SUGGESTIONS FOR THE SETTING OF VERTICAL FEED CHUTES

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Introduction

The fully enclosed feed chute was introduced originally in Queensland[1, 2], where it was used on mills without feeder rollers. The first time that South Africa heard about these chutes was when Dr. H. W. Kerr, Director of the Sugar Research Institute in Mackay, visited our industry during 1957 and gave a lecture in Durban. [3]

Since that time an increasing number of factories have installed these feed chutes with varying degrees of success and it is my belief that before long they will have become a common feature of all Natal sugar factories. However, it should be borne in mind that the feed chutes as installed in Natal are basically different from the chutes in Queensland in that the chutes in Natal feed a mill which is generally provided with a feeder roller. It is felt that this addition to the chute arrangement necessitates a different approach with regard to calculating its settings.

The Australian Point of View

The point of view of Murry and co-workers [4, 5] is that the thickness of the cane mat should be such as to ensure maximum feed rate. They conclude that a feed chute should have a width of half the sum of the roller diameter and the feed opening. This coincides with Donnelly's [1, 2] experiences — he recommends settings as wide as half the diameter of the top roller.

However, in his latest discussions on the width of feed chutes [2] Donnelly writes:

> "With roller surface speeds of up to 35 feet per minute, it has been found that the thickness of the mat of feed presented to the mill through a closed chute (acting under gravity alone), may be equal to from half to three-quarters of the diameter of the mill roller. From this it should not be assumed that the feed is entering the mill in a continuous and unbroken mat, for, if watched closely, the speed of portions of the mat appears to vary appreciably, with some sections moving faster than others for a while and then slowing down. This differential movement appears to take place over the whole width of the mill and also from front to back of the mat. This leads to the belief that the volume of material being presented to the mill is more than it can accept (as a mat), and only a portion is being withdrawn continuously by the feed and top rollers."

To my mind, this is an elaborate way of saying that continuous and considerable slip takes place, which must lead to unnecessary wear of rollers and (as a result of occasional overfeeding) to choking of the mills. Ultimately, the danger of roller breakage is a real hazard, as will be seen from the following considerations.

The S.M.R.I. Approach

Contrary to the Australians, we think that we should feed not the *maximum* amount in a mill opening, but exactly the *right amount.*

It is our aim to crush a certain tonnage of fibre and it is quite obvious that the same amount of fibre must go through any cross section of the path that this fibre follows through the mill, whether it be in the discharge opening, the feed opening, the feeder opening or the chute. The size of this cross-sectional area depends on the velocity of the travelling fibre, the bulk density of the bagasse containing the fibre and the fibre percentage of the bagasse (or cane), all per unit length of the rollers.

In figure I the geometry of a mill is shown. For the sake of simplicity the size of the feeder roller is chosen identical to the size of the other rollers. Consequently, the centre of the feeder roller now becomes higher than the centre of the top roller. For the later calculations this is of no practical importance as the width of the chute at the base is R_2K sec β which is only slightly larger than the horizontal projection R_2K. For a normal mill the angle β would be $6\frac{1}{2}°$ and at the most 10°. The sec of 10°, however, is only 1.015. In other words we make an error of $1\frac{1}{2}\%$ (or $\frac{1}{8}$ inch in 8 inches).

From the above it follows that:

$$R_2K \doteq R_2K \sec\beta = R_1K + 2\,\frac{D\,(1 - \cos\propto)}{2}$$

or

$$R_2K = R_1K + D\,(1 - \cos\propto). \qquad (1)$$

Concerning the discharge opening K of a mill we know, according to Mutual Milling Control Progress Report No. 2 [6], the fibre indices (I) and the fibre contents of the bagasse (F) of the first and last mills, which were as follows:

	I	*F*	Ratio *I/F*
First Mill . . .	31.0	26.53	1.17
Last Mill . . .	53.9	44.43	1.21

The theoretical relationship between the work opening and the fibre index is:

$$K = \frac{183\,Cf}{nDLI} \text{ where}$$

K = work opening in inches.
C = tons of cane per hour
f = fibre % cane
n = r.p.m. of top roller
D = mean diameter of top roller in inches.
L = length of top roller in inches.
I = fibre index in lb. fibre/cu. ft. escribed volume

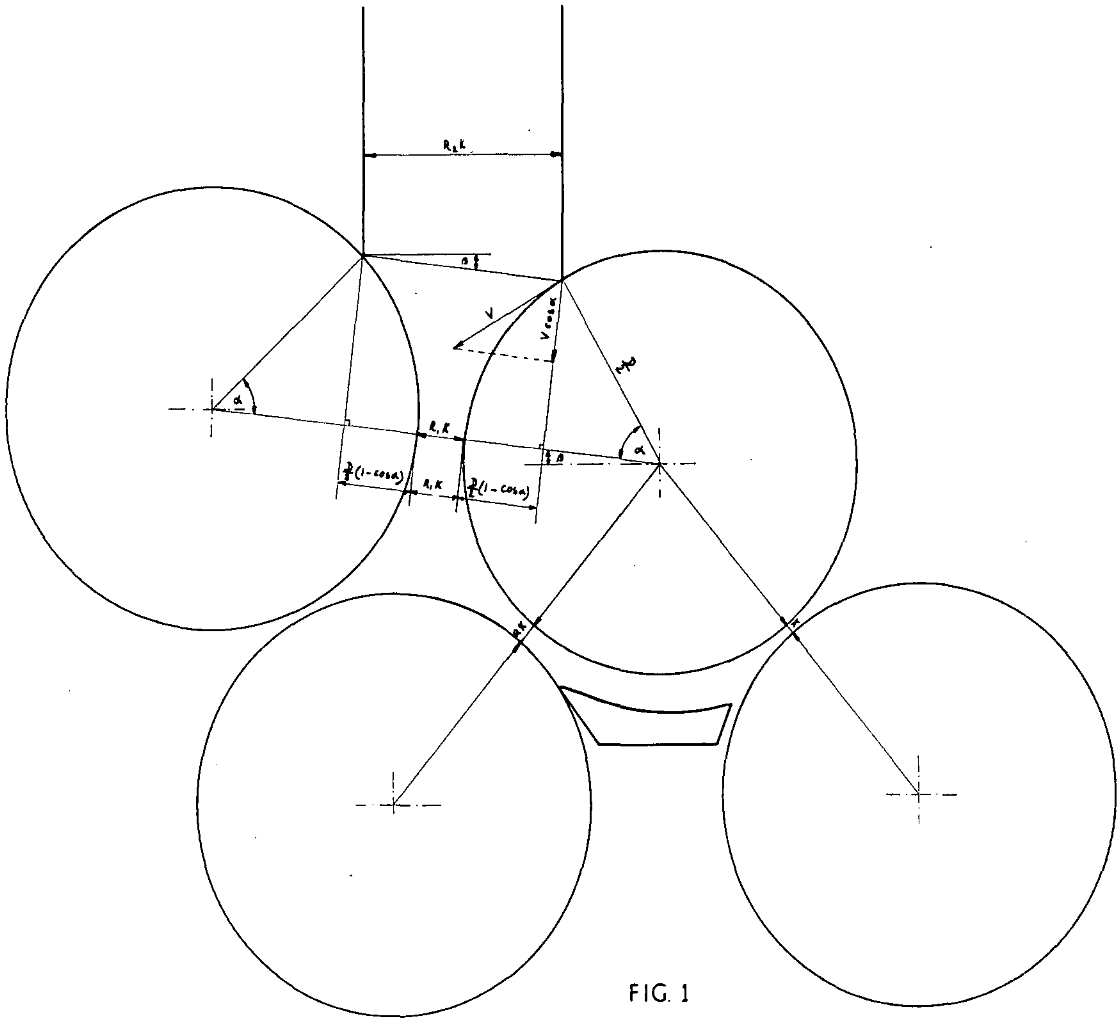

FIG. 1

GENERAL ARRANGEMENT OF A MILL WITH FEEDERROLLER AND VERTICAL CHUTE

R = ratio (feed/discharge work opening)

R_1 = ratio (feeder opening/discharge work opening)

R_2 = ratio (chute opening/discharge work opening)

From this it would follow that:

$$K = \frac{153\ Cf}{nDLF} \qquad (2)$$

if F = fibre % discharged bagasse and if the ratio I/F is assumed constant at 1.2 (in Java 1.1).

In our figure the discharge opening K is therefore, a known size through which goes a known quantity of fibre. Assuming that *no slip* occurs and that all roller diameters are equal, the fibre index in the feeder opening and feed opening of the mill must be I/R_1 and I/R respectively.

The volume of material passing through the feeder opening at V ft./min. will be R_1 K V cu. ft. per unit length per minute and hence $R_1 KVI/R_1 = KVI$ lb. fibre. The material passing through the chute opening (R_2K) will be R_2 K V cos ∝ cu. ft./min.

Assuming the actual bulk density of the material to be d lb./cu. ft. and also that the fibre percentage of the material is f, then pounds of fibre per minute will be R_2 K V cos ∝ df.

$$\text{Now: } K\,V\,I = \frac{R_2\,K\,V\ df \cos \propto}{100}$$

$$\text{or} \quad R_2 = \frac{100 x I}{df \cos \propto} \qquad (3)$$

The equations (1) and (3) may be solved for cos∝ :

$$\cos \propto \; = \frac{(R_1\,K + D) \pm \sqrt{(R_1\,K + D)^2 \pm \dfrac{400\,I\,K\,D}{df}}}{2\,D} \qquad (4)$$

It is clear that in this equation the term $\dfrac{400 x I x KD}{df}$ is most significant as D and R_1K are dimensions which are either given or about which we have concrete information. The same holds for I and f. In fact only d, the density of the material at the bottom of the chute, is really unknown. Once more it should be emphasised that this formula is correct except for the 1½ per cent approximation by not introducing sec β.

Example

Consider a tandem, consisting of 6 mills with 38 inch by 84 inch rollers crushing 180 tons of cane of 15.0 per cent fibre per hour. Vertical feed chutes are on all mills. The rollers have a speed of 35 ft./min. The first mill is preceded by a shredder. What would be the setting of the feed chutes at the base?

For each mill K and I may be calculated by assuming the fibre % bagasse, F, and the use of formula (2). The following table 1 may then be drawn up :

TABLE I

Mill	*F*	*K*	*I*
1	30	1.22	36
2	35	1.05	42
3	38	0.97	46
4	41	0.90	49
5	43	0.85	52
6	45	0.82	54

From the assumed fibre contents of the bagasses leaving a mill, the fibre content of the bagasse entering a mill may be easily calculated if it is assumed that the imbibition is 250 per cent on fibre, as shown in Table II:

The value of R_1 varies from one factory to another, but in general it may be said that a good value for the first mill is 7 and for the last mill 5. In Natal values in excess of 7 and lower than 5 are found. It seems reasonable to choose values between 7 and 5 for the intermediate mills (see Table III).

TABLE III

Mill	R_1
1	7.0
2	6.6
3	6.2
4	5.8
5	5.4
6	5.0

	Tons Fibre in Feed	F	Tons Bagasse Leaving Mill	Tons Imbibition Liquid added	Feed Material		
					Mill	Tons	*f*
Cane	27.0	15.0	180.0	—	1	180.6	15.0
Bagasse 1 . . .	27.0	30.0	90.0	84.6	2	174.6	15.5
Bagasse 2 . . .	27.0	35.0	77.1	78.3	3	155.7	17.3
Bagasse 3 . . .	27.0	38.0	71.1	73.3	4	144.4	18.7
Bagasse 4 . . .	27.0	41.0	65.8	70.3	5	136.1	19.8
Bagasse 5 . . .	27.0	43.0	62.8	67.5	6	130.3	20.7
Bagasse 6 . . .	27.0	45.0	60.0	—			

TABLE II

The density of the material at the base of the chute has not been measured in South Africa. This determination would be facilitated by the use of radioactive isotopes or by measurement of the di-electric constant of an air bagasse mixture of varying proportions. For the purpose of this paper, however, we may base our calculations on the lowest density measured in Australia [5] for the material entering the first mill and for the highest figure [4] quoted for the bagasse entering the last mill. For intermediate mills values between these two extremes would be acceptable. (See Table IV.)

TABLE IV

Mill	*d. (lb./cu. ft.)*
1	25
2	27
3	29
4	31
5	33
6	35

It is fully realised that these figures are questionable but no other are available to my knowledge.

Formula (4) may now be solved for cos ∝ and formula (1) for R_2. The results are shown in Table V:

TABLE V

Mill	*First Root* (+)		*Second Root* (−)	
	Cos ∝	R_2	*Cos* ∝	R_2
1 . . .	0.870	11.0	0.354	27.1
2 . . .	0.860	11.7	0.323	31.1
3 . . .	0.896	10.3	0.262	35.1
4 . . .	0.920	9.2	0.217	38.9
5 . . .	0.929	8.6	0.192	41.8
6 . . .	0.956	8.0	0.172	43.1

It is evident that the values of the second root are not applicable. The values for R_2 vary between 11.0 and 8.0 and this is readily understood if it is realised that the bulk density and the fibre content of the different bagasses increase continuously from the first to the last mill.

Conclusion

The feed chute setting ratios arrived at are very much lower than those normally accepted. In fact they are so low hat they illustrate the absurdity of feeder ratios, (R_1) in excess of from 7 to 5, depending on the position of the mill concerned in the tandem. A further step would be to question whether these ratios 7 and 5 should, in fact not be reduced to 6 and 4 or even less. The ratios used at Darnall are 4.6 and 4.0, respectively, and according to the manager, are so high only because the strength of the feeder roller does not permit lower ratios, although little juice is expressed. It is evident that the precompression of the material in gravity feed chutes, the consequently lower ratios for the setting of the feeder roller and the necessity of stronger feeder rollers will inevitably lead to the introduction of four roller mills at one stage.

This will bring Natal to where Australia is now, viz. three actual squeezes per mill but with the advantage that a full roller is saved.

References

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(4) Murry, C. R., and Hutchinson, R. I., Movement of Bagasse in Long Chutes, Proc. Q.S.S.C.T., 1958, p. 75.

(5) Murry, C. R., Holt, J. F., and Munro, B. M. An Investigation of Factory Feed Chutes, Proc. Q.S.S.C.T., 1962, p. 143.

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(7) van Hengel, A., and Douwes Dekker, K., Some Notes on the Setting and Operation, of Mills, Proc. S.A.S.T.A., 1958, p. 57.

For discussion on this paper see page 39.