SHREDDER DRIVES

T. L. BOSHOFF
Tongaat-Hulett Sugar Ltd, Glenashley

Abstract

Shredders can be driven by steam turbines or electric motors, each with its own advantages and disadvantages. The optimum choice depends on the individual application.

Introduction

Cane shredders are driven by steam turbines or electric motors, each of which has advantages and disadvantages.

This brief paper examines the relative merits of the two alternatives.

Shredder load characteristics

Speed

Most modern shredders in South Africa operate at rotational speeds between 900 and 1 200 rpm. With a typical swept diameter of 1.78m (70"), the tip speeds lie between extremes of 83 and 111 m/sec, with the more usual range being 90 to 105 m/sec.

Power

The results of shredder power consumption tests by a number of investigators has been summarised by Marson (1980), the summary being given in Table 1.

Table 1

Shredder power measurements (Marson 1980)

Investigator	rmp	kW/tch	kW/tfh
Marson	1 132 995	7,1 4,6	53 31
Renton		1,7 to 2,7	14 to 19
Cullen and McGinn	1 200 960	2,0 to 8,0 2,0 to 4,5	13 to 66 13 to 37
van Hengel		2,4	15
Clarke and McCullogh	960	6,5 to 13,0	16
Clarke	1 200	4,7	33

There is wide scatter between the results obtained by the various investigators. Marson found that the specific power consumption and preparation index (PI) increased with increasing speed and that the specific power consumption was higher with trashed cane than with burnt cane.

Taking into account the fluctuating nature of the shredder load and the load surges often experienced, a value of 45 kW/tfh for the installed power has been found satisfactory.

The power absorbed by the knives preceding the shredder has been found to have little effect on the power absorbed by the shredder. Too much knifing prior to the shredder can result in over-preparation, with resulting poor percolation in diffusers.

Load fluctuations

The normal shredder load contains high frequency torsional fluctuations, as anyone who has been close to an operating shredder and experienced the typical "growl" can testify.

The frequency of these fluctuations depends on the configuration of the shredder internals and drive, and the operating speed. Their amplitude appears to be close to that of the average torque.

There are also lower frequency load swings of much larger amplitude, which depends on the uniformity of the cane feed to the shredder and the characteristics of the drive.

These load swings occur typically 10 to 60 times per minute with magnitude between 80 and 120% of the average load. With a non-uniform cane feed and a "stiff" drive characteristic these fluctuations can however be as large as 0 to 300% of the average load.

Speed fluctuations

The large rotating mass of a typical shredder provides a flywheel effect which stores energy. If the shredder slows down because of increased load, this energy is released and smooths the load on the prime mover.

In order to make use of this stored energy, the drive speed must be allowed to fluctuate. Speed recordings taken on the 3500 kW shredder turbine at Amatikulu mill show a speed range from 4% below to 2% above the nominal 1000 rpm, ie a range of 6%. A speed reduction of 4% will release about 8% of the stored energy.

Steam turbine drives

Rotational speeds

The rotational speed of a turbine is much higher than that of the shredder and a gearbox is always required. The gearbox design application factor, which takes into consideration the nature of the load, should not be less than 1,8 to accommodate the varying nature of the load.

Speed/torque characteristic

The speed/torque characteristic of a turbine is well matched to the requirements of a shredder, in that a reduction in speed due to increased load results in an increase in available torque as the speed governor provides more steam. Even with the steam control valve wide open, the available torque would increase as the turbine slowed down.

Electric motor drives

General speed characteristics

Electric motors are essentially fixed speed devices, and if the supply frequency is fixed, the scope for speed changes is limited. The available nominal speeds are also limited, and for 50 Hz supply frequency are 3 000, 1 500, 1 000 and 750 rpm, being the synchronous speeds corresponding to 2, 4, 6 and 8 poles respectively.

The nominal motor speeds usually considered for shredder drives are 1 500 and 1 000 rpm. If a shredder speed of say 1 200 rpm is chosen, a gearbox will be essential as there is no matching motor speed. For a nominal shredder speed of 1 000 rpm, either a 1 000 rpm or a 1500 rpm motor could be considered.

An investigation has shown that the cost of a 1 500 rpm motor plus speed reducing gearbox can be cheaper than the cost of a 1 000 rpm motor alone. However when the cost of gearbox maintenance is taken into account, this option is not recommended.

Motor "slip"

The stator magnetic field rotates at the synchronous speeds referred to above. The motor rotor always rotates at a lower speed, the difference in speed being referred to as the "slip" and is expressed as a percentage of the synchronous speed.

This relative speed between rotor and magnetic field is necessary for the motor to develop torque, and if more torque is required, more slip is necessary. A typical 6-pole motor has a full-load speed of 980 rpm, ie 2% slip relative to the synchronous speed of 1 000 rpm. At this speed of 980 rpm the torque and current will be 100% of the rated values.

As an approximation, if the slip doubles the torque and current will double to 200% of the rated values (Figure 1).

The motor "slip" represents lost energy, and for large motors the manufacturer generally tries to provide a high efficiency. The 3 000 kW shredder motors at Felixton Mill have full load slip of only 1%. This means that if the slip increases from 1% to 3%, the current and torque increase to about 300% of the rated values. A total slip range from 0 to 3% therefore results in the current and torque fluctuating from zero to 300% of the rated values. A low full-load slip value is therefore undesirable in a shredder drive.

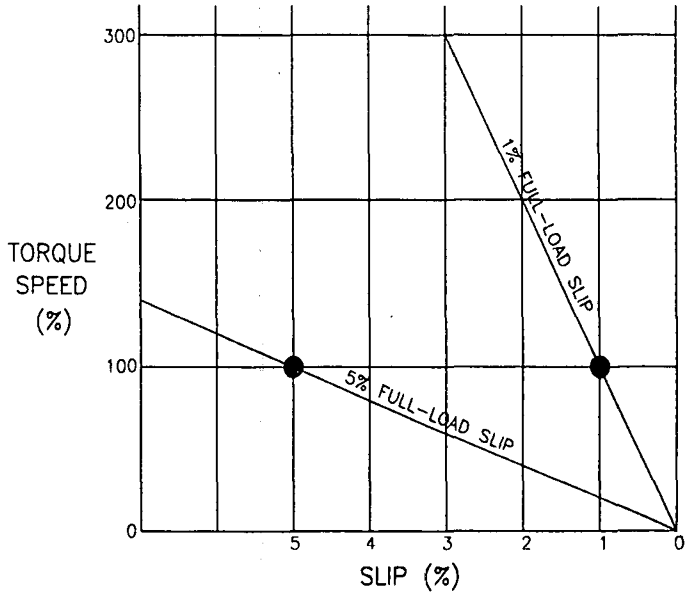

FIGURE 1 Motor torque/slip characteristic

Another problem which can arise with electrical shredder drives concerns a fluctuating supply frequency. Because of the large inertia of the shredder, a sudden 0,5 Hz increase in supply frequency represents a sudden increase in motor slip of 1%. In the case of a Felixton shredder this would cause a sudden doubling of the current and torque with no change in cane throughput.

Felixton has two large shredders the cane supply to which is not particularly well regulated. A change in load on one shredder can cause a supply frequency fluctuation which in turn can cause load swings on the other.

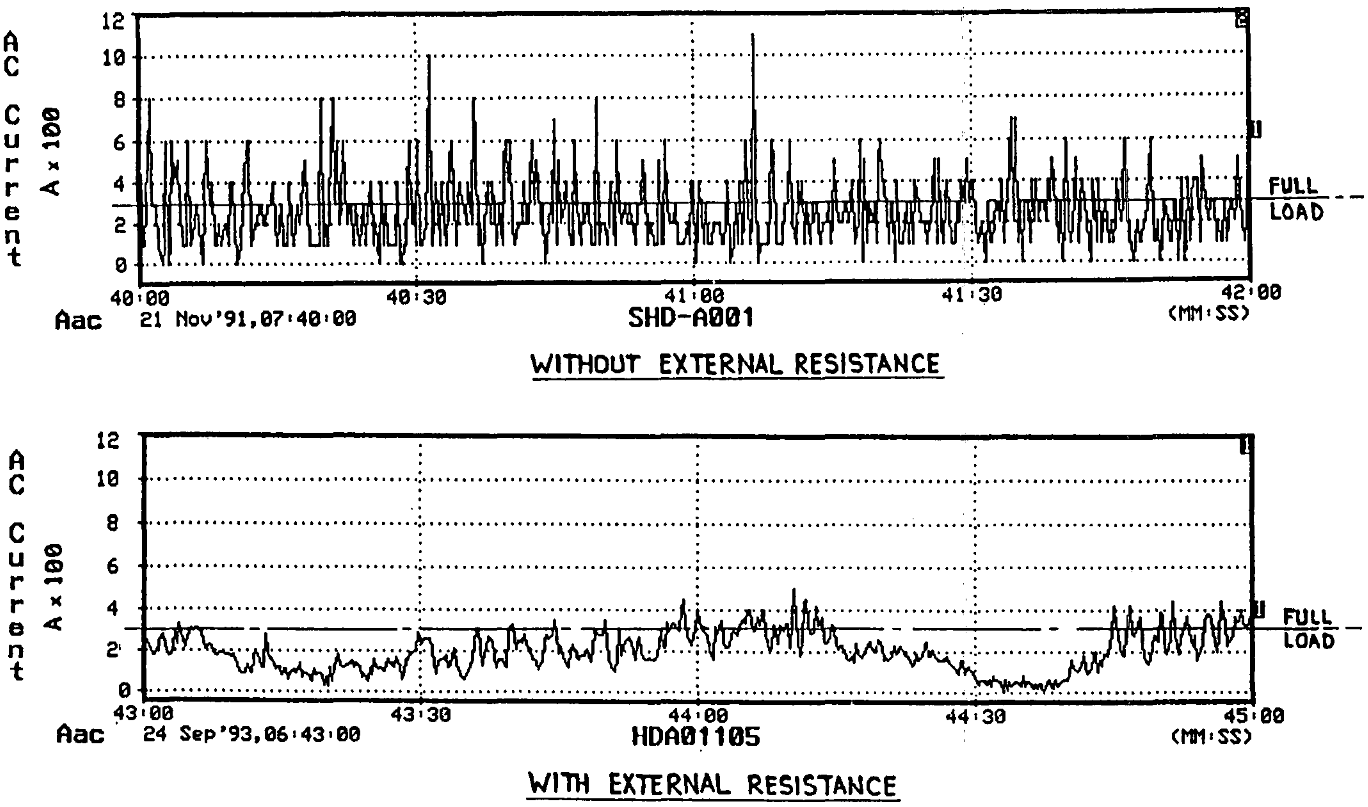

FIGURE 2 Shredder motor current

Rotor resistances

Shredder motor rotors generally have sliprings and external starting resistances to provide the necessary high starting torque. This provides the possibility of running the motor with a permanently-connected external resistance to increase the full-load slip and hence allow the motor speed to fluctuate without excessive fluctuations in the torque and current.

Figure 2 shows stator current recordings on a Felixton shredder with and without an external resistance connected. The value of the additional resistance is calculated to increase the full-load slip from 1% to 2%.

The smoothing effect of the external resistance is clear. The 2 000 kW shredder motor at the new Komati Mill is provided with an adjustable external resistance, and the shredder was recently commissioned with resistance to provide 7% full-load slip. Exceptionally smooth operation resulted.

The 2 800 kW shredder motor at Sucoma Mill is also running well with an external resistance to provide 7% full-load slip. It should be noted that 7% slip on a 2 000 kW motor represents 140 kW of losses.

Advantages/disadvantages of turbine and motor drives

General

The necessary speed/torque characteristics are inherent in turbine drives, but can be achieved with motors by installing external rotor resistances.

The cost of a motor drive is generally less than that of a turbine drive, especially when long steam pipe runs are involved. This is true even when the additional capacity of the Mill turbo-alternators (TAs) is taken into account. When adding a new shredder drive in an existing Mill, factors to be considered include:

Capacity of existing TAs

- Capacity of existing electrical reticulation system.
- Quantity of exhaust steam from turbines vs factory requirements.
- Pipe runs to and from shredder location.
- Need for remote operation.

Advantages of turbine drive

- Good speed/torque characteristics.

The disadvantages of turbine drive

- High capital cost of turbine/gearbox.
- High cost of high pressure and exhaust steam piping, valves, etc.
- Higher maintenance costs.
- Possibly lower steam efficiency than the mill's main turbo-alternators (TAs), leading to excessive quantities of exhaust steam.
- More complex operating procedures, especially during start-up.

Advantages of electric motor drives

- Lower capital cost, even when the cost of additional TA capacity is taken into account.
- Ease of operation.

Disadvantages of electric motor drives

- "Stiff" torque/speed characteristic leading to excessive fluctuations in supply current, unless large external slip resistances are fitted.
- Energy losses in external resistances.

Conclusions

The advantages and disadvantages of each drive type have to be evaluated for the particular mill. The factors to be considered include the following:

- The capacity of the existing turbo-alternators and electrical distribution system.
- Location of shredder in relation to existing steam services.
- Need for remote startup facilities.
- Factory exhaust steam demand in relation to existing turbo-alternator exhaust steam quantity.

REFERENCES

Marson, JL (1980). Mathematical Modelling of an Industrial Cane Shredder. MSc thesis, Univ of Natal.