QUALITY ASSESSMENT OF THE FILTERING SCREENS USED IN SUGAR PROCESSING CENTRIFUGALS

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Abstract

The condition of the filtering screens used for separating sugar crystals and molasses in continuous centrifugals has a major influence on sugar losses, separating efficiency and throughput. Several methods, which characterize screen quality in terms of the slot width, uniformity, per cent open area and the resistance to fluid flow have been assessed by Sugar Research Institute. These are a photographic method, an automated microscopic technique, video image analysis and screen flow resistance measurement. Various applications of the methods are discussed.

Introduction

The filtering screens conventionally used in the centrifugals in the Australian sugar industry are electroformed chrome-nickel screens about 280 μm thick comprising a nickel base with a thin coating of chromium 15 to 20 μm thick. The screens in general use have slots 0,06 mm wide, 1,67 mm or 2,2 mm long, providing an open area of 6 per cent. Screens of other dimensions have been investigated, including screens of 0,04 mm slot width with 4 per cent open area and screens of 15 per cent open area with 0,06 mm wide slots. On the working side of the screens the slots have a square cut entrance but diverge on the outlet side to assist molasses drainage and to minimize the tendency of fine crystals to block the slots. A backing gauze, normally woven wire, is installed on the basket to assist drainage of the separated molasses and to provide flat support areas for the thin filtering screens.

The sucrose loss to molasses can be divided between the physical loss of crystal passing through the screen slots into the molasses, and that caused by dissolution due to water and steam addition. Jullienne[4] determined that on average about 60 per cent of the total sucrose loss in centrifuging was due to the physical loss of crystal through the screen. This loss depends on both the screen slot dimensions (particularly the slot width) and the size distribution of the crystals in the massecuite (Greig *et al.*[3]). Typically the size distribution of the crystals in the feed massecuite has a number-mean size of about 0,3 mm and a coefficient of variation of 0,3.

It is important that the filtering screens are maintained in good condition and repairs or replacement undertaken when slots become enlarged. Changes to the screen slots can result from corrosion of the screen surface or base material, erosive wear, impact damage, stretching or indentation into the backing gauze. The corrosive and erosive mechanisms of screen wear have been studied (Greig *et al.*,[1] Kelly *et al.*[5]). The most serious form of damage to screens which contributes to crystal loss is when slot distortion provides an opening substantially larger than the original slot specification of 0,06 mm, e.g. up to 0,1 mm. Figure 1 shows photomicrographs of the profile of slots in a new centrifugal screen and in a screen where the slots have distorted due to embedding of the screen into the backing gauze.

A study by White *et al.*[7] assessed the substantial cost which results from the increased loss of crystals to final molasses by retaining worn screens in centrifugals. This work determined that, for typical massecuite loadings, the optimum replacement time was after about one month's use. At this frequency of replacement, centrifugal screens cost the Australian sugar industry approximately $0,5 million per annum.

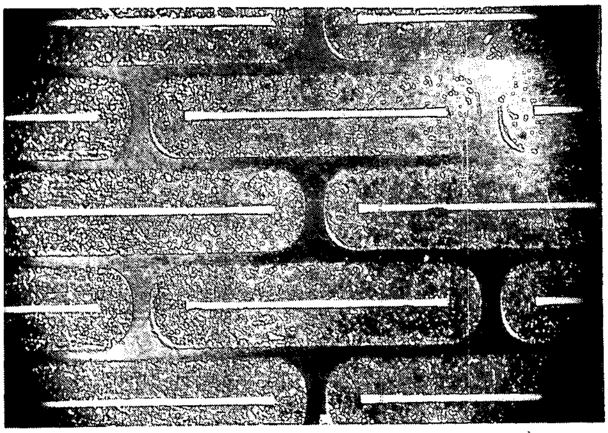


FIGURE 1 Photographs showing slots on new and distorted screens (at 16 magnification).

Screen evaluation

The properties of the screens for which information was sought from the measuring systems included:

- mean slot width
- slot uniformity
- percentage open area
- resistance to the flow of molasses through the screen
- screen wear, including changes in the slot profiles and changes in the resistance to flow of the molasses.

Four measuring systems have been used to evaluate the properties of the screens and these are described in turn. Until now these procedures have been used for laboratory measurements on loose screens and have not been applied to fitted screens within the centrifugals.

Photomicrographic techniques

With this method, sections of the screen were photographed using a 35 mm camera body attached to an optical microscope. The negatives obtained were enlarged to yield prints suitable for estimation of slot dimensions (width and length), slot uniformity and percentage open area.

It is imperative that care be taken in selecting an appropriate film type and exposure value to give a sharp, black image of the slots without inducing excessive flaring or halation of the negative from overexposure. If it is desired to include details of the screen surface this can be achieved using 'grazing incidence' illumination.

Although the accuracy of the method is good and a permanent record is obtained, there are disadvantages. The measuring process is time consuming and tedious and the sampling ratio is necessarily small. Furthermore, it is difficult to obtain good reproductions from used screens which have suffered distortion and indentation.

Automated microscopic measurement

This procedure allows successive measurements of the width of the slots to be made rapidly and with good accuracy, providing information on the mean slot width and uniformity. The open area of the test section of the screen can then be determined. Details of the technique have been given by Wright *et al.*[8].

The general arrangement of the automated microscopic system is shown in Figure 2. The basic instrument used is a Nikon profile projector which illuminates a portion of the screen with parallel light from the underside and projects the slots onto a flat vertical image plate. The projector was modified by motorising the sample traversing plate, and mounting a linear array of photodiodes into its image plane. As the magnified image of a slot passes beneath the photodiode array, an analog output, proportional to the number of photodiodes which are conducting, is logged and processed by a microcomputer system. The mean slot width, together with the root mean square deviation of the slot widths are determined.

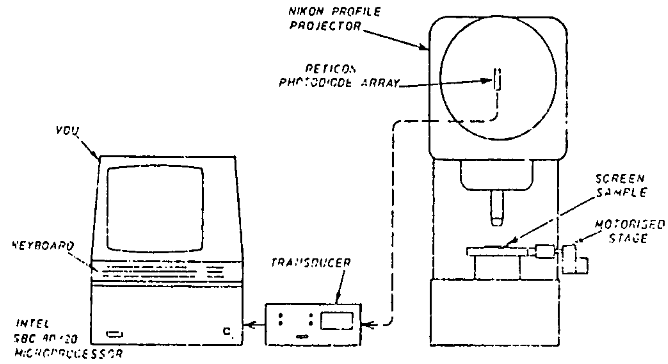


FIGURE 2 Major components of the automated microscopic technique.

A magnification of 20 was generally used and, for a slot of 2,2 mm length, about 700 readings were taken along a single slot. At this magnification excellent precision was achieved with an overall accuracy of 2 μm.

The main limitation of the technique is the necessity to maintain good focus on the slot. This is relatively easily achieved on a new screen or on flat sections of used screens at the 20 magnification setting. For dented screens it is not possible to maintain perfect focus at the point of measurement as the linear array housing obscures the critical portion of the image being measured.

A further limitation in the procedure is that only about six slots in a single line can be inspected per run, due to the limited traverse of the sample plate. In addition the construction of the projector limits the region of the screen which can be monitored to within 120 mm of the outer edge.

Image analysis of slots

The Institute currently applies an automated vision technology system to crystal sizing and the equipment has also been evaluated for slot measurement. The components of the image processing system include a CCTV video camera for image data acquisition, hardware for digitizing the image, a display monitor and image memory. An image comprising 512 x 512 pixels (picture elements) is processed by a host computer which undertakes overall control and computations.

The screen images were obtained through the TV camera mounted on an Olympus BH-2 microscope. The image was then digitised to binary format by thresholding the individual pixel intensity values to either zero or one corresponding to the screen metal or slot segments respectively. It was then relatively simple to determine slot dimensions in the binary image.

The system was of limited value due to the high length to width ratio of the slots. For a magnification which gave an image of the full slot length, the slot width was represented by only eight pixels and the accuracy was poor. One option which has yet to be examined is to take more than one image for a single slot but this introduces problems in precisely locating the screen to the next position for image analysis.

Measurement of screen flow resistance

The rate of separation of the molasses from the massecuite as it passes across the filtering screen depends on the resistance to flow offered by both the crystal layer and the screen. Work by Swindells[6] determined that the screen resistance is a significant proportion of the overall resistance to molasses flow and consequently strongly influences throughput rate and purging efficiency. During use, the flow resistance of the filtering screen will change due to (a) wear causing an increase in the slot dimensions and (b) fouling of the non-working side of the screen due to scale deposition.

The flow of molasses through the screen slots is laminar, with the Reynolds number being typically in the range 0,001 to 0,01. The flow resistance of a screen was determined using the simple apparatus shown in Figure 3 by measuring the flowrate of a sugar solution (of known viscosity) through the screen due to a measured pressure drop. Flow through the screen slots was laminar (Reynolds number at typical test conditions 0,03) allowing the resistance, R_S to be calculated by the expression

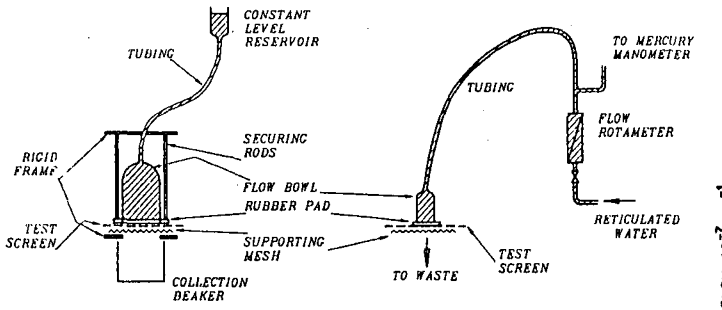
$$R_s = \frac{\Delta P}{u_s \mu} \qquad (1)$$

where Δ P is the pressure drop resulting in a superficial fluid velocity, u_s for the fluid of viscosity, μ.

Measurements of the screen flow resistance were possible to a repeatability of about four per cent though some care was required with the technique to avoid the entrapment of any bubbles during the filling of the apparatus. For the conventional screens of 0,06 mm slot width and 6 per cent open area, flow resistance values of new, clean screens were generally in the range (0,5 to 1,5) $\times$ $10^7 m^{-1}$. These values are in good agreement with the measurements by Greig *et al.*[2].

For laminar flow through the slots Greig *et al.*[2] determined that the flow resistance of the screen is related to the mean slot width (2,1 mean), w_2 and the screen open area η by the relationship

$$R_s = \frac{K_s}{w_2 \eta} \quad (2)$$



A. SUCROSE SOLUTION FLOW METHOD B. WATER FLOW METHOD

FIGURE 3 Apparatus for measuring the flow resistance of filtering screens.

where the value of the screen constant K_s depends on the geometry of the slots. For filtering screens with slots of very large length/width ratio the value of K_s should be substantially constant.

The screen constant K_s has been determined for a number of new, clean screens from the measured value of screen flow resistance and the '2,1 mean' slot width, as measured by the automated microscopic technique. These data are plotted in Figure 4 and indicate a reasonably constant value for K_s of 21 ± 4 (ignoring the single outlier). This value is approximately half that determined by Greig *et al.*[2].

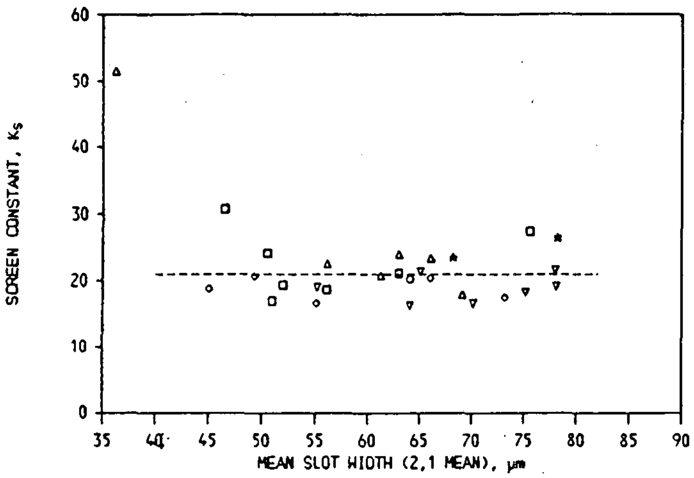


FIGURE 4 Values of screen constant, K_s for screens of different supply.

Measuring the screen flow resistance using a sugar solution is laborious and not readily adapted to measurements on screens within a centrifugal. This technique is therefore not suitable for routine use by factory personnel to assess wear of the fitted screens.

An alternative procedure was devised where a desired flow of water was forced through the test section of screen and the pressure drop was measured. The schematic arrangement of the apparatus for this method is also shown in Figure 3. For all tests the pressure drop was measured for a superficial velocity of 0,3 m/s. This technique was simpler to perform than the measurements using a sucrose solution and has the benefit that the measurements can be undertaken on a screen within a stationary centrifugal. It can be performed rapidly and all areas of the screen are accessible to the technique with each test encompassing a large number of slots.

The flow resistance value, R_w is calculated from equation (1); the temperature of the water being measured to allow the viscosity of the water to be estimated. Equation (1) is not strictly applicable for the usual water flow conditions as the flow regime through the slots is intermediate between laminar and turbulent (Reynolds number being about 1500 compared with the critical Reynolds number of 10 for laminar flow through an orifice).

A comparison of the screen resistance values by the two methods is given in Figure 5.

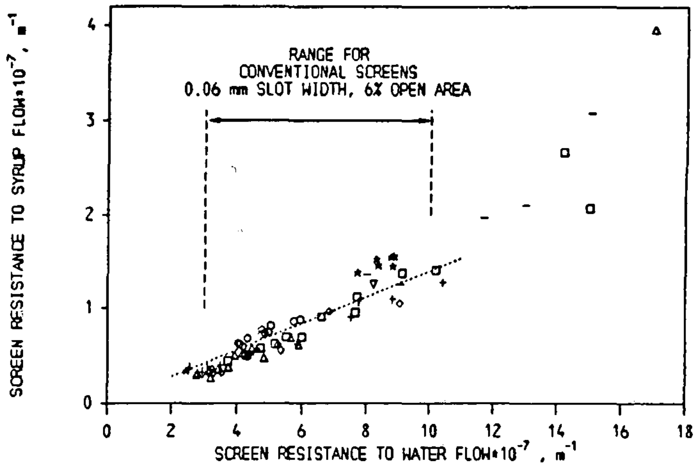


FIGURE 5 Comparison of the Screen Resistance Values determined by the Water and Sucrose Solution flow methods.

The difference between the values is attributed to the use of equation (1) for the non laminar flow results from the water flow procedure. Nevertheless there is a good correlation between the results of the two procedures, and for the screens with 0,06 mm slot width and 6 per cent open area a simple relationship applies, viz.

$$R_s = 0{,}14\ R_w \quad (1)$$

The measurement of screen flow resistance by either method does not provide an absolute measure of the slot dimensions and is most useful when interpreted together with physical measurements of the slots.

Application of the screen evaluation procedures

The measuring procedures based on images of the slot profiles, use projected images and are suitable for new screens and worn screens which are relatively flat. Where slots have distorted in a plane normal to the screen surface, the assessment of the slot width will be underestimated. This type of damage is significant where screens have indented into the backing gauze, and is best quantified by the screen flow resistance measurement.

Assessing the qualities of new screens using the different procedures has ensured that sugar mills are supplied with screens of a high standard, with abnormalities being referred to the supplier. The most effective way to establish quality has been to conduct preliminary water flow tests to give the mean resistance and variability for the screens. If significant variations occur, further testing is performed using the photomicrographic and automated microscopic methods.

Examination of screens following use has given insight into the wear pattern of different brands. For example, for one supply the slot edges in new screens are parallel along most of the length with marked flaring at the ends. Subsequent inspection showed that wear was concentrated in the central parallel section of the slot, resulting in a widened central zone, but without a significant increase in the width of the flared sections. Overall, the slots developed as fairly smooth rectangles. A different supply has slots with jagged edges. After use the slots had widened through general wear, and the edges of the slots remained jagged where 'chunks' of metal had broken away.

The increase in the mean width of slots was determined using the automated microscopic method for several sets of screens. It was found that the slot width had increased on average by 10 to 20 μm after extensive use. As expected, due to the abrasive action of the viscous masssecuite, most wear occurred in the lower section of the screens, although there is some variability in the data. In several examples the slots near the top of the screen showed a decrease in mean width, possibly due to the retention of scale within the slot despite a careful cleaning procedure.

Inferential method for assessing screen condition within the centrifugal

It is anticipated that the water flow resistance procedure can be developed for *in situ* measurements and that progressive evaluations may be made at selected locations on the screens. This would provide a mechanism where changes in the screen resistance due to slot wear, screen blinding and washing procedure could be monitored.

During centrifuging of the massecuites, the wearing of the screens results in a widening of the slots with negligible change in the slot length. From equations (2) and (3) it can be determined that the relative change in water flow resistance is inversely proportional to the square of the relative change in the slot width. Thus a screen of 0,06 mm nominal slot width would show a 26 per cent reduction in flow resistance, R_w for an increase in slot width by 10 μm.

Conclusions

Measuring procedures which have been been used to determine the dimensions of the slots in the filtering screens of sugar centrifugals have been described. The flow resistance of the screens has also been measured. These procedures have been applied to ensure the quality of supply of new screens to the industry is maintained at specification, and to measure changes in screen condition with wear and damage during use.

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