AN INVESTIGATION INTO THE PERFORMANCE OF A DIFFUSER DEWATERING MILL

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Abstract

In an attempt to reduce the high bagasse moistures at Maidstone an investigation was done to determine which factors influence bagasse moistures. The single, pressure fed, dewatering mill at MS was fitted with various instruments, which were connected to a data acquisition computer. The performance of the mill over an eight hour shift was correlated with factors such as escribed volume, fibre fill, reabsorption factor, and mill lift. Some results of this investigation concur with what is expected according to the literature, and the theory of milling. Many results, however, apparently contradict the conventional wisdom of sugar milling.

Introduction

It is generally accepted that reabsorption factor is one of the most important determinants of final bagasse moisture. Crawford (1959) looked at the causes and influencing factors of reabsorption from a theoretical point of view, and he also did practical work on an experimental mill with fixed work opening and roll speed (hence constant escribed volume). Douwes Dekker (1959) examined the theory of mill performance, and used factory data from Java to make the important recommendation that "when considering the effect on certain measures on the performance of an individual mill one must always try to establish whether it is due to a different volumetric coefficient (fibre fill) or an alteration in reabsorption." Walkers Ltd of Queensland suggest that reabsorption be used to evaluate the performance of a mill, and as a guide in making adjustments. To this end they provide graphs developed by Muir *et al.* (1962) to aid in the evaluation of reabsorption factor. Mason *et al.* (1983) did experimental work using instrumentation on production mills to establish the effects of fibre and more specifically cane varieties on mill performance. Their results showed that final bagasse moisture for various varieties of cane was dependent on *relative* reabsorption, which is defined by Mason *et al.* as the reabsorption factor adjusted for work opening and roll speed at the time of the measurement. Upadhiaya (1988) and Wienese (1990) both reviewed mill setting calculation methods and both discussed the role of reabsorption and reabsorption factor.

There appears to have been very little investigation into the factors which influence the final mill bagasse moisture on a full size production mill. While much work on the causes of reabsorption has been done, very little effort has been put into establishing what actually affects dewatering mill performance. It is the aim of this paper to assess what factors really influence final bagasse moisture and fibre throughput.

Theoretical background

The following concepts are important in the milling of sugar cane:

- Escribed volume, which is the volume of cane 'extruded' out of the nip between two rollers per unit time, usually measured in m^3/min (see Figure 1).

$$Vol_{escr}[m^3/min] = \text{Roll length}[m].vel_{periph}[m/min].\text{work opening}[m] \quad (1)$$

- Fibre fill, also known as volumetric coefficient or fibre index, is the mass of fibre per cubic metre of escribed volume (units of kg/m^3.)

$$\text{fibre Fill}[kg/m^3] = \frac{\text{Fibre throughput [kg/min]}}{\text{Escribed volume } [m^3/min]} \quad (2)$$

- Reabsorption factor, is the ratio of the volume of bagasse that actually went through the mill to the volume escribed in the same time.

$$\text{Reabsorption factor} = \frac{Volume_{bagasse}[m^3/min]}{Volume_{escribed}[m^3/min]} \quad (3)$$

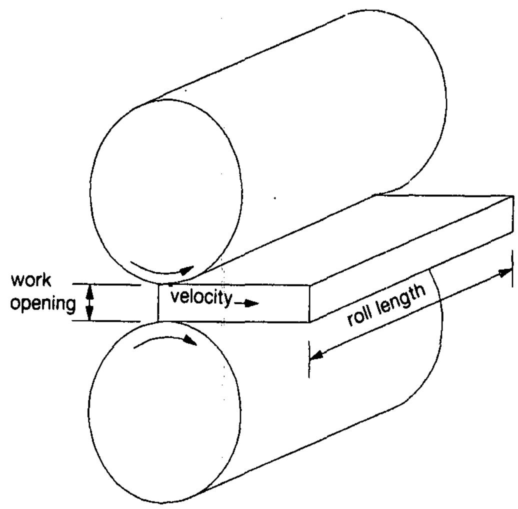

FIGURE 1 Escribed volume

These three formulae are used in the calculation of mill settings, given the expected fibre throughput. They of course can also be used to establish what fibre fill and reabsorption factor is actually achieved, given the final bagasse throughput and bagasse properties, and the volume actually escribed by the mill. The first two data are routinely provided by the South African Sugar Association's Cane Testing Service (SASA CTS). The volume escribed by the mill is not constant over time because the top roll floats and the mill turbine speed varies and hence the escribed volume must be calculated continuously while the mill is actually working. This is done by measuring the average top roll lift and the mill turbine speed. The work opening was calculated as follows:

$$\text{Work opening} = 0{,}8 \text{ lift} + \text{set opening} \quad (4)$$

The peripheral velocity was calculated as:

$$\text{Vel [m/min]} = \frac{\pi.N[rpm].dia[m]}{\text{Gear ratio}} \quad (5)$$

where N = turbine speed.

The roll length is constant at 2,134 m. The calculated escribed volume from equation (1) is an instantaneous value, but the bagasse figures provided are total mass and average properties over an eight hour shift. This means that in order to obtain realistic figures for fibre fill and reabsorption factor, escribed volume must be integrated over the same period, i.e. eight hours or 480 minutes.

$$\text{Escribed Vol}_{total} = \int_0^{480} V_e(t)dt \qquad (6)$$

Experimental method

The following transducers were fitted to the mill: top roll lift (developed by the Sugar Milling Research Institute), turbine speed, mill top roll hydraulic pressure, turbine nozzle box pressure. Also attached were sensors to detect the SASA CTS time of bagasse sampling, and to detect if there was bagasse leaving the mill.

All the analog signals (4 to 20 mA) were fed into an interface which digitised the signals and then sent them in serial form along an RS232 line to an IBM type personal computer (Figure 2). A package called TurboLink was then used to manipulate, display, and store these data.

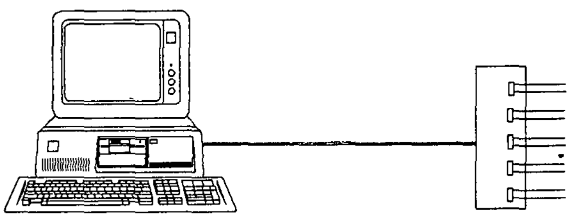

FIGURE 2 Data acquisition configuration

The data acquired, as described above, were processed as follows:

- If the mill was running (i.e. bagasse was being processed) then escribed volume was calculated each sampling period, and the values were numerically integrated over an eight hour period corresponding to the normal shifts worked. The time period that the mill was operational in that shift was also recorded. Averages were taken of parameters such as mill lift and turbine speed.
- If the mill was not running then these calculations were not done.

The above description may seem self-evident, but necessary because if for instance the carrier feeding the mill becomes choked, it is quite probable the mill will continue turning and so escribing volume but no bagasse is being processed, and the results will be distorted.

At the end of each eight hour shift the results mentioned above were printed. Use was made of the SASA CTS 'Milling Shift Report' to get the mass of bagasse processed, and the average fibre % bagasse, moisture % bagasse, and brix % bagasse for the eight hour period.

From these data the density of the bagasse was calculated as shown in Appendix 1*. Reabsorption factor, fibre fill, average escribed volume, and average fibre throughput were calculated from both the SASA CTS data and the measured mill data.

Results

There are 91 data points so that the number of degrees of freedom for a linear correlation is 89. The linear correlations attempted are given in Table 1 together with the corresponding values of r^2 corrected for the number of degrees of freedom. (See also Figures 3 to 13). Although some of the correlation coefficients seem to be very high, correlations are mathematically biased, due to one variable being calculated as a function of another. It can be seen from equations (1), (2) and (3) that reabsorption factor, fibre fill and escribed volume are all related to each other mathematically, and to fibre throughput. Thus the high correlation coefficient shown between these particular variables must be viewed with suspicion, and does not really imply meaningful cause-effect relationships.

Table 1

Linear correlation coefficients. (Note r^2 is significant at the 5% level for r^2>0,04)

Fig No.	Variables in correlation	Relationship	Correlation r^2
3	Moisture vs fibre fill	−	0,322
4	Moisture vs escribed volume	+	0,295
5	Moisture vs turbine speed	+	0,241
6	Moisture vs mill lift	−	0,193
7	Moisture vs reabsorption factor		0,073
8	Moisture vs fibre throughout		0,050
−	Fibre throughout vs reabsorption factor	+	0,676
−	Fibre throughout vs fibre fill	+	0,605
9	Fibre throughout vs turbine speed	+	0,036
10	Fibre throughout vs escribed volume	+	0,032
−	Fibre throughout vs mill lift	+	0,006
−	Fibre throughput vs work opening	+	0,000
−	Reabsorption factor vs fibre fill	+	0,893
−	Reabsorption factor vs escribed volume	−	0,112
−	Reabsorption factor vs turbine speed	−	0,027
−	Fibre fill vs fibre throughout	+	0,621
11	Fibre fill vs escribed volume	−	0,213
12	Fibre fill vs turbine speed	−	0,090
13	Fibre fill vs work opening	−	0,043

APPENDIX 1

Bagasse density calculation

The density of bagasse is given by

$$\rho_{bagasse} = \frac{\frac{153000\ B}{100 - F} + 388926}{\frac{BF}{100 - F} 1.358F + 390}$$

Where B = Brix % bagasse and
F = Fibre % bagasse

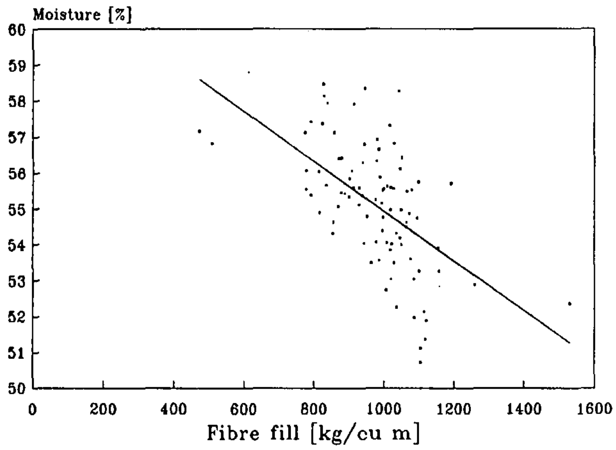

FIGURE 3 Moisture versus fibre fill

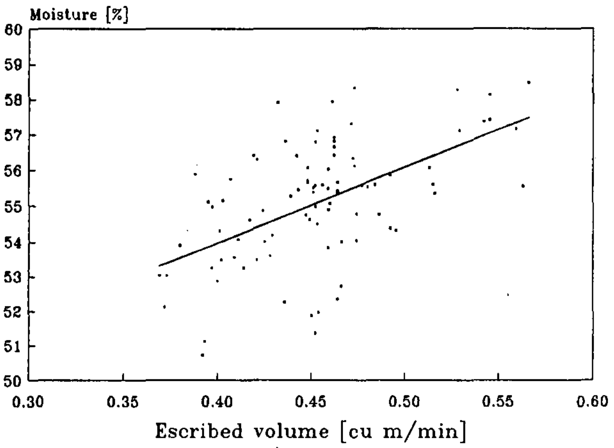

FIGURE 4 Moisture versus escribed volume

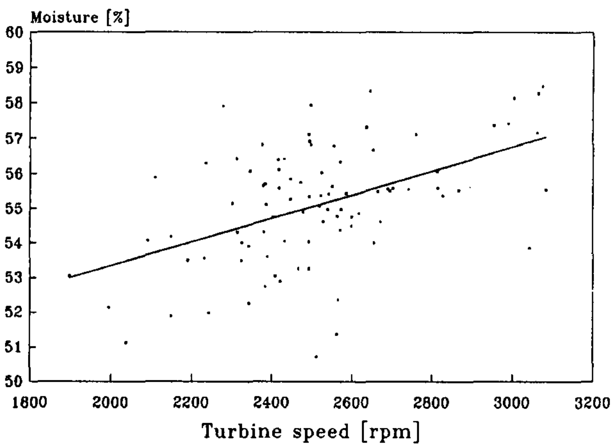

FIGURE 5 Moisture versus turbine speed

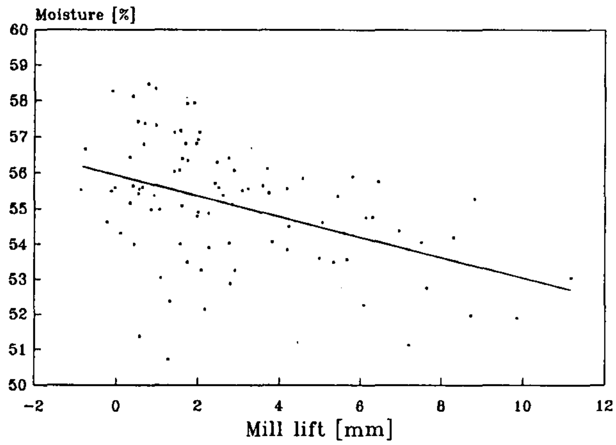

FIGURE 6 Moisture versus mill lift

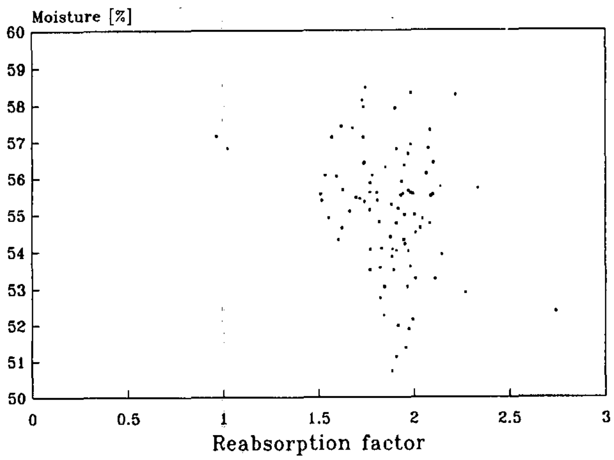

FIGURE 7 Moisture versus reabsorption factor

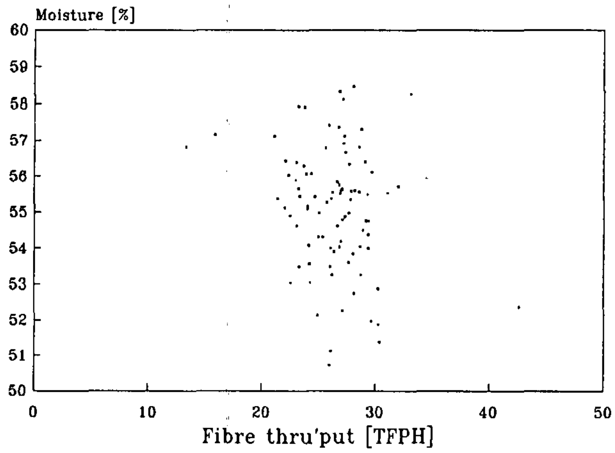

FIGURE 8 Moisture versus fibre throughput

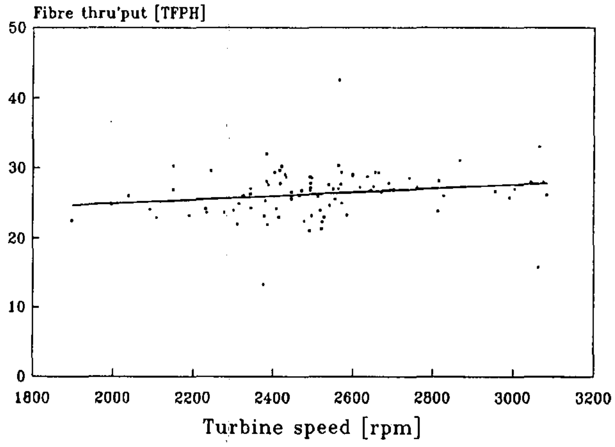

FIGURE 9 Fibre throughput versus turbine speed

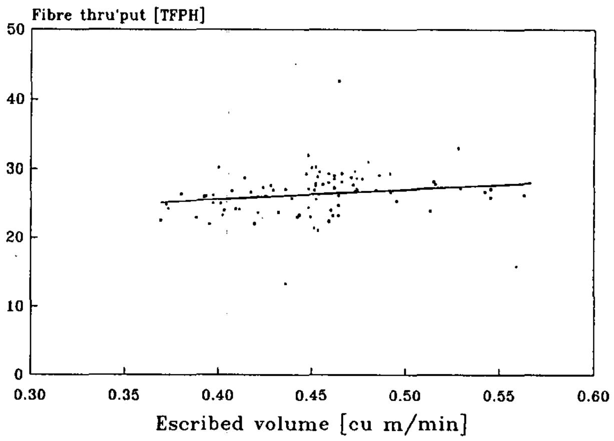

FIGURE 10 Fibre throughput versus escribed volume

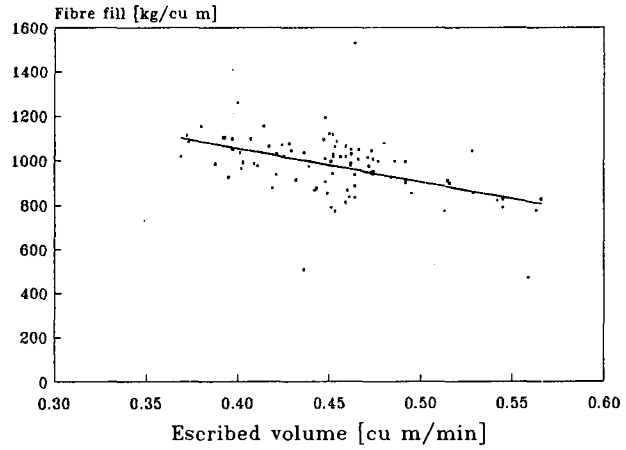

FIGURE 11 Fibre fill versus escribed volume

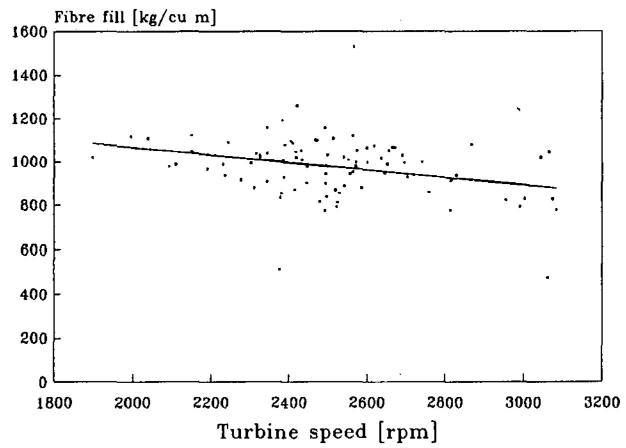

FIGURE 12 Fibre fill versus turbine speed

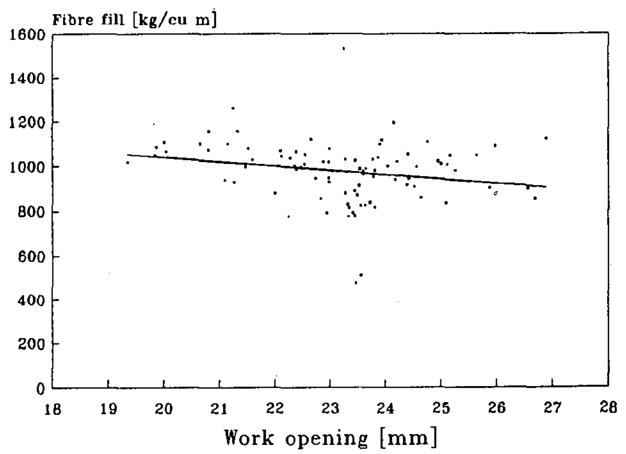

FIGURE 13 Fibre fill versus work opening

Discussion

Final bagasse moisture

From the data plotted in Figures 3 to 8 it is clear that:

- The higher the fibre fill the lower the moisture (Figure 3). This is expected, since the greater the fibre fill, the greater the squeeze and the lower the moisture. Douwes Dekker (1959) concluded that there is not much benefit from having a fibre fill greater than 55 lb/ft^3 (881 kg/m^3). From the data in this paper 1100 kg/m^3 seems to be optimum.
- The moisture % bagasse goes up with the escribed volume (Figure 4). This is related to Figure 5 (moisture versus turbine speed), since the greatest variation in escribed volume is due to variation in mill speed. One could offer the explanation that reabsorption increases with increasing speed, and hence moisture increases with speed. This explanation is not well supported by the actual measurements (see Figure 7. It was noted during mill operation that if the top roll was in a lifted position and floating, and the mill speed increased, the top roll almost immediately dropped to its bottom position and the squeeze on the bagasse was not maintained. If the mill turbine slowed down the top roll took many minutes to return to a floating position. This link of speed and lift is supported by the moisture versus mill lift relationship in Figure 6. More lift gives lower moisture.
- Fibre throughput and work opening have little influence on the final bagasse moisture. It is generally believed that in order to get a mill to perform it must have sufficient fibre in order to make the mill 'work'. This belief is not borne out by the moisture versus fibre throughput graph in Figure 8.

A multiple linear correlation gives the following relationship, with all variables significant, and an r^2 value of 0.412:

Moisture % bagasse =

$$40.9 - 0.170 \text{ tfh} + 0.00451 \text{ rpm} + 0.3166 \text{ work opening} \quad (7)$$

This equation does show the effect of fibre throughput (tfh) and turbine/speed on moisture in bagasse.

Fibre throughput

Fibre throughput is not easily related to the usual parameters of milling. Figures 9 and 10 show fibre throughput to be relatively insensitive to turbine speed and escribed volume. It is expected that if the escribed volume is doubled the fibre throughput should double, but this is not the case. Mill lift and work opening also do not influence fibre throughput, as shown in Table 1. It must be noted, however, that during this experimental period, extremely high fibre % cane figures were encountered and milling conditions were far from ideal. Fibre throughput was lower than required and changes were made to mill settings to improve the throughput. These changes in settings were taken into account in preparing the above graphs.

Reabsorption factor

Reabsorption factor increases with fibre fill as shown in Table 1, but the high correlation is affected by mathematical bias. In fact it is difficult to draw any conclusions about what affects reabsorption factor because of the mathematical bias. It is however an important parameter, and its effect on bagasse moisture is clearly established in Table 1.

Fibre fill

Figures 11 to 13 show that in order to achieve a high fibre fill, the mill speed and the work opening, and hence the escribed volume, must be minimised. These are expected results, although it is disappointing to note the low correlation coefficients for these relationships.

Conclusions

In summary, in order to reduce bagasse moisture the mill should be run as slowly as possible, with as much lift as possible, and the mill must be set such that the fibre fill is as high as possible but less than 1100 kg/m^3. Fibre throughput seems relatively insensitive to mill settings. At first this may appear surprising, but it is only on rare occasions a mill can be set to perform adequately without further adjustment. Unfortunately this work is not able to shed light on how to make the adjustments with regard to fibre throughput.

Reabsorption factor is not the 'wonder' figure that tells all about mill performance. Fibre fill is, however, a useful figure in establishing if a mill is working. On-line calculation and numerical integration of escribed volume also aid in the understanding of the milling performance at any instant and over a shift or a day.

REFERENCES

Crawford, WR (1959). Reabsorption: A limiting factor in mill performance. *Proc int Soc Sug Cane Technol* 10: 100-111.

Douwes Dekker, K (1959). The performance of milling trains: Some theoretical considerations. *Proc int Soc Sug Cane Technol* 10:86-97.

Mason, V, Edwards, BP and Cullen, RN (1983). The effects of varying cane fibre characteristics on milling performance. *Proc Aust Soc Sug Cane Technol* 5:289-295.

Muir, DJ and Atherton, PG (1962). A graphical method for milling train volume calculations. *Proc int Soc Sug Cane Technol* 11:1087-1090.

Upadhiaya, UC (1988). A review of methods to calculate mill discharge opening. *Int Sug J* 90(1075):124-129.

Wienese, A (1990). Mill settings and extraction. *Proc S Afr Sug Technol Ass* 64:154-157.