Jones, J.N., Schofield, W., McKenzie, N.J. and Olson, B.C.
Proc. Aust. Soc. Sugar Cane Technol., Vol. 24, 2002

FACTORY RATE CONTROL BASED ON MORE CONSTANT FIBRE RATE

By

J.N. JONES[1], W. SCHOFIELD[1], N.J. McKENZIE[2] and B.C. OLSON[3]

[1]*Tully Sugar Limited, Tully, Qld*
[2]*Sugar Research Institute, Mackay, Qld*
[3]*BSES, Meringa, Qld*

KEYWORDS: Fibre Rate, Control, NIR, Crushing Rate.

Abstract

During the 2000 crushing season, Tully Sugar Mill implemented a new rate control system that aimed to process cane at constant fibre rate using a belt weigher to measure crushing rate and the NIR Cane Analysis System to measure fibre % cane. The control system was extensively used in the 2001 crushing season and its benefits were compared to the conventional constant No. 1 mill speed control system in a designed experiment. This paper describes the new control system, the reasons for its implementation and the comparison of its performance to the conventional mill speed control system. The results show that it has been successful in reducing the range in crushing and fibre rate and has brought some improvements to the factory's overall performance.

Introduction

During the 2000 crushing season, large variations in crushing and fibre rates processed by Tully Sugar Limited's milling train were experienced, which at times caused interruptions to crushing operations such as overfull feed chutes, juice ups and bagasse system overloads. It was expected that these interruptions could be minimised if the crushing and fibre rates through the milling train could be smoothed to eliminate extreme conditions.

This paper describes a fibre rate control system that was introduced to smooth the factory rate to eliminate interruptions to crushing operations. A comparison of the effects of the constant fibre rate control system to the conventional constant No. 1 mill speed control system is made.

Background

Prior to the introduction of the fibre rate control system, Tully controlled rate through a conventional fixed No. 1 mill speed control system. The No. 1 mill is a conventional six-roll mill with a conventional control system. Adjusting the speed of the cane carriers controlled the level of prepared cane in the mill feed chute. Adjusting the flap on the mill feed chute, the *torque control flap*, controlled turbine chest pressure.

To gain some understanding of the factors influencing the variation in crushing and fibre rates, an investigation of milling operations was carried out approximately half way through the 2000 crushing season, concentrating on the following aspects:

(a) crushing rate;
(b) % fibre in cane;
(c) % extraneous matter in cane; and
(d) position of the torque control flap.

The extreme hourly average crushing and fibre rates for the period examined are presented in Table 1. During this period, the No. 1 mill turbine speed was constant at 4800 r/min and the No. 1 mill feed chute level was satisfactory. The turbine speed was chosen to achieve budget crushing rate of 675 tonnes of cane/hour with an average fibre content of 14.5%. This should give an average fibre rate of 98 t/h.

Table 1— Extreme hourly crushing and fibre rates (2000 season).

	Rate (t/h)	
	Minimum	Maximum
Crushing rate	545	786
Fibre rate	92	118

An in-depth study into these extreme highs and lows in crushing and fibre rate was carried out. The following is believed to be (on most occasions) the main causes of the four extremes:

1. High crushing rate: Average to below average fibre % cane, below average extraneous matter, average to above average bin weights, torque control flap opening above average (good millable cane).

2. Low crushing rate: Above average fibre % cane, above average extraneous matter, average to below average bin weights, torque control flap opening below average (poor millable cane).

3. High fibre rate: Slightly below average to slightly above average fibre % cane, below average extraneous matter, above average bin weights, torque control flap opening above average (good millable cane).

4. Low fibre rate: High fibre % cane, above average extraneous matter, average bin weights, torque control flap opening below average (poor millable cane).

As expected, the fibre content of the cane has a larger effect on crushing rate than on fibre rate. The millability of the product being crushed was found to have a big effect on the crushing rate, presumably because the control system adjusts the feed chute setting and consequently the mill feeding performance. It is also very obvious that high levels of extraneous matter, which are quite common at Tully because of the regular wet weather conditions, have a large detrimental effect on rate.

After studying the findings of the investigation, it seemed quite obvious that a more constant fibre rate could be maintained by varying the speed (within limits) of the No. 1 mill turbine. An automatic control system to achieve this task was subsequently developed.

The fibre rate control system

The fibre rate control system was designed to vary the speed of the No. 1 mill turbine between 4400 r/min and 5200 r/min to achieve a fibre rate of typically 98 t/h (crushing rate of 675 t/h at a fibre content of 14.5%).

An overview of the control system is presented in Figure 1. In the conventional constant No. 1 mill speed control system, the PID block for the No. 1 mill speed control (right hand side of Figure 1) has a set point (SP) that is manually set. In the fibre rate control system, this set point is set from the output (OP) of the fibre rate control PID block.

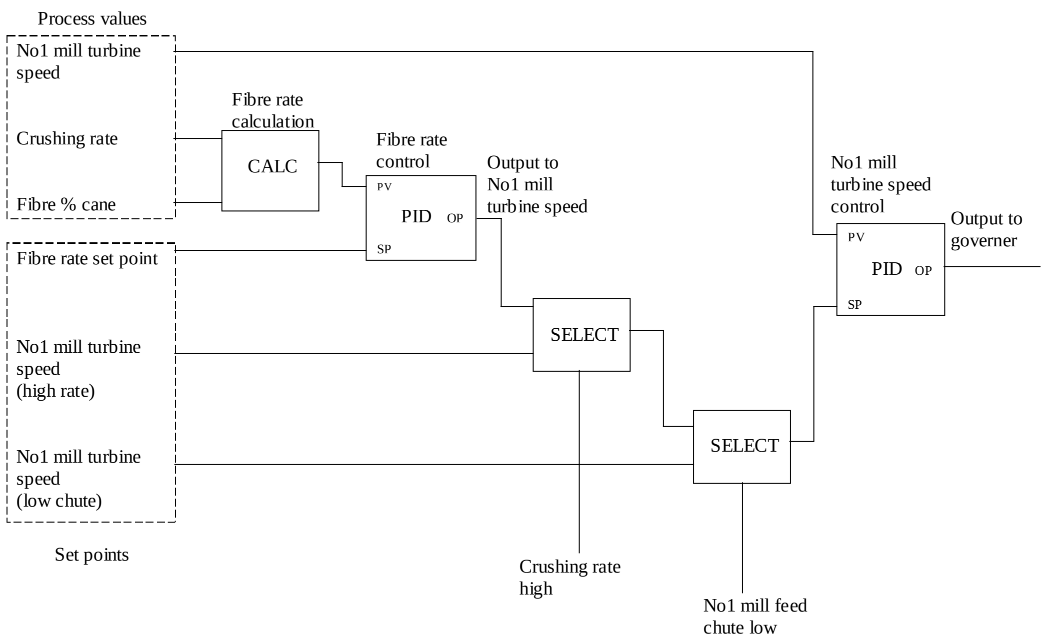

Fig. 1—Overview of the fibre rate control system.

The fibre rate control PID block is the main feature of the fibre rate control system. The operator, through the selection of a target crushing rate and an expected fibre % cane, manually sets the fibre rate set point. The set point is compared to the fibre rate (Process Variable) calculated from the crushing rate and the fibre % cane. Crushing rate is calculated from a belt weigher installed as part of the soil monitor development (Mathew *et al.* 1994). Fibre % cane is calculated from the NIR Cane Analysis System (Staunton *et al.* 1999). A 90 second smoothing is used on both the fibre and belt weigher readings to steady the control signal. The PID block then controls the speed of the No. 1 Mill between 4400 r/min and 5200 r/min to maintain constant fibre rate.

Turbine speed limits were built in to the control system to overcome the following two problems:

1. Low feed in No.1 mill chute. This overriding control is used to slow the mill down to its minimum speed setting (4400 r/min) when the level in the No. 1 mill feed chute falls below 30% for more than 5 seconds. This is a built in safeguard to keep feed in the No. 1 mill chute, both for efficient extraction and to ensure the stability of the NIR fibre

reading which requires a constant mat of prepared cane at the base of the feed chute. This normally happens when low bin weights occur (which can be quite frequent in wet weather) and the rotary tippler station then starts limiting the required crushing rate**.** As the feed in the chute returns to above 40%, the fibre rate control takes over again and steadily returns the speed of the mill to the setting required by the control system This same overriding control system has been in operation on the No. 1 Mill for the last 3 seasons while operating on the fixed speed control system.

2. High rate when processing low fibre cane. This overriding control was designed through necessity, for after a few weeks of operation in 2001, high crushing rates were still occurring when low fibre cane was being processed. In an attempt to maintain the fibre rate set point, with the No. 1 mill turbine speed controlling between 4400 r/min and 5200 r/min and the fibre rate set point on 102 t/h (680 t/h at 15% fibre), to crush 13% fibre cane, the crushing rate would have to climb to 785 t/h. This over-riding rate limiting control limited the maximum speed of the No. 1 mill turbine to 4700 r/min. When this part of the control system becomes active, it is not uncommon for the No. 1 mill to stay on this 4700 r/min setting until the entire rake of low fibre cane has been processed. Then as soon as the crushing rate falls below 700 t/h the fibre rate control takes over again.

This ‘more constant fibre rate control’ was first trialed in the last 2 weeks of the 2000 crushing season. During this short period it showed promise, in that it could maintain a more constant fibre rate to the milling train than was being achieved on the fixed No. 1 mill turbine speed system. The system was again implemented after the fourth day of the 2001 crushing season and used for the majority of the 2001 crushing season. The rate control only reverted to constant No. 1 mill speed control when No. 1 mill had to be set on minimum speed to reduce the crushing rate for either cane supply or troubles in the factory.

The development of the control system is continuing. It is evident that further improvements can be made through further tuning of the control system. Further improvements are also likely in the handling of extreme cane conditions.

Comparing the constant fibre rate control system to the constant No. 1 mill speed control system

Preliminary expectations

The following benefits to factory operation were expected from the introduction of the fibre rate control system:

1. a slight increase in extraction from a more constant imbibition % fibre ratio (at constant fibre rate, constant imbibition % fibre requires a simple constant imbibition rate);
2. a slight decrease in final bagasse moisture;
3. smoothing out of the peaks (high and low loads) in the bagasse system, leading to benefits in the operation of the boiler station and bagasse system; and
4. smoothing of the juice flows, which in turn should bring benefits to the clarifiers, effets and steam flows, and consequently, sugar quality.

A designed experiment to compare rate control systems

During November 2001, a randomised block experiment was conducted to compare the constant No. 1 mill speed control system to the constant fibre rate control system. The experiment consisted of five blocks corresponding to five days of testing and two treatments corresponding to the two control systems. Each test was conducted for four hours. The order of the trials each day was randomised.

The operational data collected throughout each trial included the cane belt weigher tonnage, NIR prepared cane analysis, each mill turbine speed, flap position, chest pressure and chute height, the mixed juice flow and tank level, the two ESJ flows, turbidity and maceration flow. Boiler steam flows and bagasse conveyor loads were also recorded. The operational data were recorded at one minute intervals. Final bagasse was sampled at approximately 20 minute intervals during the trials and was mixed and analysed for brix, pol and moisture. Extraction was calculated from the final bagasse analyses and the on-line NIR prepared cane analysis, which records prepared cane brix, pol, fibre and moisture.

Figure 2 shows the fibre rate comparison between the two control methods for the third day of tests. The curves have been superimposed to aid comparison. In actual fact, one test was completed before the other began. It is abundantly clear from this graph that constant No.1 mill speed control does a good job of fibre rate control most of the time. Over this period of testing, the advantage of using the fibre rate control system appears to be during prolonged periods of good feeding, high fibre canes. For the period shown in Figure 2, the milling train was set up to crush an average fibre rate of 105 t/h. For the constant mill speed operation, the milling train operated for a significant period with a fibre rate of 150 t/h.

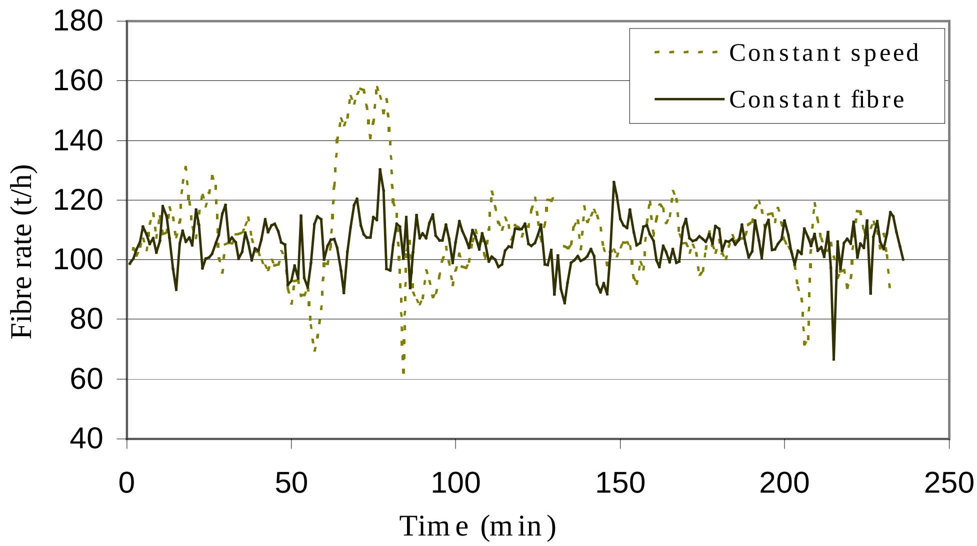

Fig. 2—Fibre rate comparison for day three.

An analysis of variance was carried out to identify significant differences between the two control systems. The results from the bagasse analysis showed no significant difference in extraction or final bagasse moisture between the two control systems.

In order to compare the variability of the two control systems, standard deviations (expressed as a percentage of their means) were calculated and compared in an analysis of variance. Surprisingly, the analysis of variance did not detect a significant difference in the fibre rate variability achieved by the two control systems. As discussed above, constant No. 1 mill speed does achieve reasonably constant fibre rate most of the time. The analysis of variance confirms this result. It is believed that the main advantage in the constant fibre rate control is in its control of extreme conditions.

The analysis of variance shows more variability in shredder turbine chest pressure and pol in open cells (as measured by the NIR system), and more variability in mill turbine speeds and mill feed chute heights in the constant fibre rate control system. This variability is likely to result from the continual changes in No. 1 mill speed. Once again, it is likely that any improvements in performance will occur during control of the extreme conditions.

The analysis of variance showed lower deviations in the juice handling system while operating with the constant fibre rate control system. The constant fibre rate control system was found to have less variation in mixed juice tank level. In addition, ESJ turbidity was found to be lower from the constant fibre rate control system, which may result in improved sugar quality.

In summary, the investigation has provided some evidence to support previous observations from factory staff that the constant fibre rate control system resulted in smoothing of factory operation. The results showed a reduction of extremes in fibre rate and crushing rate entering the factory, with likely benefits for bagasse handling, supporting the initial justification for the implementation of the system. There is some evidence of smoothing of juice flows with possible advantages for sugar quality. The trials also identified an increase in the variability of the milling train operation as a possible detrimental result of fibre rate control.

Comparison of factory performance 2000 crushing to 2001 crushing and observations

In Table 2, the production results and some relevant lost time figures for the 2000 crushing season operating with fixed No. 1 mill speed are compared to the 2001 crushing season operating with No. 1 mill set on constant fibre rate control. Considerably less variation in crushing rate was measured under constant fibre rate control operation. The results also show a higher extraction, lower bagasse moisture and less mill stops while operating under constant fibre rate control. The full season results differ from the short controlled experiment discussed above where the analysis of variance indicated no difference in extraction performance and final bagasse moisture. Whether these changes are as a result of the constant fibre rate control system is not clear although the results are encouraging.

Table 2—Comparison of factory statistics between 2000 (with constant No. 1 mill speed control) and 2001 (with constant fibre rate control).

Production figures	2000 crushing	2001 crushing
Average hourly crushing rate (t/h)	668	666
Highest hourly crushing rate (t/h)	786	750
Lowest hourly crushing rate (t/h)	545	630
Fibre % cane	14.58	15.35
Average fibre rate (t/h)	97.4	102.2
Final reduced extraction (%)	96.45	96.82
Moisture % final bagasse	49.91	49.16
Number of mill stops from bagasse system overloads	6	0

Conclusions

Tully Sugar Limited has implemented a ‘more constant fibre rate’ control system that appears successful in reducing variations in crushing rate. Under constant fibre rate control, mill stops from bagasse system overloads were eliminated, presumably because of the reduction in fibre rate variation. There is experimental evidence to show that juice flows are smoother under constant fibre rate control system and that ESJ turbidity is lower, indicating the potential for improved sugar quality. The effect of the constant fibre rate control system on milling train operation is less clear. Experimental evidence suggests that turbine speeds and chute heights are more variable under constant fibre rate control although the improved handling of canes under extreme conditions may provide some benefits.

It is Tully Sugar Limited’s intentions to use this more constant fibre rate control again for the coming 2002 crushing season. However, it is believed that there is still some room for further improvement in the control system to smooth the crushing and fibre rate even further, especially during changes in cane variety.

Acknowledgments

The authors gratefully acknowledge Tully Sugar Limited for permission to publish this paper. The authors also acknowledge financial support from SRI and BSES and their assistance in assessing the benefits of the constant fibre rate control system.

REFERENCES

Mathew, P.J., Fuelling, T.G., Dow, J.C., Phillips, P.L. and Noble, A.G. (1994). A soil monitor for sugar cane. Proc. Aust. Soc. Sugar Cane Technol., 16: 307–313.

Staunton, S.P., Lethbridge, P.J., Grimley, S.C., Streamer, R.W., Rogers, J. and Mackintosh, D.L. (1999). On-line cane analysis by near infra-red spectroscopy. Proc. Aust. Soc. Sugar Cane Technol., 21: 20–27.