MILL SETTINGS AND REABSORPTION

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Abstract

This paper describes the Natal Method for the calculation of mill settings. Particular attention is given to the effect of the reabsorption coefficient on these calculations. Experiments were carried out on the last de-watering mill at Umzimkulu to estimate this coefficient. Weekly average values of 1,36; 1,48 and 1,46 were found. This is higher than most figures quoted for other countries but lower than the only reference found related to the South African sugar industry.

Keywords: Milling, Mill Settings, Reabsorption

Introduction

Mill settings are important for two reasons, firstly to achieve good milling results (lift) and secondly to prevent damage to equipment (misalignment). Although the importance of correct mill settings is generally acknowledged, most mill engineers follow the calculation procedures of either their predecessors or as laid down in the mill manual. Both these routes can easily result in the wrong settings due to differences between the past and the present and/or the particular characteristics of the location. This inadequacy can be seen at various mills, which show very little or no top roll lift. The paper describes the fundamentals of mill setting calculations and looks, in particular, at the effect of reabsorption on these calculations. In addition it presents the work carried out at the Umzimkulu mill in an attempt to establish the reabsorption coefficient of a de-watering mill.

The examples used in this paper are available in an Excel spreadsheet on request for sponsors of the Sugar Milling Research Institute only.

Theory of mill settings

In a broad sense 'mill settings' refer to the settings of all the adjustable components of a mill and include items such as the feed chute, feeder rolls, main rolls, trash plate, scraper plates, etc. A more common view, and the one which is the focus of this paper, deals with the relative position of the three main rolls or more specifically with the openings between the feed and top, and discharge and top rolls. These openings are important to ensure lift of the top roll at all times while at the same time minimising misalignment between the top roll and the main drive shaft over the full range of operating conditions. The ratio between the feed and discharge openings determines the balance of the work done by the feed and discharge rolls and has an effect on mill performance.

Although there are various methods used to calculate mill settings, they are all based on a figure that expresses the compression between the rolls. The most common method used in South Africa, known as the Natal method, was developed by the Sugar Milling Research Institute as far back as 1958 (van Hengel and Douwes Dekker, 1958). The calculation of mill settings is a volumetric calculation relating a volume of bagasse to an escribed volume. The no-void volume of bagasse (*Bv*) passing between two rolls equals the mass of bagasse (*Bm*) divided by the no-void density (*Bd*):

$$Bv = Bm / Bd \qquad (1)$$

The calculation of this no-void volume requires prior knowledge of the bagasse and its composition. The mass of bagasse is approximately equal to the mass of cane multiplied by the fibre percent cane and divided by the fibre percent bagasse. However, this introduces a new, often unknown, variable in the form of the fibre percent bagasse. The bagasse density, which is a combination of the density of fibre and juice, can only be ascertained from an analysis of the bagasse. The density of fibre is similar to the density of cellulose and is in the order of 1,52 t/m^3 (Hugot, 1986). The density of juice is close to 1 t/m^3 and is a function of the brix. The escribed volume (*Ev*) is a function of the roll diameter (*Rd*), length (*Rl*) and speed (*Rs*) and of the work opening (*Kw*) (opening under load) and in equation form looks as follows:

$$Ev = 60 * \pi * Rd * Rl * Rs * Kw / 10^9 \qquad (2)$$

Although one would expect the bagasse volume to be equal to the escribed volume, the former is greater than the latter. This phenomenon is well covered in the literature (Munro, 1964; Jenkins 1966; Hugot, 1986). While not fully understood, it is believed to be caused by a combination of squirting, extrusion, forward slip and reabsorption. The term reabsorption has been generally adopted and is defined as the ratio between the no-void bagasse volume and the escribed volume. Combining the equation for the bagasse and escribed volume with the reabsorption coefficient (*Cr*) results in the following equation for the work opening:

$$Kw\ 10^9 * Bm / (60 * \pi * Rd * Rl * Rs * Cr * Bd) \qquad (3)$$

The product of the reabsorption and the bagasse density is sometimes referred to as the apparent density of bagasse. The set opening (*Ks*) (opening under no load) is the work opening minus the lift (*Rf*) taking into consideration the mill housing inclination. With a standard inclination of 35 degrees the set opening is:

$$Ks = Kw - 0,8 * Rf \qquad (4)$$

The set opening determines the lift of the top roll and the calculation of this parameter is the main purpose of the mill setting calculations. Contrary to what some mill engineers believe, the purpose is not to control the throughput. The importance of mill lift cannot be over emphasised and is not always given the attention it deserves.

The method described here applies to all mills and is equally true for the discharge opening as for the feed opening. However, bagasse passing through the last discharge opening (final bagasse) has the advantage of being analysed on a routine basis while bagasse passing through any feed opening cannot be sampled and hence is not analysed. The feed work opening is therefore normally not calculated as described here but by applying a ratio (between 1,5 and 3) between the feed and discharge work opening corrected for any difference in fibre. This difference relates to the fibre in the expressed juice. Figure 1 shows an example of a mass balance around a mill together with the corresponding mill settings.

In this example the density of fibre (*Fd*) is taken as 1,52 t/m^3 and the density of juice (*Jd*) as a function of the brix (*Jb*) is based on the following empirical equation:

$$Jd = 0,998 + 0,00376 * Jb + 0,0000176 * Jb^2 \qquad (5)$$

The bagasse density (*Bd*) is calculated from the fibre percent bagasse (*Bf*) and the fibre and juice densities as follows:

$$Bd = 100 / (Bf / Fd + (100 - Bf) / Jd) \qquad (6)$$

The throughput is mainly determined by the roll length, roll speed and the work opening. However, only the speed can be used to regulate the throughput. The roll length is a mill design feature and is obviously fixed while the work opening is virtually independent of the set opening at a constant ratio of the feed to discharge work opening. Some of the factors that have a limited effect on the work opening are feeding devices, roll speed, hydraulic loading, cane preparation and roll arcing.

Feed (t/h)	148.20		Mill	59.54	Disch (t/h)
Feed brix (%)	1.80	1028.00	Roll diameter	1.95	Disch brix (%)
Feed fibre (%)	20.50	2132.00	Roll length (mm)	48.05	Disch fibre (%)
Feed moisture (%)	77.70	2.00	Roll speed (rpm)	50.00	Disch moisture (%)
		10.00	Roll lift (mm)		
Feed set opening	89.65	2.00	Mill ratio	37.97	Disch set opening
Feed work opening	97.65	1.30	Reabsorption	45.97	Disch work opening
		88.66	Juice (t/h)		
		1.70	Juice brix (%)		
		2.00	Juice fibre (%)		
		96.30	Juice moisture		

Figure 1. Mill mass balance with associated mill settings (red are input figures).

Reabsorption tests

Although the reabsorption coefficient plays a significant part in the calculation of mill settings, it is hardly ever measured and certainly not on a routine basis. The only South African quantitative reference related to reabsorption was found in some Sugar Technology Course Notes[1]. These notes, which are more than 25 years old, mention an average apparent density of bagasse for Natal conditions of 1,855 t/m^3. The obvious reason for this lack of information lies in the difficulty of obtaining the necessary data and the problem of synchronising that data. Some data, such as the bagasse mass and composition, are more accurate over longer periods of time while others, such as roll speed and lift, are more reliable over short periods and averaging becomes a major problem. In addition, the measurements themselves can introduce serious errors. Nevertheless, in the beginning of 1999 it was decided to attempt to measure the reabsorption coefficient in order to get a better feel for the magnitude of this coefficient for present South African conditions. To that end tests were carried out for four consecutive weeks on the discharge side of the last of two de-watering mills at Umzimkulu. The results for the second week had to be discarded due to mill repair resulting in incomplete data. The remaining weeks were:

sugar industry week 30	19/09/99-25/09/99
sugar industry week 32	03/10/99-09/10/99
sugar industry week 33	10/10/99-16/10/99

Mill lift indicators were fitted on both gear and pintle sides. These indicators were electronic displacement transducers made by the SMRI. They were connected to the bearing housing of the top roll via the existing indicator rods. The 4 to 20 mA output signal of the transducers corresponded to a lift of between 0 and 50 mm. Turbine speed was taken from the existing factory speed transducer. This transducer also produced a standard output signal of between 4 to 20 mA

[1] Notes compiled from lectures for the National Diploma in Sugar Technology

that compared to a turbine speed of 0 and 6000 rpm respectively. The gear ratio between turbine and mill speed was 1781. Lift and speed readings were taken virtually continuously and stored on disk for later processing. This processing consisted of converting the electronic signals into roll lift and speed, screening the data by discarding any outliers and calculating weekly averages. The final results are given in Table 1.

Table 1. Average measured data.

	Week 30	Week 32	Week 33
roll lift (mm)	1.72	3.09	7.90
roll speed (rpm)	2.07	1.90	1.98

Because the mill under investigation is the last mill, the bagasse passing through the top and discharge roll is final bagasse. Although not directly given, information on this bagasse is hidden in the SMRI weekly reports. To make this data available mass balances on brix, fibre and water were carried out over the extraction plant as a whole (Appendix A). The relevant data are given in Table 2.

Table 2. Bagasse data from the SMRI weekly reports.

	Week 30	Week 32	Week 33
bagasse mass (t/h)	64.66	64.24	66.91
bagasse brix (%)	1.69	1.62	1.74
bagasse fibre (%)	48.34	48.72	48.24
bagasse moisture (%)	49.97	49.66	50.02

Umzimkulu supplied information on the set opening, the top and discharge rolls diameter and the length of the rolls on a weekly basis. These data are shown in Table 3.

Table 3. Mill data supplied by Umzimkulu.

	Week 30	Week 32	Week 33
set opening (mm)	45.00	43.50	40.00
roll diameter (mm)	1028.00	1028.00	1028.00
roll length (mm)	2132.00	2132.00	2132.00

The calculation of the reabsorption coefficient from the above data is very similar to the calculation of the mill settings as outlined earlier. The only difference is that the latter calculates a set opening from a known reabsorption coefficient while the former calculates the reabsorption coefficient from a given set opening. In the process of this calculation, other information such as the bagasse volume and density, apparent bagasse density, escribed volume and work opening come to the fore. These calculated data are given in Table 4.

Table 4. Calculated data.

	Week 30	Week 32	Week 33
bagasse density (t/m^3)	1.21	1.21	1.21
apparent density (t/m^3)	1.63	1.78	1.76
bagasse volume (m^3)	53.63	53.21	55.50
escribed volume (m^3)	39.56	36.07	37.98
work opening (mm)	46.37	45.97	46.30
reabsorption coefficient (-)	1.36	1.48	1.46

The reabsorption coefficients found at Umzimkulu are somewhat higher than the average 1,3 quoted by Jenkins (1966) and Hugot (1986). This might be attributed to typical South African conditions. The apparent density of 1,855 t/m^3, quoted earlier, applied to the Umzimkulu figures equate to a higher reabsorption coefficient of 1,54. This could be as a result of changes in the South African Sugar Industry over the last 25 years such as the move from milling tandems towards diffusers, increased imbibition rates, improved arcing and better (or worse) cane preparation. The available information does not explain the difference in the reabsorption coefficient between week 30 and the weeks 32 and 33. Despite the change in set opening, the difference in the work opening is insignificant and can be attributed to experimental error. This supports the theory that the work opening is independent of the set opening.

Conclusion

The purpose of mill settings is to ensure lift of the top roll at all times while at the same time minimising misalignment between the top roll and the main drive shaft. When these objectives are met good performance can be expected with a minimum damage to equipment. Throughput is mainly determined by mill speed. Mill settings have little or no influence on this since at a constant ratio between feed and discharge work opening the work opening is independent of the set opening. The calculation of mill settings is inevitably based on some inaccurate data and needs to be accompanied by common sense, record keeping and experience.

Although reabsorption has a significant effect on mill settings only one South African reference was found related to this phenomenon. Recent attempts to measure the reabsorption coefficient on the last de-watering mill at Umzimkulu suggest a figure between 1,36 and 1,48. This is slightly higher than the values quoted for other countries but lower than the one mentioned in an old South African reference. These discrepancies might be due to inaccuracies or can be the result of differences in time and place. The fact that the results are in line with those of others instils confidence in the measurements and in the procedures that were followed.

The reabsorption coefficient is not only a prerequisite for the calculation of mill settings, it is also an important milling performance indicator. It is therefore recommended that this coefficient should be measured on a regular basis.

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NOMENCLATURE

Bd = bagasse density (t/m^3)
Bm = bagasse mass (t/h)
Bf = bagasse fibre (%)
Bb = bagasse brix (%)
Bv = bagasse volume (m^3)
Ev = escribed volume (m^3)
Jb = bagasse juice brix (%)
Jd = bagasse juice density (t/m^3)
Ks = set opening (mm)
Kw = work opening (mm)
Rd = average roll diameter (mm)
Rf = roll lift (mm)
Rl = roll length (mm)
Rs = roll speed (rpm)
Cs = reabsorption coefficient (-)

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APPENDIX A

Week 30
Imbibition % fibre 557.00

	Mass	Fibre		Brix		Moisture	
	t/h	t/h	%	t/h	%	t/h	%
Cane	218.00	31.98	14.67	39.63	18.18	146.39	67.15
Mixed Juice	327.46	0.72	0.22	38.54	11.77	288.19	88.01
Bagasse	64.66	31.26	48.34	1.09	1.69	32.31	49.97
Imbibition	174.12	0.00	0.00	0.00	0.00	174.12	100.00

Week 32
Imbibition % fibre 551.00

	Mass	Fibre		Brix		Moisture	
	t/h	t/h	%	t/h	%	t/h	%
Cane	214.00	32.04	14.97	37.32	17.44	144.64	67.59
Mixed Juice	322.20	0.74	0.23	36.28	11.26	285.18	88.51
Bagasse	64.24	31.29	48.72	1.04	1.62	31.90	49.66
Imbibition	172.43	0.00	0.00	0.00	0.00	172.43	100.00

Week 33
Imbibition % fibre 533.00

	Mass	Fibre		Brix		Moisture	
	t/h	t/h	%	t/h	%	t/h	%
Cane	221.00	33.00	14.93	39.71	17.97	148.29	67.10
Mixed Juice	326.13	0.72	0.22	38.55	11.82	286.86	87.96
Bagasse	66.91	32.28	48.24	1.17	1.74	33.47	50.02
Imbibition	172.04	0.00	0.00	0.00	0.00	172.04	100.00

Red are input figures