Improving Screen System Operation in a Board Mill

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ABSTRACT

Macrostickies removal efficiency was measured in a Board Mill to track brown stock screening improvements by using smaller slots and other system modifications. The agglomerated microstickies in the feed and accept lines to the fine pressure screens in the system were measured using the new Pulmac Classifier. Preliminary data indicate that the primary screens produce microstickies when the slot width was reduced from 0.25 mm (0.010 inch) to 0.2 mm (0.008 inch).

Two common sense rules are proposed for screening system design considerations. We recommend that the conventional cascade system be replaced by the forward flow arrangement in compliance with the two rules.

Microstickies in the headbox and white water are also being monitored to control effect on paper machine runnability and product quality. Results will be reported in future.

Introduction:

Stickies cause tremendous problems on the paper machine and affect product quality. The effective removal of stickies by implementing commercially available unit operations is vital to the economic viability of a recycling mill. Some of the widely used unit operations include screening (coarse screens with holes and fine screens with slots), cleaning (forward cleaners, reverse cleaners and rotating body cleaners) and flotation - both froth flotation (FF) for deinking and dissolved air flotation (DAF) for water clarification.

Various strategies at the disposal of a paper mill manager to combat stickies and other contaminants include (1):

1. Recovered paper grade inspection and selection
2. Gentle pulping
3. Effective screening
4. Efficient cleaning
5. Selective froth flotation (FF)
6. Dispersion and kneading
7. Water clarification for example, by DAF
8. Additives to pacify stickies using, talc, anionic polymers, surfactants, etc..

We will primarily focus on stickies removal by screening in this project.

Background

Paper recycling mills rely heavily on coarse screens with holes and fine screens with slots to remove many types of contaminants like plastics, staples, stones, inks, paper flakes, fiber bundles, stickies, etc. Fine screens with slot width ranging from 0.10 mm (0.004 in) to 0.40 mm (0.016 in) are commonly used for the effective removal of contaminants.

Some of the important parameters affecting the performance of screens include:

- Slot or hole size
- Reject ratio
- Thickening ratio
- Rotor design and speed
- Screen design
- Passing velocity (relates to open area and throughput)
- Consistency
- Furnish characteristics
- Contaminants type and dimensions
- Pressure drop
- Temperature
- Process control

It is clear that the operation of pressure screen is very complex as interaction of above parameters impact screen performance measured in terms of contaminant removal efficiency and yield.

In general, smaller hole or slot size will increase contaminant removal efficiency as long as disintegration or shape alteration of contaminants is avoided (2, 3, 4). Smaller hole or slot size may lead to lower open area and affect throughput to some extent. Additionally, smaller slot size screens are prone to fiber fractionation resulting in the loss of long fibers in reject stream.

Reject ratio is usually around 15% to 30%. It is an important parameter to control as it has a direct effect on both contaminant removal efficiency and yield. As reject ratio increases the flow of both fibers and contaminants in reject stream increases. Reject ratio together with feed consistency and the flow of dilution water, if added will affect thickening ratio (5).

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Screen manufacturers are actively working to improve screen design and rotor configuration so as to increase contaminant removal efficiency without sacrificing yield. For example, Lindroos and Puro (6) used computational fluid dynamics (CFD) to evaluate the performance of three different rotor foils and two different wedge wire designs. Results were used to design a new screen basket with lower energy consumption and thickening while increasing capacity and improving pulp quality. Olson et al. (7) patented dual element foil (DEF) so as to intensify negative pressure pulse and virtually eliminate positive pressure pulse. This resulted in significant energy savings while increasing stickies removal efficiency.

Many in the industry believe superficial velocity through the screen opening or passing velocity (volumetric throughput/screen open area) is one of the key parameters in evaluating screen performance (2). This is only partially true as passing velocity is usually not constant but is relatively high near the inlet and low near the outlet of the screen in most cases.

Stock consistency plays a crucial role in screen operation. As consistency is increased aggressive action near the screen plate is needed to maintain pulp in fluidized state which may lead to contaminant disintegration. Operating consistency range is dictated by screen design as well as stock characteristics. Pulp with long fibers like OCC, needs to be screened at lower consistency while pulp with short fibers like ONP, can be screened at somewhat higher consistency.

Contaminant dimensions and shape, pressure drop across the screen plate, temperature and overall process control have strong effect on the passage of fibers and contaminants through the screen opening. For example, relatively high shear forces and somewhat elevated temperature (greater than 45^0C or 110^0F) necessary to maintain throughput inevitably lead to deformation and disintegration of fragile contaminants like stickies (2, 3, 4). Mill data indicate that stickies in the screen accepts were significantly larger than the screen slot size, and in some cases, were an order of magnitude larger (8).

Another factor that is also important but not mentioned in the above list is overall screen system design with three or four stages. This will be discussed later in this article.

Objective

Objective of this project is to evaluate the effect of screen slot size on macrostickies and microstickies removal efficiencies in a mill system. Results will be used to discuss screening system design concepts.

Stickies Measurment

Various methods used for the measurement of macrostickies and microstickies were recently reviewed by Doshi (9). We used Pulmac Master Screen (here after referred as laboratory slotted screen) and recently developed Classifier attachment (10, 11, 12) to measure macrostickies and agglomerated microstickies area and count. Problematic microstickies that tend to agglomerate in the paper machine system were measured by this method. As a result, measurement of agglomerated microstickies is expected to correlate with associated deposit problems on the paper machine.

Besides the obvious requirement of repeatability and reproducibility, there were six principal design criteria for the micro/macrostickies Classifier attachment:

1. Permit retro-fit to at least the latest version laboratory slotted screen shown in Figure 1;
2. Be reasonably automated (i.e. minimize operator involvement in the test procedure) and be designed to permit future modifications towards full automation (i.e. sample collection, processing, classification, and electronic data transmission);
3. Have excellent self-cleaning characteristics and be simple to access for service;
4. Be engineered to deliver the same performance reliability in a harsh mill environment as the laboratory slotted screen itself has demonstrated in over thirty years of industrial application experience;
5. No additional services beyond air, water, electricity, and drain; and
6. Relatively flexible and easy to use.

The classifier is comprised of two key elements: the concentrator vessel and the agglomeration vessel as shown in Figure 2. Sample slurry is fed into the concentrator vessel. When the test is initiated, the sample slurry is drawn through a fine wire screen into the separation vessel, thus removing microstickies, fillers and fines. A combination of a mixing stirrer in the vessel and a hydro-rotor operating beneath the

Figure 1: Laboratory Slotted Screen

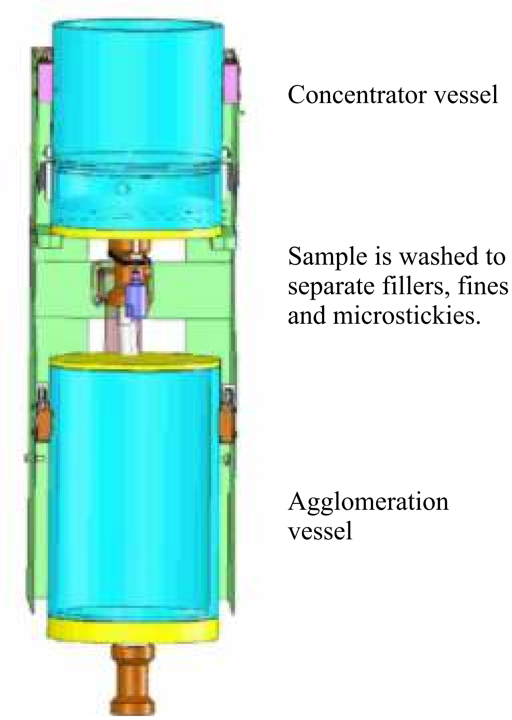


Figure 2: Micro/Macrostickies Classifier

Figure 3: Auto filter

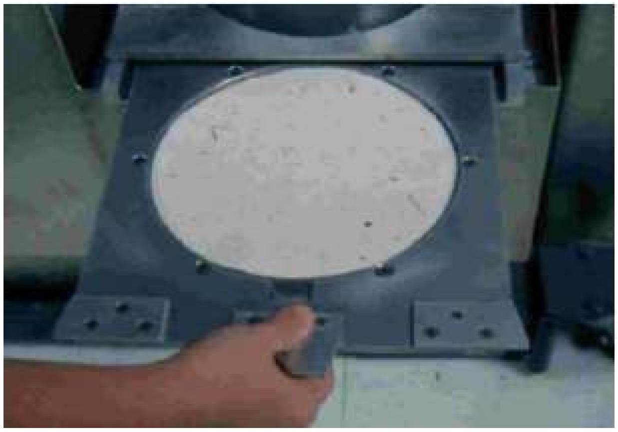


Figure 4: Auto filter cartridge + filter paper

wire prevents the formation of a mat on the screen, keeps the slurry in a uniformly dispersed state and prevents any buildup on the screen. The accepts slurry then passes into the agglomeration vessel.

There then follows a five minute agglomeration sequence, during which the proprietary agglomeration-inducing conditions are repeatably recreated and microstickies become macrostickies (12). Concurrent to agglomeration, the original macrostickies together with fiber and the larger dirt particles are reslurried in the concentrator vessel and automatically fed into the laboratory slotted screen for quantification.

Experiment Details

1. Known quantity of pulp or water sample is introduced in the Concentrator Vessel at the top (Figure 2). Sample size is determined so that at least 50 particles are collected on filter paper. For a relatively dirty sample 25 (od) g of pulp sample or 2 liters of water sample is sufficient. On the other hand if the concentration of stickies is expected to be relatively low sample size needs to be increased to 50 (od) g of pulp or 4 liters of water.
2. Put a new filter paper in the laboratory slotted screen auto filter cartridge (Figure 3, 4).
3. Press the START switch on the laboratory slotted screen and washing process will begin. Temperature in the Concentrator Vessel is maintained between $40^{\circ}C$ and $50^{\circ}C$. Stirrer in the Concentrator Vessel plus air pulses from the bottom will prevent the mat formation over the screen in the Concentrator Vessel.
4. During the washing process filtrate is collected in the Agglomeration Vessel (Figure 2). Fibers and macrostickies are retained in the Concentrator Vessel while fines, fillers and microstickies accumulate in the Agglomeration Vessel.
5. Once the washing cycle is completed (about 20 minutes) fibers and macrostickies are transferred to the laboratory slotted screen. Macrostickies are collected on the filter paper by following the standard laboratory slotted screen process. In the meantime, while macrostickies are screened and collected, microstickies in the Agglomeration Vessel are agglomerated by the proprietary method. If macrostickies measurement is not of interest, retained pulp can be sewered instead of sending it to the laboratory slotted screen.
6. When the laboratory slotted screen cycle is complete, filter paper containing macrostickies is removed and a new filter paper is placed in the Auto Filter Cartridge.
7. Agglomerated microstickies are automatically transferred to the laboratory slotted screen and again the standard laboratory slotted screen process is followed.
8. When the laboratory slotted screen cycle is complete, filter paper containing agglomerated microstickies is removed.
9. Collected macrostickies and agglomerated microstickies can be measured by any one of the known

methods such as, TAPPI Method, INGEDE method, hydrophobic blue dye method, hydrophilic black ink method, and laminator method (Figure 5).
10. If the number of collected particles is less than 50 repeat the procedure with a larger sample.

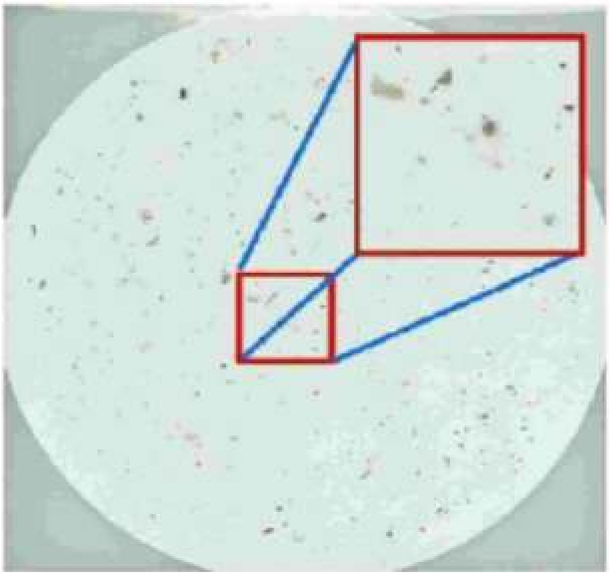


Figure 5: Scanned image of stickies

Macrostickies and Microstickies Removal Effficiency

Three stage screening system in a board mill that manufactures 100% recycled linerboard was analyzed. Fine pressure screen system has 3-stage cascade arrangement with 5 primary screens and one each in the secondary and tertiary stages. Interestingly, primary screen slot sizes are different varying from 0.2 mm to 0.25 mm (0.008 to 0.01 inches) as shown in Figure 6.

We measured macrostickies in feed and accepts from fine pressure screens at the mill using 0.15 mm (0.006 in) slot screen plate in the laboratory slotted screen. However, we observed significant variations in feed concentration of the five primary screens. For example, feed stickies area greater than 0.06 mm^2 varied from 47.6 mm^2/g to almost 1500 mm^2/g as shown in Table 1. This was attributed to the malfunction of rotor in the feed chest. Also, there is a strong possibility that most of the secondary screen accepts are going to the screen no. 5 (see Figure 6). Respective macrostickies area in accepts and macrostickies removal efficiencies are also shown in Table 1.

As expected screen with the smallest slot size (0.20 mm) is the most efficient with macrostickies removal efficiency of 94%. Two screens, no. 3 and 5, with the largest slot size of 0.25 mm have macrostickies removal efficiency of 29 and 72 respectively. The high efficiency of screen no. 5 can be attributed to the mixing of secondary screen accepts to the feed. The results are also shown graphically in Figure 7.

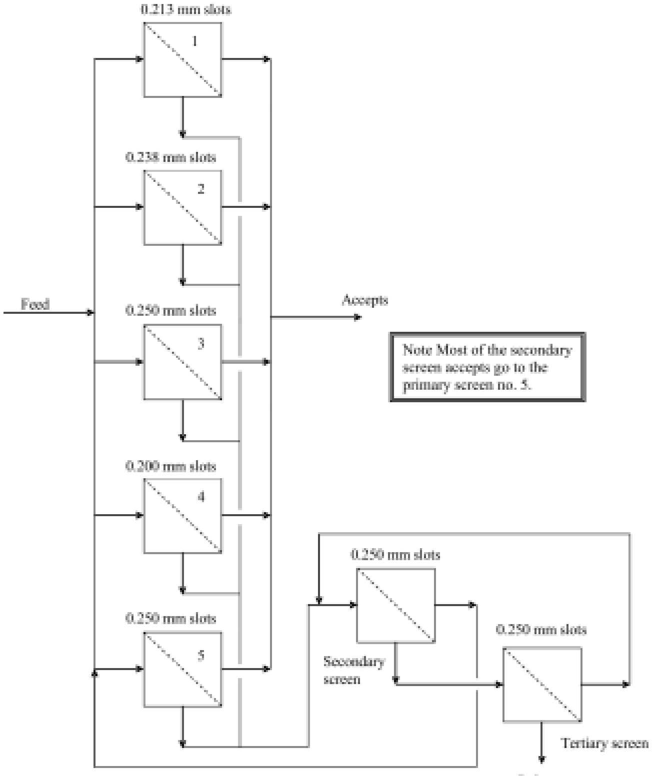


Figure 6. Three stage cascade screening system at a packaging mill.

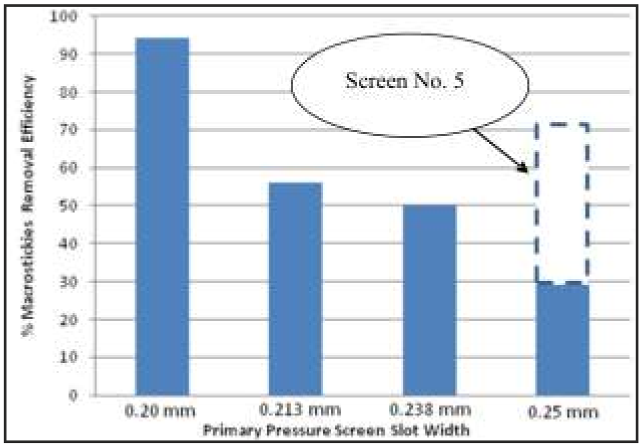
Table 1. Primary pressure screen macrostickies area (mm^2/g) and removal efficiency in a packaging mill.

Screen No.	Slot Width, mm (inches)	> 0.06 mm^2 Feed (X)	> 0.06 mm^2 Accepts (Y)	%SRE^
1	0.213 (0.0085)	53.4	23.7	56
2	0.238 (0.0095)	110.3	55.1	50
3	0.250 (0.010)	47.6	34.0	29
4	0.200 (0.008)	134.0	7.6	94
5	0.250 (0.010)	1498.9	419.4	72

^SRE: Total macrostickies removal efficiency = 100[1 (Y/X)]*

Figure 7. Primary pressure screen macrostickies removal efficiency.

Macrostickies removal efficiency increases as slot size decreases.



We observed that there were quite a few large size stickies (associated with fiber bundles) in both feed and accepts as shown in Table 2. One would think that the majority of macrostickies with area greater than 1.5 mm^2 (equivalent circle diameter of 1.38 mm) would be easily removed by screens

Table 2. Primary pressure screen large macrostickies area (mm^2/g) and removal efficiency in a packaging mill.
Large macrostickies: Area >1.5 mm^2 (Equivalent circle diameter greater than 1.38 mm).

Screen No.	Slot Width, mm (inches)	> 1.5 mm^2 Feed (X)	> 1.5 mm^2 Accepts (Y)	%SRE^
1	0.213 (0.0085)	46.5	14.1	70
2	0.238 (0.0095)	97.8	42.1	57
3	0.250 (0.010)	40.3	25.6	37
4	0.200 (0.008)	119.8	3.9	97
5	0.250 (0.010)	1166.4	376.4	68

^SRE: Total macrostickies removal efficiency = 100[1 (Y/X)]*

with slot size 0.25 mm or lower resulting in much smaller amount in accepts. However, that is not the case indicating that relatively high pressure drop plus other factors (like rotor design, consistency, temperature, reject ratio and nature of stickies) are driving these relatively large size stickies through much smaller slots.

We note that measured stickies area is somewhat larger than the native value due to pressure and heat applied during lamination. Nevertheless, the amount of large stickies in accepts seems to be quite high indicating squeezing or oozing of these stickies through the screen slot opening.

Microstickies removal efficiency as measured by the accelerated agglomeration method is shown in Figure 8. We note that fine screen with slot sizes of 0.20 mm or 0.213 mm (0.0085 inches) have negative efficiency while screens with slot sizes 0.238 mm or 0.25 mm have positive efficiency, except for one corresponding to screen no. 5. It is likely that when slot size is reduced while maintaining throughput, consistency and reject ratio results in the disintegration of stickies creating microstickies. Screen no. 5 receives recirculated fragile stickies via secondary screen accepts that are prone to disintegration.

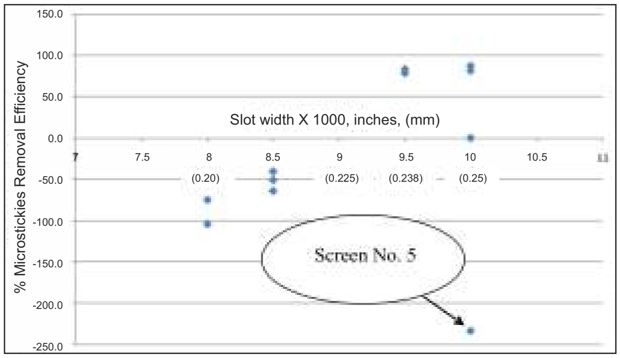


Figure 8. Board mill fine pressure screen microstickies removal efficiency.

One would expect most of the non-removable microstickies in accepts of the primary screen and consequently lower levels in secondary and tertiary screen feed streams assuming no disintegration of macrostickies. However, data in Figure 9 reveal that microstickies level is higher in secondary and tertiary screens. The higher levels of microstickies in feed streams of secondary and tertiary screens could be due to the addition of dilution water and/or due to the disintegration of macrostickies.

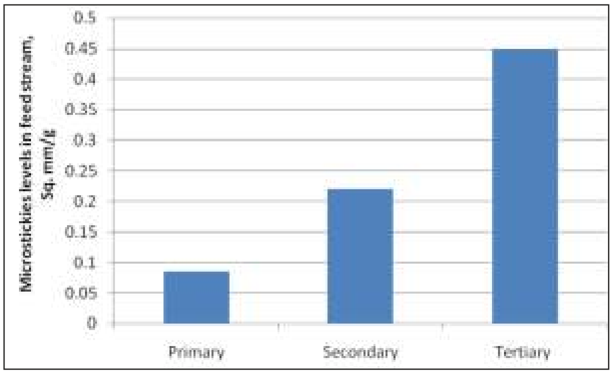


Figure 9. Microstickies levels in feed streams of screens in a packaging mill.

The packaging mill was not able to reduce the slot size in the secondary and tertiary screens due to capacity constraints. As a result, some of the macrostickies rejected by the 0.238 mm or smaller slot primary screens are being accepted by the 0.25 mm secondary screen, which sends them to the 0.25 mm primary screen where they can be accepted to become "microstickies". This arrangement is no doubt causing a bigger "microstickies" problem in their process water system and could explain why the mill was reporting longer lasting episodes for stickies problems, in spite of the smaller slot widths in some of their primary screens.

Results from a tissue mill using a pressure screen with slot size of 0.15 mm (0.006 inches) indicate negative microstickies removal efficiency, as shown in Table 3, possibly due to the disintegration of macrostickies.

Table 3. Macrostickies and agglomerated microstickies (AMS) removal efficiency of slotted screen in a Canadian tissue mill.

	0.15 mm (0.006 in) slot screen		
mm^2/kg	Feed	Accepts	% Eff.
Macrostickies	2480	1276	48.5
AMS	83	1039	-1152
Total	2563	2315	9.7

Screen System Design

As mentioned earlier, most pressure screens operate with mass reject ratios of 15-30%. To minimize fiber loss, second, third, and sometimes fourth screening stages are utilized. The arrangement of these tailing stages is critical to the contaminant removal efficiency of the system. In a conventional cascade system (Figure 10), the recirculation of contaminants between stages is possible and this can be detrimental to overall system efficiency, particularly when stickies disintegration occurs in screens with very small slot sizes 0.20 mm (0.008 inches) or smaller (2, 3, 4).

We therefore, need to rethink screening system design concepts. In the new system design we want to follow two common sense rules:

1. **Do not recirculate stickies.**
   In other words, once stickies have been removed by primary screen do not bring some of them back via secondary screen accepts as being practiced in conventional cascade system (Figure 10).

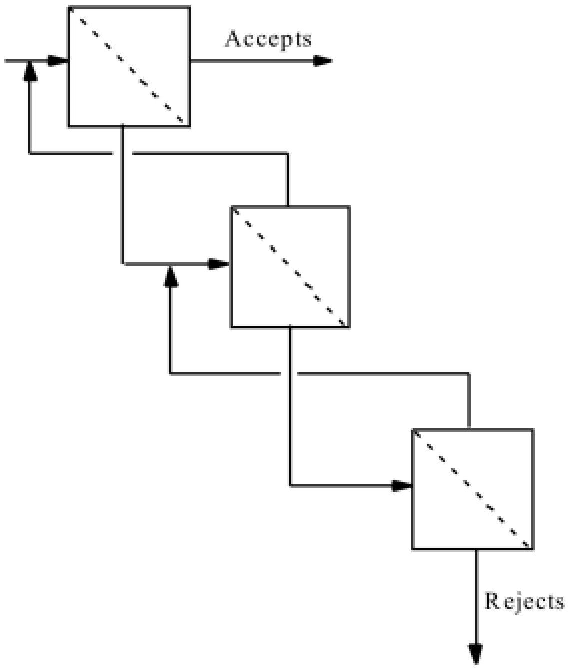


Figure 10. Conventional cascade screening system.

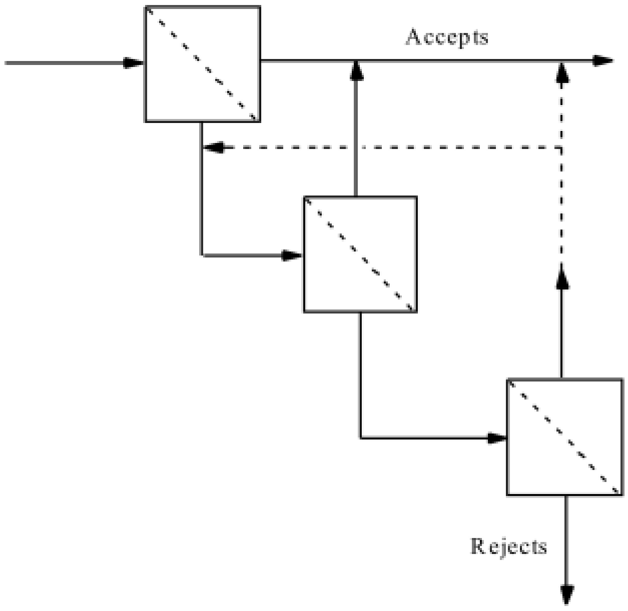


Figure 11. Forward flow screening system.

2. **Do not mix clean stream with a dirty stream.** For example, when secondary screen accepts are mixed with primary screen accepts (Figure 11) we need to make sure that contaminant levels in both streams are somewhat similar.

The use of forward-flow arrangement, shown in Figure 11, is proposed in compliance with these rules (1, 13). In this example, the primary and secondary stages have slots of the same size. The secondary screen accepts are moved forward, rather than being moved to the primary feed stream as in the conventional cascade system. Secondary screen consistency and reject ratio should be adjusted to make sure that accepts are as clean as the primary screen accepts in accordance with the Rule number 2.

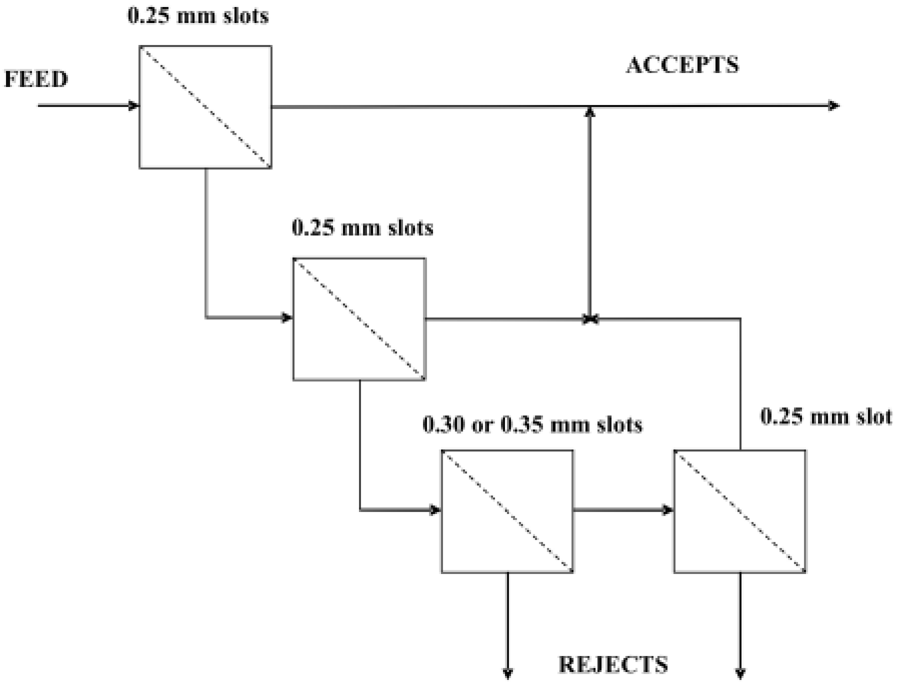


Figure 12. Forward flow screening system with two screens in series in tertiary stage.

Tertiary screen feed is loaded with contaminants rejected by both primary and secondary screens. Therefore, it is relatively difficult to make tertiary screen accepts as clean as primary or secondary screen accepts We can reduce slot size while at the same time adjust consistency and reject ratio to ensure that the second rule is not violated. This is not always possible. Besides, the use of smaller slot size may lead to the creation of more microstickies. A simple solution is to use two slotted screens in series in the third stage, as shown in Figure 12. Thus, by moving third-stage, slotted-screen accepts forward, the recirculation of contaminants is avoided. An added benefit is the reduced capacity requirements in all three stages by not recycling accepts from the secondary or tertiary stages back to the primary and secondary stages, respectively. Slot size in the first tertiary screen may be slightly larger than the primary or secondary screen so as to reduce load on the next tertiary screen.

A simple mass balance calculation that does not take into account macrostickies disintegration will show that the conventional cascade system is superior to the forward flow arrangement. However, when stickies disintegration is taken into account mass balance calculations confirm that the forward flow arrangement is a better choice as shown by Doshi and Prein (13).

Conclusion

As expected, macrostickies removal efficiency increases as slot size is reduced. However, when fine screen slot size is reduced intense shear force may be needed to maintain capacity. This may potentially lead to the disintegration of macrostickies resulting in the negative microstickies removal efficiency. These microstickies are prone to agglomeration and deposition on the paper machine system.

Two simple common sense rules are proposed to guide in screening system design. The forward flow arrangement should be preferred over the conventional cascade system when macrostickies disintegration is pronounced. The measurement of agglomerated microstickies is of paramount importance in evaluating and designing individual screens and screening system.

Future Plans

The microstickies Classifier is useful in evaluating the performance of unit operations in recovered paper processing system. Ideally one should measure microstickies removal efficiency of unit operations and establish data base that can be used later for system improvements or for troubleshooting when problems arise.

Our next step is to monitor microstickies in the paper machine headbox and white water and correlate that to associated stickies deposition or product quality issues.

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