REFEREED PAPER

DIFFUSER JUICE SCREENING USING FINE WOVEN MESH SCREENS - TRIAL RESULTS AND FULL SCALE DESIGN

JENSEN PS

[1] *Tongaat Hulett Technology group*
paul.jensen@tongaat.com

Abstract

Wedge wire screens with apertures between 500 and 1000 µm are used in most sugarcane factories to remove large fibres from mill or diffuser juice. They are followed by settling clarifiers which, if working correctly, remove the remaining suspended solids. The Direct Clear Juice (DCJ) concept, which clarifies the juice in the diffuser, requires the removal of bagacillo particles down to 80 µm. At this aperture, woven mesh screens have a much larger open area than wedge wire screens and thus a smaller screening station is required. A trial woven mesh screen was installed at Maidstone in November 2015 to assess its effectiveness at removing bagasse at the concentration and particle size typically found in diffuser juice. Based on the promising results a full scale woven mesh screening station was designed. Woven mesh screens are sometimes installed as safety nets after clarification to remove any fibres which did not settle. With the economic drive towards more compact clarifiers, it is expected that the popularity of these screens will also increase.

Keywords: screening, clarification, diffusion, DCJ, woven mesh, wedge wire

Introduction

Diffuser juice or draft juice (DJ) screening, using either “DSM” or rotary screens with “large” apertures (500 to 1000 µm), is common in many diffuser factories. The screens are located above the diffuser so that screened fibre, which originates from the shredding of sugarcane stalks, can fall back onto the cane bed. DJ screening removes large fibres which tend to settle and form clumps in the mixed juice (MJ) tank. These clumps can cause blockages in the MJ pumps and heaters. Small fibre particles (bagacillo) are not usually a problem and actually assist the clarification process (Baikow, 1967). Their complete removal before clarification is undesirable. Most factories practise mud filtration which requires bagacillo to be added to the mud prior to filtration and if more bagacillo is removed during DJ screening, it will require additional bagacillo addition to the mud. There is therefore no reason to use DJ screens with apertures below 500 µm if they are followed by settling clarification.

Clear juice (CJ) screens with apertures less than 100 µm are sometimes used in factories which are prone to mud carryover. Given the small amount of fibre in CJ and the large open area of these screens, a relatively small screen area is sufficient. The screened fibre is, however, not as easily dealt with as that from the DJ screens which is just “dropped” onto the cane bed in the diffuser below. Under the South African cane payment system, returning this fibre to the diffuser is not practical as it requires a transport mechanism and must be analysed to avoid double accounting of sucrose in MJ. A DCJ factory (Jensen *et al*, 2015) has the opportunity of using a fine aperture screen in place of a large aperture DJ screen as no further treatment of the already clarified juice is required. A small woven mesh test screen was constructed and its performance tested at Maidstone factory towards the end of 2015.

Specification of juice screens

From a processing point of view, the two most important parameters in the selection of a screen are its aperture and open area. The aperture determines the particle size which will pass through the screen. The largest particle size which appears to pass through the screen is somewhat smaller than the screen aperture and is defined by Manson and Ames (1982) as the cut-off. This is due to the angle at which the juice contacts the screen, as well as the layer of fibre which builds on the screen, and acts as a filter itself. The open area affects the maximum juice loading of the screen. The screen capacity is the juice loading, expressed in $t/h/m^2$ (an SG of 1 was assumed for all samples), at which the screen begins to "flood"; the higher the capacity the smaller the screening area required.

Rotary and "DSM" screens generally use wedge wire screen material to remove suspended solids. Manson and Ames (1982) report that the cut-off size for wedge wire screens is approximately half the aperture size. A screen supplier ([1]unpublished data) explained that rotary wedge wire screens typically remove 95% of the particles larger than the aperture, and 50% of particles larger than half the aperture. For a given aperture, the open area is a function of the thickness of strand wire used. This relationship is described in Figure 1 and equation 1.

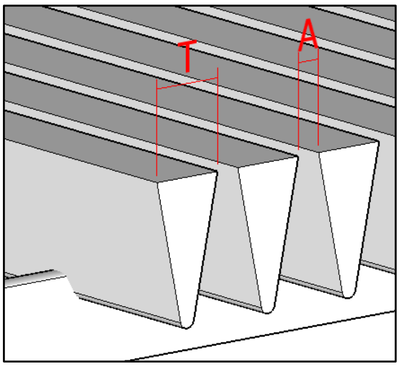


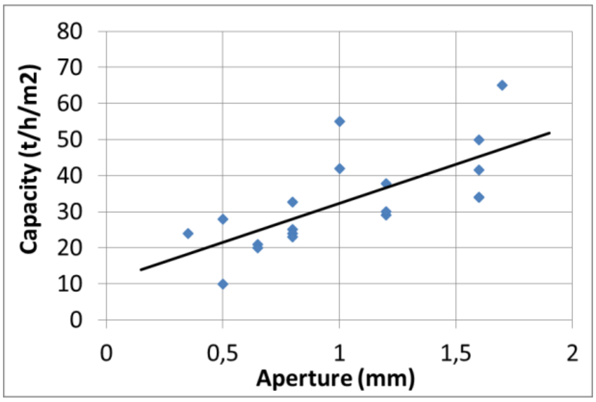
Figure 1. Wedge wire screen using wire of thickness (T) and aperture (A)

Open area % (wedge wire) = A/(A+T))……………………(equation 1)

Wedge wire screens are generally self-supporting as the relatively thick wire strands are welded to backing strands to form a robust construction. Wedge wire strand thickness varies between about 1 and 2 mm. With a 1 mm strand thickness and a 0.5 mm aperture, the open area is 33% (equation 1) but reducing the aperture to 0.08 mm reduces the open area to just 7%.

Figure 2 (left) shows that the screen capacity is a strong function of the aperture; smaller apertures give screens with lower capacities. This results from the difficulty in constructing wedge wire screens with both a low aperture and high open area. Interpreting Figure 2 (right) shows that if two screens with the same open area are compared, the screen with the smaller aperture will have the higher capacity. For example, a 0.4 mm aperture screen will have a 50 % higher capacity than a 1.5 mm aperture screen with the same open area.

[1] Mr D Taylor, Industrial Screening Technology (Pty) Ltd (2014).



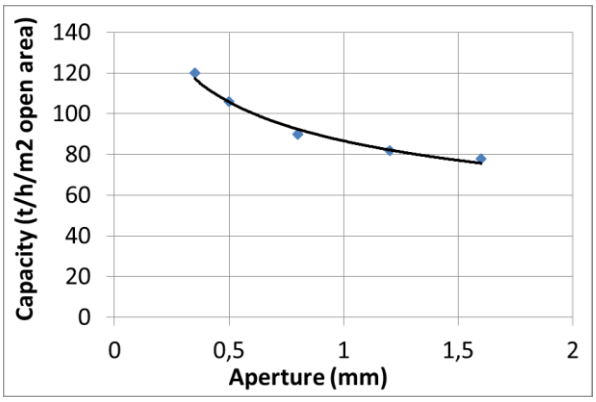


Figure 2. Wedge wire screen capacities as a function of screen aperture, showing data from Brotherton and Noble (1982) and Manson and Ames (1982)

Woven mesh screens are usually supported by a backing screen which provides structural support. They can therefore be constructed from much thinner wire. The relationship between wire thickness, screen aperture and open area is described in Figure 3 and equation 2.

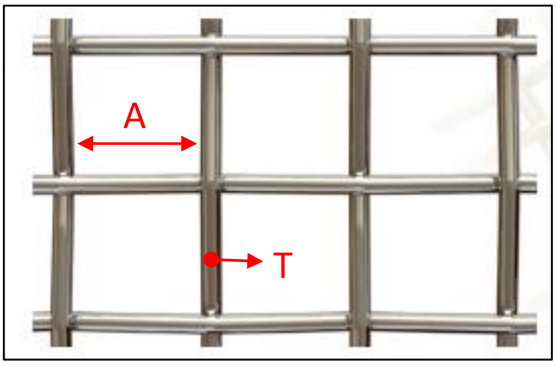


Figure 3. Woven mesh screen using wire of thickness (T) and aperture (A)

Open area % (wire mesh) = $A^2/(A+T)^2$……………………(equation 2)

For a 0.08 mm aperture, a 0.055 mm wire strand could be used. The corresponding open area is 35% compared with 7% for a wedge wire screen of the same aperture (1 mm wire). The high open area is demonstrated by the ease with which a jet of water passes through the screen (Figure 4).

Figure 4. Pressurised water penetration through a 0.08 mm aperture, 35% open area woven mesh screen

Fibre in juice and screen selection

Raw juice from a milling tandem may contain up to 3 % insoluble solids, while raw juice from a diffuser typically contains less than 0.1 % (Rein, 2007) as the 1.8 m deep shredded cane bed in the diffuser filters out much of the fibre. Most of the fibre in DJ originates from the front of the diffuser where the scalding juice first contacts the cane and the bed is still too loosely packed to act as an efficient filter. Changing the diffuser to a DCJ configuration (Jensen *et al*, 2014) allows juice exiting at the diffuser feed end to be filtered through the cane bed allowing the bagacillo concentration in diffuser juice to be further reduced.

On a laboratory scale, it was found that after a few minutes the juice circulating through a column filled with shredded cane contained no visible solids at all (Jensen, 2012). On a full scale plant, however, the continuous interaction between the dragging cane bed and the diffuser screen results in some small particles becoming "dislodged" and penetrating the screen. The quantity of fibre in juice was measured by filtering a sample through a 53 µm screen (bagacillo particles are generally larger than 100 µm), drying it, and expressing the mass as ppm on juice. The average bagacillo contamination found in unscreened DCJ was 83 ppm and this needs to be reduced to below 10 ppm to meet direct consumption sugar norms (Jensen *et al*, 2014).

Sixteen particle size analysis tests, using stacked sieves, were performed on the dried bagacillo screened from diffuser juice. Figure 5 shows that less than 5 % of the bagacillo in DCJ is below 106 µm. Based on this small amount, it was assumed that the concentration of particles smaller than 53 µm was minimal. The low turbidity of DCJ (Jensen *et al*, 2015) suggests that particles between 0 and 53 µm are removed by inclusion in mud particles.

A screen aperture of 80 µm was selected for the trial. It is expected that a screen with much smaller aperture than the particles being screened would be less susceptible to blinding than one with apertures similar to the particle size. The open area of the screen was 35%.

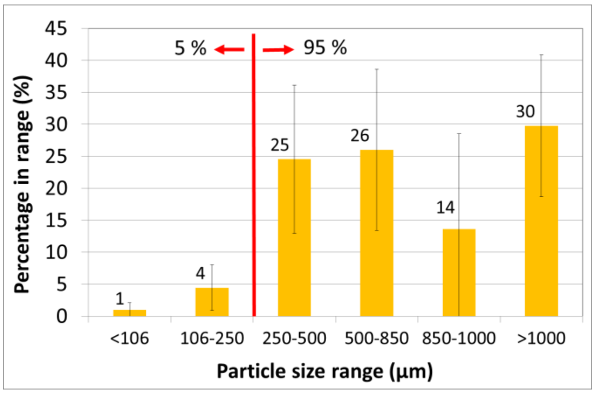


Figure 5. Results of particle size analysis for bagacillo screened from diffuser juice using a 53 µm sieve

Screening Trials

A sketch of the trial equipment is shown in Figure 6. The diffuser was configured in DCJ mode, evident by the raw juice being removed from stage one as opposed to the DJ stage as in a conventional diffuser. Lime and flocculent were, however, not added to the diffuser during the trials due to problems with the lime pumps. A frame to support a 0.5 m x 0.5 m woven mesh stainless steel screen was constructed and a hinge mounted on the roof of the Maidstone diffuser so that different screening angles could be tested. The screened fibre was returned to the diffuser through a hole in its roof. A sample line of raw juice was directed onto the woven screen through a distributer. The screened juice was returned to trough one after passing through a 55 litre tundish. The flow rate through the screen was estimated by closing the outlet of the empty tundish and measuring the time it took to fill.

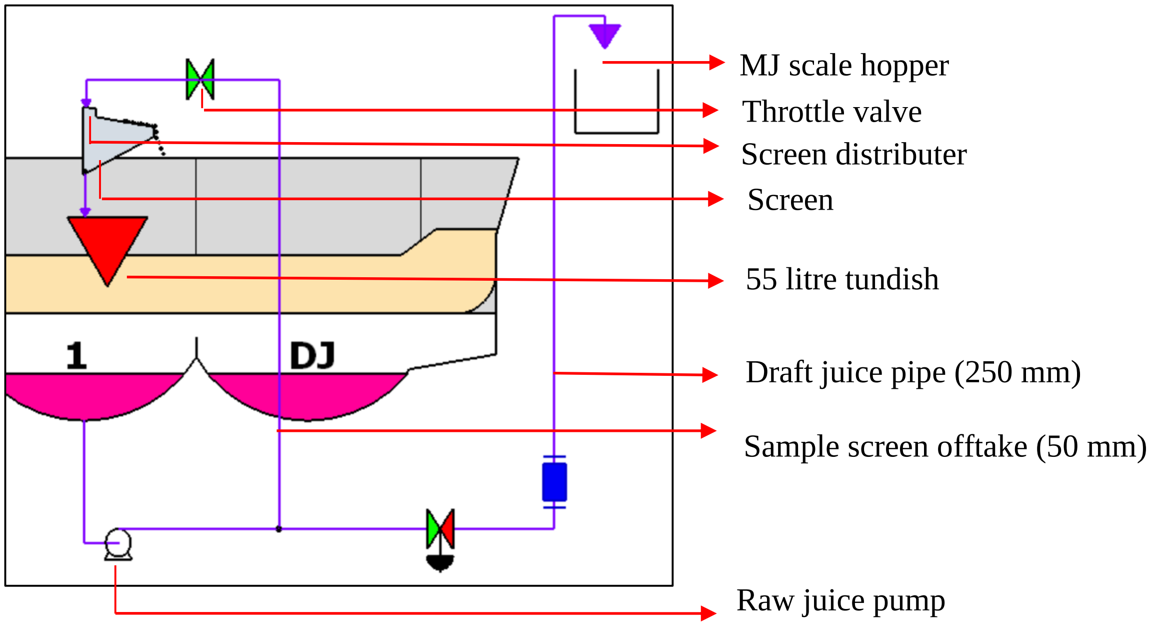


Figure 6: DCJ juice screening trial layout

Results

Screen Capacity:
The screen capacity is the juice loading at which flooding starts to occur. Unfortunately, the maximum flow rate deliverable to the screen was not limited by the screen capacity but the flow rate at which the distributer and tundish began overflowing onto the floor. The maximum juice loading tested was 77 t/h/m^2 (220 t/h/m^2 open area). Intermittent blockages in the sample line also restricted the amount of juice which was diverted to the screen. The clean screen capacity was therefore not achieved but can be estimated by observing the amount of screen which was used for screening.

Figure 7 (left) shows that even at a juice loading of 77 t/h/m^2, less than half the screen was being used for screening. A large "de-watering" section (the area of the screen free of liquid)) is beneficial to reduce juice recycling.

Figure 7 (right) shows the screen operating at a juice loading of 42 t/h/m^2. The increased area occupied by the juice on the screen compared with Figure 2 (left) is indicative of some screen blinding.

Juice loading: 77 t/h/m^2	Juice loading: 42 t/h/m^2
	

Figure 7: Juice flowing through sample screen

Juice Foaming:

Juice foaming was observed intermittently during the trials (Figure 8). The cause may have been a cavitation across the throttle valve (Figure 6) or across intermittent blockages in the line. It was initially suspected that air might be entering the raw juice pump but with trough one full, this was unlikely. Juice foaming tended to blind the screen apertures and reduced the screen capacity to about 20 t/h/m^2 (Figure 8). Foaming on a full scale screening installation clearly needs to be avoided.

Screen Capacity: 23 t/h/m^2	Screen Capacity: 18 t/h/m^2
	

Figure 8: Maximum juice loading achieved with foaming

Screened bagasse removal and screen angle:

Given the high open area of the screen, the liquid drains quickly from the bagasse resulting in a high coefficient of friction between the bagasse and sieve; so high that it does not slide across the screen even when it is removed and held almost vertically (Figure 9).

Figure 9: Vertical screen showing high friction between bagasse and mesh

This is a different dynamic to a wedge wire DSM screen, where the bagasse tends to slide across the screen. A requirement of using a woven mesh screen is therefore an option for purging the bagasse from the screen. Periodically increasing the flow rate for a few seconds was effective for this purpose. The higher flow washes the bagasse “dam wall” (Figure 11) off the screen and the short time results in only a small amount of juice being recycled to the diffuser. An automatic water spray with correctly directed nozzles, or an operator with a hosepipe in hand, would also be suitable for removing bagasse. The screen angle should be close to horizontal to minimise the chance for juice to overflow the screen and return to the diffuser. Two angles were tested, namely; 11° and 18°; it was observed that 11° was more suitable due to less juice being recycled while still having sufficient gradient to assist the bagasse in moving across the screen.

Figure 10: Trial screen positioned at an 11° screening angle

Bagacillo removal effectiveness:
The bagacillo removal effectiveness was tested the day after approximately 25 mm of rain. The level of fibre measured in unscreened juice averaged 248 ppm. The average bagacillo removal efficiency was 97 % (Table 1). In all but one of the tests the bagacillo content after screening was below10 ppm.

Interpreting the data reported by Brotherton et al (1981) shows that the bagacillo content from about 81 samples of CJ taken from three factories was 9 ppm with a minimum of 0.1 and a maximum of 50 ppm. The bagacillo content in the screened raw juice from Maidstone is therefore in the range of typical clear juice.

Table 1: Bagacillo content in screened and unscreened DCJ

	Before sieve (ppm)	After sieve (ppm)	% Removal
Test 1	272	5	98%
Test 2	200	14	93%
Test 3	114	9	92%
Test 4	406	4	99%
Avg	248	8	97%

Screen robustness:
The screen was in place for approximately three weeks. A slit/tear was caused in trying to remove bagasse from the screen with a piece of angle iron. The slit (3 cm long) was repaired with epoxy glue and no other blemishes in the screen were observed in the three-week trial. A second screen with a mesh backing was purchased; the mesh backing reduces the tension and sagging of the screen and is recommended for future installations. The screens are most vulnerable when in transportation and care should be taken to avoid contact with sharp or hard materials.

Screen cleaning:
Figure 11 shows the screen after about 2.5 hours of screening. Given the inconsistent juice flow rate, it was difficult to determine how much juice had passed through the screen. The bagasse tended to create a “dam wall” which prevented the juice flowing off the edge of the screen. Occasionally, the “dam wall” was breeched and some juice flowed off the edge of the sieve, taking with it a fair amount of fibre. In this way the screen is somewhat purged of fibre but the dynamics are dependent on the juice flow rate.

Figure 11: Fibre build-up on the sample screen

It was found that if the juice was not well-distributed as it flowed onto the screen it showed signs of blinding (Figure 12). While the rest of the screen was easily cleaned using a light pressure spray, the dark area was not able to be completely cleaned. It is expected that a higher pressure hose wash for a few seconds will dislodge these particles. A periodic wash with caustic and/or sulphamic acid (estimated three times per season) would also assist in softening particles which become lodged in the screen apertures. The open area of the dark section is much less than the rest of the screen. This shows the importance of the juice contacting the screen parallel to it rather than perpendicularly which tends to force the fine particles into the screen pores.

Figure 12: Woven screen after rinsing off bagasse after ~24h operation with uneven juice distribution onto the screen

Full screening station design

Based on the results of the trials, a full screening station was designed for installation on the Maidstone diffuser roof. A design area of 18 m^2 was selected which converts to a juice loading of 21 $t/h/m^2$ for the diffuser which has a capacity of 400 t/h juice. While the trial found the capacity of the clean screens to be more than 77 $t/h/m^2$, a conservative juice loading was targeted to allow for capacity reduction due to screen blinding, as well as the ability to remove individual screens from service without compromising the factory throughput. With these screens following the diffuser operating in DCJ mode, it is expected that Maidstone's clarification station may be bypassed without compromising sugar quality. Maidstone is planning to have the screens installed in the near future.

Conclusions

- In a factory with settling clarifiers, there is no driver for using raw juice screens with apertures below 0.5 mm.
- Clear juice screens with apertures down to 80 µm are used in some factories to prevent bagacillo carryover from the clarifiers from compromising sugar quality.
- At low apertures, the open area of wedge wire screens is greatly reduced and woven mesh screens are preferred to minimise the screening area required.
- The maximum juice loading of the 80 µm clean trial screen was 77 $t/h/m^2$ but the screen's capacity was not reached.
- Juice foaming led to a decrease in the screen's capacity to about 20 $t/h/m^2$ and measures to avoid foaming should be incorporated in a full scale design.
- The screen removed 97% of the fibre in the juice.
- A DCJ factory using 80 µm woven screens in place of DSM screens has the ability to produce good quality clear juice without the use of a settling clarifier.

References

Baikow VE (1967). *Manufacture and Refining of Raw Cane Sugar*. Elsevier. pp 103.

Jensen PS (2012). Direct clear juice: A feasibility study and piloting investigation into the production of clear juice in a sugarcane diffuser. *Proc S Afr Sug Technol Ass* 85: 344-367.

Jensen PS, Davis SB, Love DJ and Rassol A (2014). The production of clear juice in a sugarcane diffuser at Maidstone factory. *Proc S Afr Sug Technol Ass* 87: 140-162.

Jensen PS, Ramaru R and Suliman M (2015): Direct Clear Juice (DCJ): Factory trial results including bagacillo removal requirements for the continuous production of good quality DCJ. *Proc S Afr Sug Technol Ass* 88: (In Press)

Rein PW (2007). *Cane Sugar Engineering*. Verlag Dr Albert Bartens. pp 163, 171, 220

Manson PG, Ames RV (1982). Fibre removal from juice. *Proc Aust. Soc. Sugar Cane Technol*. 4, 255-259

Brotherton GA, Noble AG, Swindell RJ (1981). Juice Screening. *Proc Aust. Soc. Sugar Cane Technol*. 3, 117-124

Brotherton GA, Noble AG (1982). Performance and capacity of juice screening systems. *Proc Aust. Soc. Sugar Cane Technol*. 4, 243-248