THE APPLICATION OF AN HYDRAULIC DRIVE ON A DEWATERING MILL

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Abstract

This paper reviews the benefits of a hydraulic drive installed on the pressure feeder rolls of one dewatering mill at the Malelane sugar factory. The drive met all criteria except for the anticipated reduction in mill moistures. It emerged that other factors on the mill must be addressed before the additional power available would be of benefit in this regard. It has been concluded that the capital cost of hydraulic drives compares favourably with steam and electric drives for dewatering mill duty. The power conversion efficiency of a hydraulic drive is similar to an electric drive with conventional helical/spur gears.

Keywords: hydraulic drives, mill drives

Introduction

The TSB Malelane Mill dewatering station comprises two pressure fed 84" Walker mills in parallel, each rated for 26 tons fibre per hour. Each mill is driven by a 560 kW steam turbine with a final geared down pressure feeder roll speed of 4 rpm and mill roll speed of 3 rpm. In the off-crop of 1998, a Hägglunds hydraulic drive was installed on the pressure feeder rolls of one mill. The purpose of the new drive was to apply an additional 250 kW of power to the mill unit and to test it over a period of time to assess the following:

- Maintenance cost
- Reliability
- Throughput benefits
- Bagasse moisture reduction
- Mill hydraulic drive versus other mill drive options, e.g. variable speed electric motors.

Details of hydraulic drive unit

Drive specifications

The hydraulic drive selected was a Hägglunds MB 1600, based on Hägglunds' drive selection criteria. The drive specifications are shown in Table 1.

Table 1. Drive specifications.

Parameter	Maximum design	Actual
Specific torque	1600 Nm/bar	1600 Nm/bar
Speed	32 rpm	7.2 rpm
Hydraulic system pressure	350 bar	250 bar

Note: The hydraulic pressure has been limited to 250 bar i.e. an output torque of 400,000 Nm, to protect the mill pressure chute and related components.

Description of hydraulic drive unit

A 250 kW electric motor drives the hydraulic pump. This pump is of a swashplate design, with the angle of the swashplate determining the flow rate of the hydraulic fluid to the hydraulic motor. The hydraulic motor is of the radial piston type with rotating cylinder block and stationary housing. The cylinder block is mounted in fixed roller bearings in the housing. The pistons are radially located in bores inside the cylinder block and these pistons push against individual cam rollers. The hydraulic motor and drive can be seen in Figs 1, 2 and 3. When the hydraulic oil flow is directed to a specific piston by the distributor plate, the piston and cam roller assembly push against the slope on the cam ring that is attached to the stationary housing, resulting in torque. The available torque is therefore directly proportional to the pressure and the speed is directly proportional to the flow rate in the system. The system has an inherent overload protection, whereby the pressure compensator on the pump de-strokes the pump when the pre-set maximum system pressure has been reached. The entire system is self-monitoring with all the necessary warning and alarm facilities.

Figure 1. Photograph of drive pump and control system.

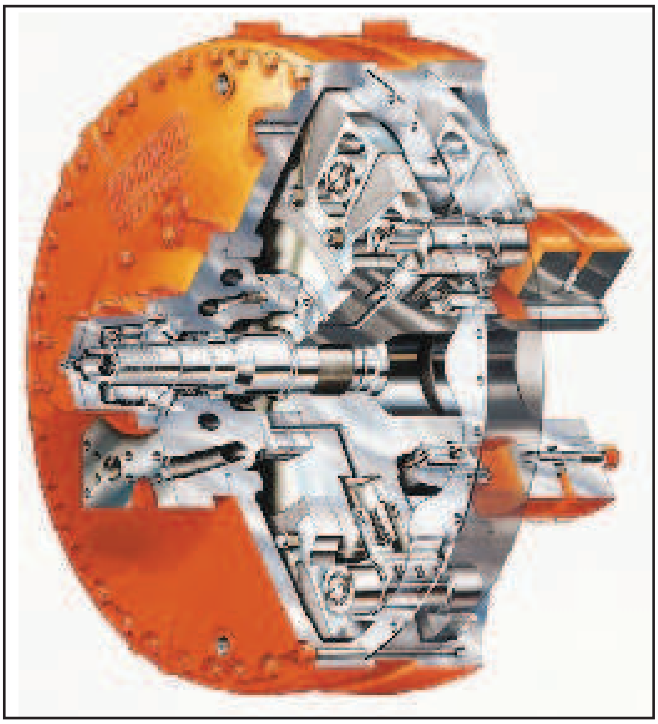

Figure 2. Cut-out view of hydraulic motor.

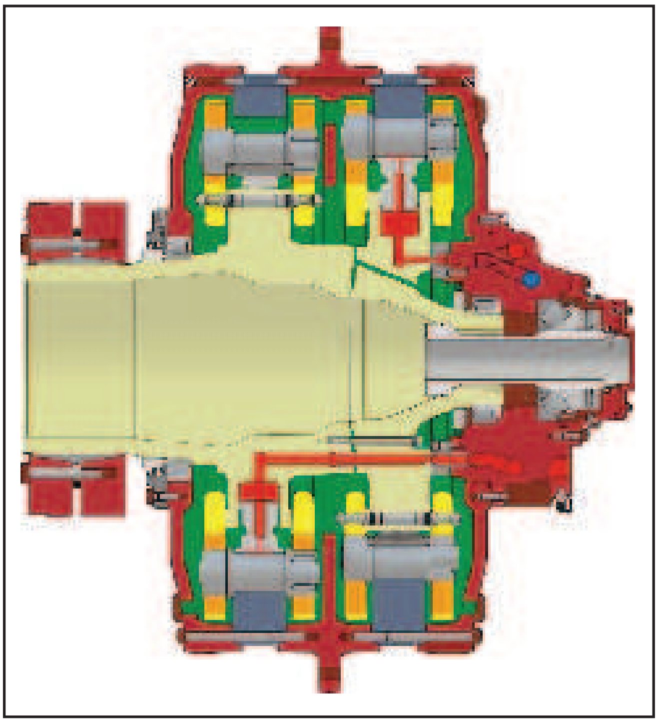

Figure 3. Sectional view of hydraulic motor.

The drive motor itself is directly shaft mounted onto the bottom pressure feeder roll, with a hydraulic coupling. A torque arm mounted on the structure absorbs the reaction torque of the drive. In the Malelane installation the torque arm has been fitted with a cylinder to fully balance reaction forces, including the weight of the motor.

Installation

The installation of the hydraulic drive proved to be relatively straightforward, with the only challenge being the design of the support structure, which must take up the reaction torque of the drive. The electronic control system is contained in the hydraulic pump panel and communication with the existing mill PLC is limited to start/stop, trip and speed setpoint parameter changes. With the help of the supplier, the connection of this system with the PLC was easily accomplished.

The hydraulic motor was mounted on the bottom pressure feeder roll shaft, with the top pressure feeder roll being driven via pinions. The pressure feeder and mill rolls were originally driven from the one turbine, via a 3-stage gearbox, with two output shafts. To accommodate the hydraulic drive, the pressure feeder roll drive shaft was removed, leaving the three mill rolls with the full turbine power output.

Commissioning

After initial tripping problems, which were quickly rectified, the hydraulic drive proved to be reliable. However, the targeted less than 50% bagasse moistures were not attained. During commissioning it was observed that the bagasse distribution was uneven across the width of the chute and it was assumed that this might be limiting performance. A bagasse spreader system was installed to even out the loading over the width of the Donnelly chute, but this did not bring the expected improvements in bagasse moisture.

Several control philosophies were experimented with, to optimise dewatering performance. These were:

Load cell control

Two load cells were mounted on the mill pressure chute surface to measure its loading / deflection. The pressure chute loading / deflection signal was then used to control the speed of the hydraulic drive. This option was discarded at an early stage due to an unsatisfactory load cell signal.

Hydraulic drive pressure control

The feed chute level was used to control the pressure feeder roll speed (hydraulic drive speed). The hydraulic drive pressure was then controlled around a setpoint derived from the mill turbine speed with load cell signal providing a high limit protection. This philosophy was soon discarded due to an unsatisfactory load cell signal and the inherent risk of over-pressurising the mill feed chute.

Nozzle bowl pressure control

The feed chute level was used to control the pressure feeder roll speed (hydraulic drive speed) whilst the turbine nozzle bowl pressure was controlled at a fixed torque by varying the mill speed. Initial results for this control philosophy were disappointing and due to production pressure it had to be abandoned without opportunity for sufficient fine-tuning.

Speed ratio control

The mill control philosophy currently employed is one of chute level control, i.e. controlling the mill turbine speed to regulate the chute level, with the hydraulic drive following at a set speed ratio.

One major advantage of the hydraulic drive is the flexibility of speed ratio adjustment, i.e. the pressure feeder rolls to mill rolls speed ratio can be adjusted within a range from 0.8 to 1.6, as required to accommodate variations in mill settings, roll surface roughness and turbine nozzle bowl pressure. This flexibility also allows for optimal use of the mill under varying cane quality conditions.

Operational results

The greatest benefit of the hydraulic drive has been in the area of capacity improvement and plant reliability, i.e.

- The additional power has enabled the fibre loading to be increased from 28 to 32 tons fibre per hour.
- The time efficiency of the drive has been 99.9% for the past year.

There have been no serious breakdowns on the hydraulic drive unit to date. The only part that requires regular replacement is the potentiometer providing the swashplate position feedback signal. Apart from this, oil filters and o-ring seals have had to be replaced from time to time. The average maintenance cost on the hydraulic drive over the last three years has been R43 000 per annum.

Comparison with other drive options

One of the stated purposes of this project was to compare the hydraulic drive with other drive options to provide information for future mill upgrades. The following table provides the information available to date.

Other mill experiences

The use of a hydraulic drive on a mill roll application is fairly new to South Africa, however, it is a well established practice in countries such as Australia, where a total of 80 drives have been installed to date. Various papers have been published world-wide containing information on alternative control philosophies, mill settings, etc. An example of the hydraulic drive's flexibility is the ability for each roll to be driven by individual hydraulic drives. (Vivas *et al*, 1999). The authors concluded that the optimal speed ratio for delivery, feed and top rolls were 0.85, 0.9 and 1.0 respectively.

In 1997, a total of three catastrophic failures were experienced at Australian mills resulting in a factory re-call of some 100 hydraulic motors for repair.

The hydraulic drives' cam rings failed due to:

- A surface hardness problem of the cam rings.
- Cam ring machining tolerance problems.
- Stray current from the mill roll arcing machines, causing pitting on the cam.

The manufacturer has since addressed the first two problems. The last item has to be addressed by good in-house earthing practice to avoid stray current damage.

Conclusion

The hydraulic drive is a viable drive option that offers advantages of simple operation, ease of retrofit, reliability and excellent mechanical performance. The expected benefit of improved bagasse moisture as a result of the additional of 250 kW of additional power has not materialised at Malelane mill. It has been determined that other factors on the mill must be addressed before the additional power available would be of benefit in this regard. The maintenance cost for the first three seasons has been low, however, the real lifetime cost will only become evident after the first decade of service. The level of in-house expertise required for extensive hydraulic repair work as the system ages could become a problem in the future. The capital investment to install a total hydraulic system compares favourably with electric and turbine drive systems. Power efficiency conversion of a hydraulic drive is similar to that of an electric drive with conventional gearing, although higher efficiencies are possible with epicyclic drives.

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Table 2. Drive comparison table.

Parameter	Drive Type		
	Steam Turbine	Electric Motor	Hydraulic Drive
Initial capital expenditure for full mill conversion (Approx. cost)	R 4,5m (for gearbox, coupling, civils and steam supply)	R 4,7m (for gearbox, coupling, civils and electric supply)	R 4,7m (for steelwork and machining)
Maintenance cost p.a.	R 193 000 p.a.	R 5 000 p.a. (Data ex Komati Mill)	R 40 000 p.a.
Mechanical efficiency*	43% (steam turbine to gearbox output shaft)	85%** (electric motor to gearbox output shaft)	85% (electric motor to hydraulic motor output shaft)

* Typical values ** Efficiencies of 97% are obtainable with epicyclic gearing