoretical part

2 Pressure screen's structure and principle

A pressure screen contains two main components: the rotor and screen cylinder. Once the unscreened pulp enters the screen via the feed stream, the accept fibres pass through small slots or holes in the screen cylinder to the accept stream, while oversized particles continue down the length of the cylinder to the reject stream. The main components of pressure screen are presented in Figure 1.

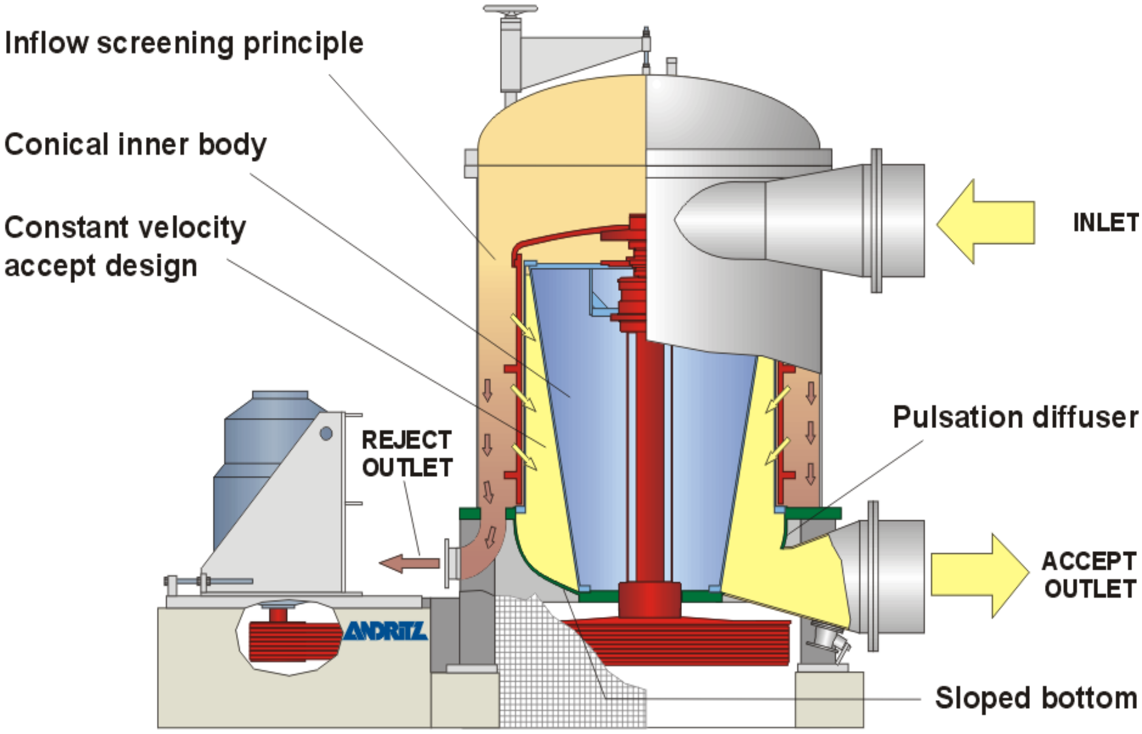


Figure 1 Pressure screen (Andritz)

The principal measures of screen performance are: 1) Contaminant removal efficiency, defined as the mass percentage of contaminants leaving the screen through the reject port to that entering the screen; 2) Capacity, defined as the maximum mass flow rate of pulp in the accept stream; 3) Power consumption, defined as the power required by the rotor; and 4) Reject rate, defined as the mass flow of fibres rejected with the contaminants. Achieving high capacity and high efficiency with reduced energy demand at low reject rate is the goal of an optimal rotor design.

3 Screening parameters

The parameters affecting the screening result can be divided into three main classes: design parameters, operating parameters and furnish parameters.

3.1 Design parameters

Design parameters consist of the rotor design and screen cylinder design.

3.1.1 Feed construction

The feed construction can be either axial or tangential and the chamber size can be varied. The existence of a feed chamber was found to reduce the efficiency of the pressure screen which suggests that the capacity of the screen is improved. (Niinimäki 1998.) However, if a feed chamber in terms of volume is too small, the capacity of an axially fed pressure screen can be decreased significantly.

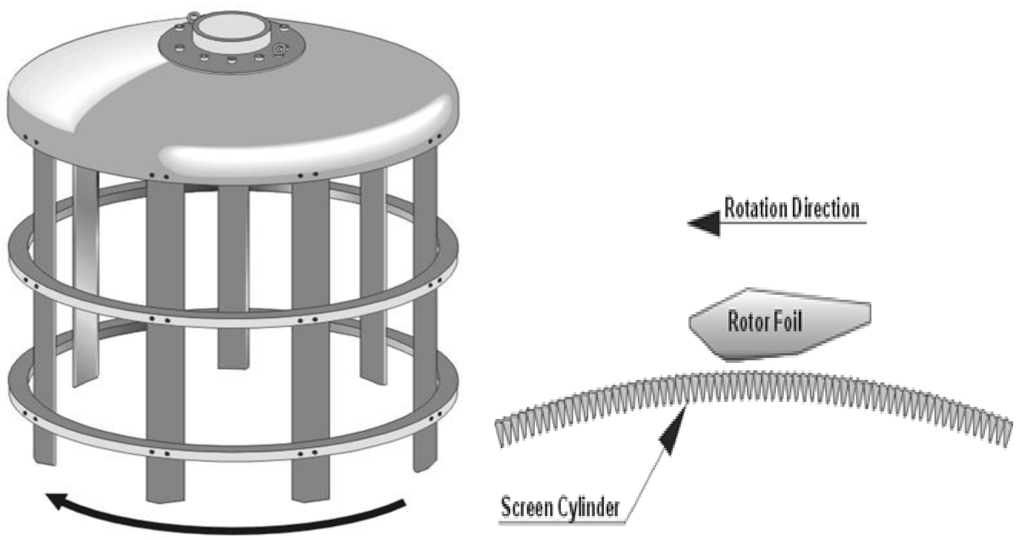
3.1.2 Rotor design

The rotor plays a critical role in screen operation. Functions of rotor are to accelerate the pulp suspension on the feed side of the screen to a high velocity and to induce turbulence on the surface of the screen plate. Rotor is also used to create a negative pressure pulse that backflushes the screen apertures, clearing fibre accumulations and preventing plugging of the apertures (Feng 2003, Feng et al. 2003 and Gonzalez 2002). The rotor design and speed thus directly affect the maximum capacity of the screen. (Olson et al. 2007.)

Additionally, a decrease in the clearance between the foil and screen plate improves capacity but reduces screening efficiency.

There are two classes of rotor design in widespread use: solid-core and foil rotors. The solid-core rotors have a solid cylindrical core with various shaped hydrodynamic elements on the surface. The advantage of the foil design is the ability to optimize the angle of attack and the gap between the foil and the screen cylinder for a given type of pulp.

A cross-section of a rotor foil and screen cylinder with an illustration of the local flow patterns is shown in Figure 2 (Andritz). It shows pulp flowing outward through the apertures ahead of the foil, a suction pulse and a flow reversal adjacent the foil. The outward flow through the apertures in the screen cylinder resumes in the foil's wake. During the suction pulse phase, the slot is cleared by the flow which returns from the accept side to the feed side of the screen cylinder. The strength of the pulsations may be increased by changing the foil design, decreasing the gap between the rotor and cylinder surface, or by increasing the speed of the rotor. It is important to make the pulsation on the screen plate surface to keep it open, but it is equally important to keep the pulsation low. Too high pressure pulse causes both fines and coarse fibres pass to the accept side, and too high suction pulse makes the fines come back to the reject side and eventually to the reject outlet. Thus strong pulses will reduce efficiency.



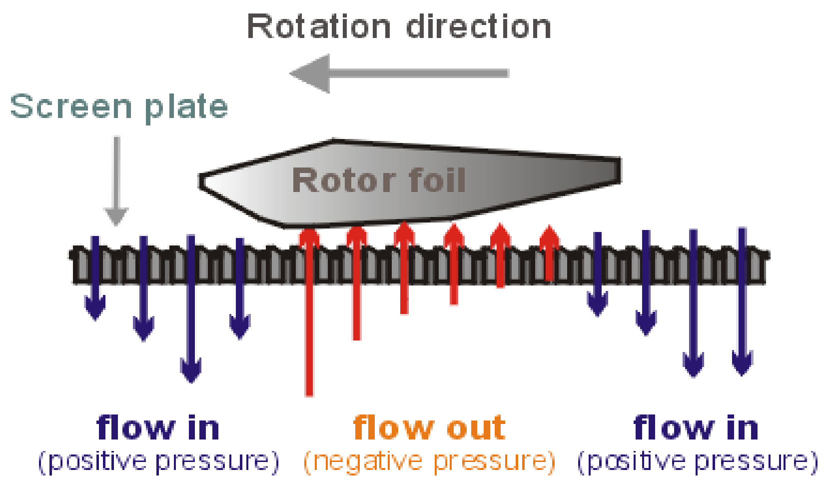


Figure 2 Schematic image of a rotor foil passing a section of a screen cylinder (Andritz)

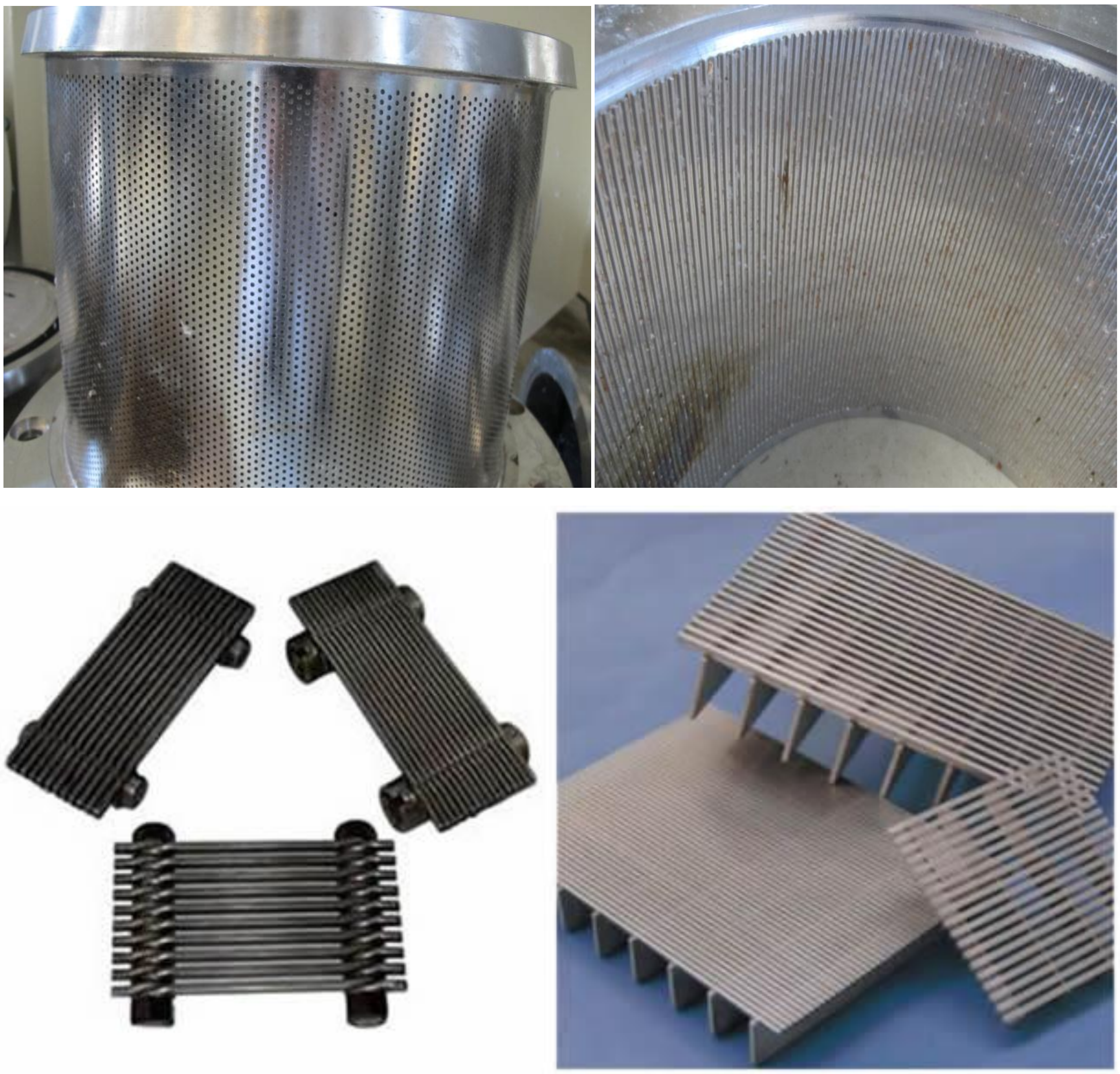
Reject thickening is related to the ratio of the duration of the positive pulse to that of the negative pulse in each pulsation cycle. The greater this ratio is, the more probable it is that the reject will tend to thicken (Yu 1994). This explains most of the differences observed between the types of rotor. In the case of the foil type, the width of the foil can be used to control reject thickening. In low-consistency screening is possible to use narrow foils, because the reject pulp can be allowed to thicken to a reasonable extent, but in the case of high consistency screening, long, powerful suction pulses brought about by very wide foils are needed to avert reject thickening and screen plugging (Ämmälä 1997-2000.)

3.1.2 Screen cylinder design

There are three types of screen cylinders: holed, slotted and wedge wire (picture 1). The slot type screen basket is made up of milling slots on the screen plate by cutter and then rolling it up round. The hole type screen basket is made up of drilling holes on the screen plate and on the profiled surface. Wedge wire screen is made in panel or cylinder type from V shaped profile wire with an unique welding process, offering great strength, precision and long service life. Wedge wire panels offer a perfectly flat and smooth surface with rectangular openings. The screen surface can be on the inside or outside of the cylinder, to give flow in to out, or out to in. (Sanya Wedge Wire Factory.) Slot and hole have to be vertical against rotor's rotation direction for maximized filtration effect. The aperture type, size and open area of the screen plate varies depending on the manufacturer and application. Nowadays, holed screen plates are used as first stage screens in a screen room and sometimes before the paper machine headbox. Depending on the application, the size is typically between 1.2 and 3.0 mm having an open area of 10 - 25%. Slotted screens when used as headbox screens have slot widths varying between 0.20 to 0.5 mm and open area from 7 to 15% (Bliss 1992.)

Both of the above three types of baskets have two kinds of surfaces: smooth surface and contoured surface. Contours are depressions or protrusions on the feed side of the screen plates. Fundamental research has shown that contours can greatly reduce the hydraulic resistance of a screen plate by streaming the flow through it. Contours can also reduce accumulations of fibres in the slot by increasing the turbulence level at the entry and downstream of slots. The biggest effect of the contours is that they can dramatically increase the screening capacity (Bliss 1992.)

Each cylinder type has an optimum operating point, holed and slotted cylinders have distinct operating characteristics. Slotted cylinders have higher contaminant removal efficiencies, but also require stronger and more frequent rotor pulsations. Small slots offer particularly high screening efficiencies. Slot width has the greatest effect on screen capacity, efficiency and other performance variables.



Picture 1 Holed screen cylinder (upper left), slotted screen cylinder (upper right) and wedge wire panels (down – Sanya Wedge Wire Factory)

3.2 Operational parameters

The operational parameters of screening are the aperture velocity, rotor tip speed, volumetric reject rate, feed consistency, temperature and pH.

3.2.1 Aperture velocity

The effects of the aperture velocity (accept flow rate) are linked to the pressure difference across the screen plate. To reduce screening efficiency, aperture velocity is increased, especially if the debris is compressible. On the other hand, there are also observations pointing to no effect of slot velocity on screening efficiency (Seifert 1993). A higher aperture velocity will increase the accept consistency, leading to an improvement in production rate.

3.2.2 Rotor tip speed and rotor frequency

A higher foil tip speed will increase the capacity and reduce the screening efficiency. The effect is based on increasing turbulence and fluidization of the pulp suspension, which is thought to reduce the flow resistance over the screen plate and it appears to be clearer with profiled screen plates. According to Niinimäki (1998b), energy consumption is related to rotor frequency, the frequency required being dependent on the network strength of the fibre suspension and the desired accept capacity. Capacity will be increased and screening efficiency will be decreased with increasing rotor frequency (McCarthy 1988) so the highest possible circumferential speed of the rotor is economically desirable. Increase in rotor frequency also increases the amount of accepted long fibers, and the rotor frequency may be used as a tool for optimizing the long fiber acceptance (Repo & Sundholm 1995).

3.2.3 Feed consistency

Feed consistency is the most widely used control variable in pressure screening. Capacity increases with increasing feed consistency, but then decreases rapidly after a certain threshold consistency has been reached (McCarthy 1988). Increasing the feed consistency is usually improving the screening efficiency although it has also been suggested that the latter is independent of feed consistency.

3.2.4 Volumetric reject rate

The volumetric reject rate is mainly responsible for the operating point of screening, because it is instrumental in determining the reject thickening behaviour, together with the mass reject rate (Ämmälä 1997-2000). Kubat & Steenberg (1955) have said that this is not an operating parameter anymore, it is rather a combined function of operating, design and furnish parameters, but it has been found to be very useful because the screening efficiency responds to the mass reject rate significantly if particle separation is based on probability.

3.3 Furnish parameters

The furnish parameters can be considered to comprise pH, temperature, fluid viscosity and fibre properties, and also properties of debris.

3.3.1 Temperature and pH

According to Levis (1991), to decrease screening efficiency and to increase capacity the pH is increased. This is due to the lubrication effect of alkalis, which improves the passage of fibres through the screen apertures.

Levis (1991) has also found that an increase in temperature will reduce the screening efficiency, as debris will soften at higher temperatures. McCarthy (1988) attributes the effect of temperature to the change in the viscosity of the fluid, but Wakelin & Paul (2000) suggest that the increase in the passage of fibres at higher temperatures is due to softening of the fibres and not to any alteration in the viscosity.

3.3.2 Viscosity

Paul et al. (1999) has found that the screening capacity and long-fibre yield could be improved markedly by increasing the viscosity of the fluid with carboxymethyl cellulose. Zhao & Kerekes (1993) have said that the uniformity of a suspension increases with increasing viscosity of the liquid, because a high viscosity will lower the mobility of the fibres, restraining reflocculation of the dispersed fibres under conditions of decaying turbulence.

3.3.3 Fiber properties

Fibre dimensions, especially length, have been found to have a powerful influence on the passing probability of particles (Kumar 1991). An increase in the freeness of the feed pulp will lead to higher mass reject rates and reject thickening if screening conditions remain unchanged (Wakelin *et al*. 1994). It has been suggested that the amount of debris in the accept pulp may correlate with the amount in the feed pulp (Sealey & Miller 1981).

3.3.4 Properties of debris

Properties of debris affect screening efficiency, because passing probability depends greatly on dimensions and other properties of debris particles. Debris can be defined as an unclassified assortment of material that has to be rejected. These impurities can be wood-based particles, but also material of artificial origin such as plastics and stickies. The most difficult debris type in screening is grit, because it is impossible to screen out, and if it is present, cleaners are required before the screen room to avoid serious wear problems in the pressure screen baskets. The removable debris may be looked on as three dimensional particles.

Debris particles having three large dimensions are the most dangerous, because they can protrude from both sides of a thin sheet of paper regardless their orientation. However, this type of debris is easiest to remove. A debris particle having two large dimensions, i.e. a flake, can easily hide in a sheet of the paper, but it is still unacceptable. This kind of debris particle is removable, but it can pass through the screen aperture in a certain position. The last shape type is a particle having two small dimensions and one large one, a shive. These particles are still more difficult to remove but they are less likely to cause either functional or runability problems. However, shives are the most common debris type in virgin fiber preparations, and for that reason, screening efficiency is often expressed as shive removal efficiency. The selection of screening equipment utilizing mostly barrier or probability screening must be based on the knowledge of debris types to be removed. The amount and properties of debris have to be taken into account also in screen optimization (Niinimäki 1998b.)

4 Mechanism and Theory of pressure screening

4.1 Flow patterns

The mechanism that determines whether a fiber or a contaminant passes through the screen plate or is rejected is extremely complex. According to Yu and DeFoe (1994b), the primary factor affecting throughput and efficiency is the fiber behavior at the feed-side surface, which is governed by the basket design. Meanwhile, the rotor, the internal geometry and operation of the screen affect the fiber orientation and flow path.

The flow pattern of the pulp near and through the screen apertures have been studied by many investigators. One of them found that near a slot on the wall in a rectangular channel, a highly curved flow field would be generated. Due to their experiment results, there was no signification separation of the flow on the upper wall, and the Reynolds number in their study did not have a strong effect on the flow pattern.

Yu and DeFoe (1994a) also studied about the flow pattern at the feed-side surface of smooth and contoured screen baskets. They observed the flow separation and vortices on the contoured basket screen and found out that when flow went from feed side to accept side, there was no separation found on the surface. Therefore, they concluded that the accept flow for the smooth basket was caused by local pressure, while the accept flow for the contoured basket was from reattachment of the flow stream. Halonen et al. (1990) had same opinion with Gooding and Kerekes (1989) that higher velocity implies greater capacity. However, Gooding (1986) also reported that higher slot velocities increased the probability that a shive would be accepted.

4.2 Pressure pulses

To allow pressure screens to run continuously, foils or bumps on the rotor periodically clean the fibres in the apertures of the basket are moved and it generated the negative pressure pulse. The essence of the pressure screening is the intermittent pulsing action. The magnitude and shape of the pressure pulse is critical to the performance of pressure screens. According to Karvinen and Halonen (1984), too high of a pulse will lower the capacity of the screens as a large amount of material is backflushed, while with too small of a negative pulse, the rotor is not able to clean the slots. Further, too high of a positive pulse may force deformable contaminants through the apertures. Thus, in the design of a screen, the pressure pulsation ought to be minimized but still retain its cleaning effect.

The magnitude of the negative pressure is a function of rotor type, rotational speed, and the clearance between rotor and the screen. According to Yu & Crossley (1994), the pressure-pulse signature for a foil rotor and contoured-drum rotor are quite different. Decreasing clearance between the rotor and basket significantly increases the peak to peak pressure pulse. The frequency and the magnitude of the pulsation are decreased by lowering the rotational speed.

4.3 Reject thickening

According to Martin et al. (2005), pulp samples were taken at various rotor speeds to evaluate reject thickening. According to Martin et al., reject thickening is the reject consistency (C_r) divided by the feed consistency (C_f) as in equation 1:

$$T = \frac{C_r}{C_f} \quad (1)$$

High reject thickening can be a precursor of runnability problems. It means that a high reject thickening factor can lead to blocking or plugging of the screen and therefore must be carefully monitored in order to ensure continued operation. The amount of reject thickening that occurs during screening is usually controlled by varying one or both of two factors. The first and most important of these factors is the relative flow rate between the feed (Q_f) and the rejects (Q_r). The ratio of these two flow rates is referred to as the volumetric reject rate (R_v) as in equation 2. The reject thickening increases when the volumetric reject rate is lowered.

$$R_v = \frac{Q_r}{Q_f} \quad (2)$$

The second factor in controlling reject thickening is the feed consistency. At high feed consistencies, the consistency near the reject end may increase dramatically and cause blocking of the screen.

5 Power consumption

The challenge for equipment manufactures today is to design pressure screens to provide the highest capacity, the required level of efficiency while consuming minimal.

According to Niinimäki (1998a), the total power consumption in pressure screening includes the pressure loss over the screen and the power consumption of the screen motor. Screening also includes the energy consumption of the dilution water and pumping seal water. However, they represent a negligible proportion of the total energy, thus these can be ignored.

The energy efficiency of pressure screening is normally expressed in terms of specific energy, which describes the energy used per unit mass of bone dry fiber material. In additional, design and operation and stock parameters do not have affect to energy demand of a pressure screening unit (Niinimäki 1998a.)

Niinimäki (1998a) has said that according to the report in Paper VII, the effect of the feed pulp consistency and rotor frequency on the energy consumption of the screen unit was tested. The rotor frequency has a great effect, while the effects of the pulp consistency and feed rate were found to be negligible. These findings mean that the specific energy of pressure screening increases as the rotational speed is increased and the consistency and throughput rate are decreased. The energy consumption of the screen is affected by the position and hydronamics of the foil. It means that at a constant rotor frequency, the power requirement of the screen motor increases when the gap between the screen surface and foil is decreased and the angle of incidence of the foil is increased.

The screening consistency has a great effect on the total specific energy demand in the screening process. Because a higher profile and greater aperture size in the screen plate reduce the pumping energy, it may have an effect on the total energy consumption. In other words, the smaller profile and aperture size, the greater is the energy consumption of the screen. In addition, Vitori and Philippe (1989) have found that a smooth-surfaced slotted cylinder requires more specific energy than would a profiled screen cylinder.

Pictures

Tables

Figures

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