CONTROL OF MILL CARRIERS

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Abstract

The advantage and requirements of a good carrier control system are discussed together with alternative ways of implementing a carrier control system. The system installed at Mount Edgecombe, designed and built by the author, is discussed together with the operational performance of the system.

Introduction

The problem of supplying a steady, continuous stream of prepared cane to the start of a milling tandem or the input to a diffuser has been with the sugar industry for some time.

The advantages of good carrier control are all-embracing and large benefits can be had if carrier control is improved.

Advantages of Good Carrier Control

(1) Improved throughput:
   The first mill will not stall or choke (when the chute is overfilled) or run empty.

(2) Improved extraction:
   With steady feed, the mills can be set near to their power and pressure limits.

(3) Steadier power consumption from the cane knives and shredder:
   By correctlyvarying the carrier feeding the knives and shredder, these machines can be run on their specified limits for extended periods.

(4) Less stoppages for chokes and overloads.

(5) Mill automation possible:
   Should be possible because with good chute level control, the system transients are removed.

Each sugar mill has a different cane carrier configuration and a different way of preparing the cane, but in all mills the requirements of a good cane carrier control system are essentially the same.

Requirements for a Good Carrier Control System

(1) It must be able to maintain the level of cane in the chute of the first mill within narrow limits.

(2) It must be reliable.

(3) It must ensure that while the cane is being fed through the system, equipment torque, speed and power specifications are not exceeded.

(4) The system must be stable under all conditions of cane input.

(5) The carrier speed changes must be made smoothly.

Alternative Ways of Implementing a System

Discrete Control

There are many ways of implementing a carrier control system which will provide the necessary control actions. In the sugar industry the general trend has been to stick to individual controllers, summers, limiters, etc., and to use these as blocks to build up an entire system.

Although this type of system is effective and simple, it does have certain drawbacks, namely:

(1) The systems usually require a large number of interconnections.

(2) The systems usually require a large number of power supplies. (Usually each controller has its own power supply.)

(3) The system requires a large amount of panel space.

(4) Many extra features are provided which are not needed.

(5) Discrete controllers are costly.

Microprocessor Control

Microprocessors are ideally suited for many control applications. They enable complex control at low cost. The interconnectors needed to implement a microprocessor system are far fewer than those needed for a discrete system and the system is usually compact.

The main drawbacks of a microprocessor system for carrier control are:

(1) The carrier system is essentially an analog system dealing with high power, high voltage equipment which makes interfacing to a microprocessor expensive.

(2) A high level of expertise is needed to design, install and maintain the system.

(3) The system inputs must be well protected to prevent damaging the sensitive microprocessor circuits.

Integrated Control

Another alternative is to build an integrated control system which is dedicated to the task at hand.

Such a system eliminates all the problems of the discrete control element system and also eliminates the problems associated with a microprocessor based system.

One advantage of an integrated system is that there are usually only a small number of control cards in the system and fault finding time is reduced as changing one card of the integrated system is equivalent to changing large numbers of discrete control elements.

It does have one distinct drawback and that is in its flexibility. It is usually more difficult to change control strategies than with either of the other two systems.

This forces the designer to choose his control strategy carefully and to decide exactly what is essential.

Mount Edgecombe System

At Mount Edgecombe the previous carrier control system left much to be desired. The control system did not provide good chute level control and the operator had to intervene continually to prevent the chute from overfilling or running empty. This was aggravated by the fact that —

(i) the system was unstable when the cane knives went into overload,

(ii) the first mill is fed by a slat carrier which makes control far more difficult than on a belt feed,

(iii) Heenan & Froude couplings are used for speed control. These couplings suffer from hysteresis effects which introduces deadband into the system.

This poor control was the motivation to design a control system to try to improve and chute level control on the first mill.
The system designed was a totally integrated system which accepted inputs from the two cane knives, flicker and shredder, as well as the carrier speed signals. These inputs were then compared with the various setpoints and three output signals were produced which fed to the speed references of the carrier speed controllers. (See Fig. 1)

**System Description**

**Chute Level Control Loop**

The chute level control loop tries to speed up or slow down the carriers to maintain the chute level at the setpoint set. The setpoint is permanently set on the control card to be at 50%.

From Fig. 1 it can be seen that a deadband circuit is used. This is used to reduce the unnecessary carrier speed changes which would occur due to small changes in chute level. Small changes are always going to occur especially if the chute is fed from a slat carrier.

The reason the chute level setpoint is not variable is to ensure that the error signal fed into the PID controller is always the same for a given chute level deviation.

This error can vary widely if different chute level setpoints are chosen as can be seen from Fig. 2. This effect becomes worse when fewer level sensors are used to feed the chute level transducer.

**Anti-Stall**

This loop continually monitors the speed from the turbine on the first mill and compares this with the speed set. If the turbine falls below the speed set, all the carriers immediately start slowing down. This reduces the chute level which puts less load on the turbine and in so doing prevents the turbine from stalling.

**Shredder Elevator**

Here the current load on the shredder and flicker are monitored and if either or both of these goes above the current value set, then a constant voltage is fed into the input of a proportional integral controller.

This step input to the PI controller causes the shredder elevator reference to drop immediately by an amount dependent on the proportional gain, after which the reference continues to drop at a rate determined by the integral time constant. The inverse applies when the overload condition ceases. (See Fig. 3)

As the tacho signal from the shredder elevator is used as the reference to the main carrier thyristor drive, any change on the shredder elevator also causes the main carrier to change. This prevents the carriers from choking if for some reason a fault develops on the Heenan & Froude couplings.
The advantage of having current limiting on the shredder and the flicker is that an overload condition on either of these machines usually implies a high bed of cane. If the carrier slows down as a result of the overloads implied, then there will be a smoothing effect on the flow of cane fed to the first mill carrier.

**FIGURE 3** Output signals produced when shredder and flicker go into overload

### Main Carrier Control
This control is identical to that of the shredder elevator except the loads on the two cane knives are monitored and a step input to the PI controller is produced if either or both of the cane knives goes into current limit.

As with the shredder, this current limiting acts as a filter to filter out the "lumps" (large bundles) fed into the system.

### Auto/Manual
If the operator needs to go on to manual control at any time, he can override the chute level control loop by pushing the manual button. He then can directly vary the No. 1 elevator speed and hence the other carriers.

In manual mode the operator must visually check the chute level and control accordingly.

It can be observed from Fig. 1 that in manual mode the operator still has all the protection features operational including the anti-stall protection.

### Additional Features
To ensure optimum reliability, in addition to the automatic mode described above, there are certain extra safety features built into the system.

### Emergency Manual
Under normal conditions the relay EM is energised.

If a fault does develop on the control card, the emergency manual mode can be selected. This causes the relay EM to de-energise. The system reverts to a manual system where the tacho signals from the carriers are cascaded. The values of the constants 'K1', 'K2', 'K3' are ratio values which are set so that the system still has lead speed between successive carriers. (See Fig. 1)

The emergency manual mode can be selected by either:
(i) switching a switch or the control card, or
(ii) removing the card completely.

This facility does enable the control card to be tuned or fixed on the run.

### Extra Overload and Emergency Stop
Often it is necessary for the operator to stop all carriers as quickly as possible. For this, a button is provided which when operated causes the three carrier reference signals to be reduced immediately to zero.

As component failures can occur with any control system, it is good to have built-in safeguards. With this system, there are additional overload relays which are set above the level of the normal current limit. If the overload is not reduced by the normal current limit, then the emergency current relay operates which instantly reduces the reference signal to the main cane carrier to zero.

### Practical Aspects
The system was built using readily available components. The entire control system (except the chute level transducer), is mounted on a 120 mm by 160 mm card and all components except potentiometers are removable.

All input and output signals are brought in on an 86-pin edge connector. The power supply is ±15 volts.

Having a system on one card enables the entire system to be replaced if a fault occurs.

The new control system fits into the existing thyristor control panel controlling the Heenan & Froude couplings.

The component cost of the system was less than R150,00.

The chute level transducer has six conductivity probes for level sensors and is an optically isolated card designed by the author and built by Mount Edgecombe staff. The component costs of the transducer card was less than R100,00.

### System Installation and Tuning
This control system is essentially easier to tune than systems which have multipliers and normal threshold modules.

The simplification arises in that the overload signals fed to the PI controllers are essentially constant voltage signals and do not change with current. This enables carrier responses to an overload to be easily set for all load conditions. (See Fig. 3)

The comparitors producing the overload signals are set up by primary injection through the ammeter CT's. LED's on the control card indicate when the circuit is in overload.

It was found very difficult to get good chute level control even with the PID controller due to the uneven feed from the slat carrier.

The PID controller was set up by operating the system in the manual mode and observing the type of response which worked best.

### Operational Performance
This system was installed and operational through the second half of the 1981 crushing season.
The initial results showed a dramatic improvement in chute level control (see Fig. 4) and the load swings on the shredder and on the cane knives were noticeably reduced.

The throughput appeared to be higher than normal and the operator found the anti-stall circuit on the first mill turbine to be a great help especially when sandy cane was fed through the mill.

![Percentage Chute Level Before Installation](image1)

![Percentage Chute Level After Installation](image2)

**FIGURE 4** Chute level before and after installation of control system

During the offcrop which followed, several small changes were made, namely:

1. The mill motors were tuned to give identical characteristics, and optimum performance.
2. The number of palms on the first set of cane knives was reduced.
3. The Heenan & Froude magnetic couplings were tuned to give identical transient and steady state responses.
4. A beam was removed from the shredder elevator which enabled a higher bed of cane to be fed into the shredder.
5. An educational programme was embarked upon to get the feeder table operator to have confidence in the new system and load sufficient cane into the main cane carrier. Previously the cane knives would sometimes choke and trip out and because of this, the operator was reluctant to load a high bed of cane.

These changes, together with the new carrier control system, enabled the cane throughput to be greatly increased and weekly crushing rates of above 235 tons/h were regularly achieved. During one four-week period, an average crushing rate of 238,63 tons/h was realised.

By the end of the 1982 season, several new records had been set:

<table>
<thead>
<tr>
<th>Record</th>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly crushing rate (tcph)</td>
<td>225,92</td>
<td>240,64</td>
</tr>
<tr>
<td>Yearly crushing rate (tcph)</td>
<td>210,39</td>
<td>221,43</td>
</tr>
<tr>
<td>Weekly tonnage (tons)</td>
<td>34,025</td>
<td>35,128</td>
</tr>
</tbody>
</table>

To enable comparisons to be made with other mills the equipment power ratings are shown in Table 1.

**TABLE 1**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Power (Kw)</th>
</tr>
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<tbody>
<tr>
<td>1st Cane knife</td>
<td>280</td>
</tr>
<tr>
<td>2nd Cane knife</td>
<td>310</td>
</tr>
<tr>
<td>Shredder</td>
<td>1120</td>
</tr>
<tr>
<td>1st Mill turbine</td>
<td>450</td>
</tr>
<tr>
<td>2, 3, 4, 5, 6 Mill motors</td>
<td>200/310</td>
</tr>
<tr>
<td>7th Mill turbine</td>
<td>450</td>
</tr>
</tbody>
</table>

**Conclusions**

1. It should be apparent from the above that good carrier control is essential and provides many benefits, the most significant of which is throughput.
2. Good carrier control has a smoothing effect on the load drawn by the cane knives and the shredder.
3. By operating in current limit, the cane knives can be fully utilised and at the same time the bed of cane coming out of the cane knives will be smoothed.
4. A dedicated integrated control system is a good alternative to discrete or microprocessor control systems.
5. An effective reliable control system can be built at a fraction of the cost of those systems offered by electronic firms if the designer is closely in touch with the problem.
6. By building one’s own system, one is guaranteed to have all the information and drawings needed to run and maintain the system.
7. Full mill automation is not a good proposition until the feed to the first mill is steady, i.e. until a good carrier control system is installed.