ELECTRO-HYDRAULIC ASSIST DRIVES FOR SUGAR MILLS

By

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Abstract

THE APPLICATION of the electro-hydraulic assist drive on a feed roll, also called the cane roll drive, is now the most common way to modernise the transmission of cane milling units. This paper describes the electro-hydraulic assist drives, their history, operation, advantages and qualitative and quantitative results based on data reported by users, such as La Union Sugar Mill in Guatemala, Taboga Sugar Mill in Costa Rica, and El Potrero in Mexico, as well as on the author's personal experience, ever since the first installation in the world. The use of electro-hydraulic assist drives allows for gradual modernisation of conventional mill transmissions. The possibility of increasing the power transmitted to the existing mills makes it possible to continue using the conventional transmissions without the need to reinforce them. The incorporation of additional power into the mill through the use of electro-hydraulic drives is also a more economical option than that of modifying the conventional transmissions. All the users report an increase in milling capacity, larger extraction rates and a reduction in bagasse moisture content and pol in bagasse.

Introduction

The objective of this paper is to present details of one specific application of electro-hydraulic drives to milling units and to demonstrate the resulting performance benefits.

The main elements of a high torque, low speed electro-hydraulic drive for a complete mill drive system are a power unit, a high torque hydraulic motor, the piping, and a control system (see Figure 1).
The main components of the power unit are an electric motor and a variable flow hydraulic pump, together with a tank and hydraulic accessories such as valves, coolers, filters, etc. The high torque hydraulic motor is mounted directly on the shaft of the machine being driven.

The piping allows for free positioning of the power unit with respect to the motor, although consideration must be given to the distance between these main operating components. The machine control system allows for monitoring of the operating parameters, as well as for automation of operations of the milling unit and the entire tandem, thus ensuring maximum operating torque and, consequently, maximum extraction. Following is a list of the advantages of an electro-hydraulic drive compared to a conventional, mechanical turbine drive.

1. Partial or complete elimination of the conventional gears and crowns.
2. The possible elimination of the tail bar.
3. The possibility of providing additional power to the mill, thus assisting the conventional transmission if some of it is retained.
4. Reduced space requirements for the mill drive.
5. Reduced stresses in the roll shafts because of the elimination of the tail bar and the crowns.
6. No foundations are required for the mill drive.
7. Maximum torque is available over the complete speed range, i.e. from zero to maximum speed.
8. The ability to reverse the direction of rotation.
9. Continuous variation of the speed for each individual roll.
10. Overload protection and almost immediate mill shutdown.
11. The possibility of automation of the milling process.
12. Measurement of the torque for each of the rolls.
14. Reduced size and weight of the mill drive.
15. Energy savings (high transmission efficiency, use of electric power, reduction of bearing loads).
16. Increased extraction (optimisation of the extraction process).

Different methods to drive the mill with the electro-hydraulic drives

In this section, the various ways in which an electro-hydraulic drive can be used on a milling tandem are described so that these alternatives can be compared and contrasted with the application that is the main focus of this paper.

Application on pressure feeders

One of the major applications for variable speed electro-hydraulic drives is that of pressure feeder drives. This is due to the fact that pressure feeders work much better when their speed can be adjusted with respect to that of the mill, and thus ensuring optimum mill loading and maximum extraction.

One of the options is driving each of the feed rolls separately, while another option consists of driving one of the rolls by means of a hydraulic motor, while maintaining the use of crowns between the rolls on the feeder.

The major advantage of using electro-hydraulic drives on pressure feeders, aside from the fact that this is a variable speed transmission, is supplying additional power to the mill equipped with pressure feeders. This advantage becomes even clearer when conventional three-roll mills are converted into five or six-rolls, and yet the mill is still driven by the existing transmission.

Application to drive the mill when using an open transmission

One of the solutions for driving the complete mill with an electro-hydraulic drive is installing the motor on the pinion of the open transmission (Figure 2).

This solution enables the use of a physically smaller but higher speed motor, the torque of which is increased through the open transmission.
This option is recommended at locations where an open transmission has been recently repaired or where a new, reinforced open transmission has been installed, but there is still need to modify the remaining transmission elements.

**Fig. 2—A hydraulic drive on the open gearing pinion.**

**Application to drive the complete mill through the top roll**

In this solution (Figure 3), one or two hydraulic motors are installed on the shaft of the upper roll and the crowns are retained in order to drive the bottom rolls. This solution allows for the elimination of the entire conventional transmission, with the exception of the crowns, thus making some space available for the installation of another tandem, where the conventional transmission was previously located. This type of transmission is recommended for use in small and medium-size mills and, in the case of large mills, especially in intermediate ones.

**Fig. 3—Hydraulic drives on the top roll.**
Application to drive each of the rolls separately
In this option, each of the rolls is driven separately by one or two hydraulic motors (Figure 4).

This is both the most complete and the most efficient solution and optimises the mill’s extraction process, as well as the distribution of loads within the mill (Munoz and Lewinski, 1996), thus ensuring optimum energy use.

This solution is especially recommended in the case of number one mill, where extraction can reach more than 80% and the last mill, where moisture content in bagasse can be lowered by reducing the speed of the discharge roll, thus reducing re-absorption. Through implementation of this option, the mill operator can obtain all the advantages to which reference is made in the Introduction.

Application to drive one or two bottom rolls—the Assist Drive
The assist drive involves driving the feed and/or discharge rolls by means of individual motors installed directly on the shafts of one or two bottom rolls. The top roll is driven by the existing transmission and the crowns between the top roll and the separately driven bottom roll are eliminated. It is this option that will be examined in detail in this paper.

Assist drive

History
The idea of an assist drive, in the author’s experience, has its origin in the San Jose de Abajo Sugar Mill, in Mexico. In this sugar factory, mills were driven by mechanical transmissions powered by turbines. Mills 1 and 2 had a common transmission, as did mills 3, 4 and 5. In order to increase the working life of the transmission for mills 3, 4 and 5 and to reduce loads thereby transmitted, a decision was made in 1993 to separate mill 5 from the common transmission and to drive it independently.

Due to space limitations, it was decided to use an electro-hydraulic drive, locating the hydraulic motors and planetary transmissions on each of the rolls. This arrangement allowed for measurement of the torque generated by each of the rolls, as well as for finding the optimum mill operation conditions, such as energy consumption, extraction, bagasse moisture (Munoz and Lewinski, 1996).

Due to some technical problems resulting from the hydraulic motor planetary transmission placed on the top roll plus some other problems with the electric power available, the sugar mill technicians decided to reinstall the transmission crown gear in an open gear box to move the top roll, while keeping the hydraulic motors on the bottom rolls.

This arrangement called the author’s attention to the potential benefits of gradually modernising mill transmissions by adding power capacity to a conventional transmission by separately driving the bottom rolls. The mill decided to install electro-hydraulic drives on the bottom rolls first for mills 2 and 4 in 1996 (Figure 5), on mills 1 and 3 the following year (1997), and finally, in 1998, mill 5 motors were replaced with electro-hydraulic drives (Figure 6).
The modification order may be understood by the desire of San Jose de Abajo to reduce the existing conventional transmission loads, as well as by the possibility of varying the resulting speed of the mechanically interconnected mills through the top rolls. For example, with the changes to mills 2 and 4, the speed of these mills may be varied slightly compared to mills 1 and 3 by changing the speed of the bottom rolls and thus improving flow continuity. A control system was designed to link the bottom roll drive with the conventional transmission. This arrangement was called the "assist drive".

San Jose de Abajo sugar mill was the first factory in the world to apply the assist drive at a commercial level and also the first one in the world with a complete tandem of five mills with this arrangement. In 2002, this sugar mill completely removed the mechanical transmission of mills 1 and 2, installing the hydraulic motors on the top rolls, converting these mill's drives into fully electro-hydraulic (individual drives). Finally in 2004, the conventional transmission drives for the top rolls of the remaining mills were also removed, in order to convert all the tandem transmissions into individual electro-hydraulic drives.

The idea applied in San Jose de Abajo was subsequently used to reduce the load of the existing conventional transmissions and to increase the tandem's milling capacity at La Union Sugar Mill in Guatemala. To achieve this, a single bottom roll drive was selected with the expectation that this would provide sufficient load reduction for the existing transmissions. The first year, electro-hydraulic drives were placed on the discharge rolls.
However, after a year's experience, they chose to move them to the feed roll, this time following the author's recommendations. During this first year, several good things could be noticed from the assist drive being placed on the discharge roll, such as high efficiency and reduced bagasse moisture content.

Unfortunately, it was found that the hydraulic motor's power consumption was too low (especially with the discharge roll relative speed being lower than the top one) and thus the objective of noticeably reducing the conventional transmission's power consumption was not achieved.

Instead, by placing the electro-hydraulic drive on the feed roll (cane roll drive), great advantages were achieved in protecting the conventional transmission, as well as in the milling process results.

La Union Sugar Mill was the first sugar factory worldwide to apply the cane roll drive and, by installing other drives in subsequent years, it became in 2002 the first sugar mill in the World to have a cane roll drive in all its mills.

Currently, the cane roll drive has become the most requested option in modernising sugar mills' milling sections. To the author's knowledge, there are currently 48 assist drives installed in 9 countries.

**Operation of the assist drive**

The Assist Drive consists of a high torque hydraulic motor placed directly on the mill's feed and/or discharge roll. Figure 7 illustrates the possible arrangements with the power unit, the piping and the control system.

![Fig. 7—Possible arrangements for the assist drives.](image)

The control system enables the mill to operate with a constant relationship between the surface speeds of the feed and top rolls. The mill operator can vary this relationship to suit current milling requirements.

Two speed sensors are used, one on the top roll or on one of the mechanical transmission shafts connected to the top roll, and the other on the hydraulic motor. The top roll's sensor's signal is the master signal and the feed roll follows the top roll speed in accordance to the operator-defined relationship.

Usually, feed roll peripheral speeds are higher than top roll speeds. The control system also allows automatic reduction of the feed roll's speed, in the event of system overloading, thus protecting both the drive itself, and the mill.

**Assist drive advantages**

There are both quantitative and qualitative advantages from the use of the Assist Drive concept.

**Qualitative advantages**

Qualitative advantages may be summarised as follows.

*Increase in installed power*

The cane roll drive adds power to the conventional transmission, which will just drive the top roll and the discharge roll, interconnected by the crown gears. The increase in the installed power will be directly related to the cane roll drive electric motor power.
Reduction in conventional transmission loads

Separately driving the feed roll reduces the loads conveyed by the mechanical transmission, which is now only responsible for driving the top roll and the discharge roll.

Increasing the feed roll speed relative to the remaining rolls further reduces the power transmitted through the conventional transmission, because the feed roll tends to push the top roll and the discharge roll by means of the bagasse blanket between the rolls.

Increased milling capacity

The increased total installed power increases the milling capacity. However the largest increase in capacity is due to the feed roll’s higher speed in relation to the remaining rolls, which provides better mill feeding.

Increased extraction

The higher feed roll speed relative to the remaining rolls ensures better mill feeding and allows a higher percentage of imbibition, thus ensuring a larger extraction.

Less pol in bagasse

This is directly related to higher extraction and lower moisture content in bagasse.

Bagasse moisture content

The reduction in bagasse moisture is a result of a higher feed roll speed compared to the remaining rolls. First, a larger extraction is ensured. Secondly, it is possible to use crown gears between the top and discharge rolls, thus reducing the latter’s speed.

With the lower speed of the discharge roll, there is a reduction in the effect of bagasse juice re-absorption, and due to the higher speed of the feed roll, this does not affect the milling capacity.

Reduced wear of the feed roll surface

A reduced wear of the feed roll surface results from the better feeding of the mill, given the feed roll’s higher speed. Thus, bagasse slipping against the feed roll is reduced which results in a reduction in surface wear.

The ability to gradually modernise mill transmissions

Installing a cane roll Assist Drive allows for the gradual modernisation of the existing transmissions. In particular, the installation reduces the loads conveyed through the existing drives and increases their working life.

When the condition of the conventional transmission requires a larger investment, the mill’s transmission may be converted into an hydraulic drive, either powering each roll separately (San Jose de Abajo is an example) or by mechanically interconnecting the top roll and discharge rolls and driving the top roll with one or two hydraulic motors.

Furthermore, in the event of new or used mills equipped with a top roll drive, their milling capacity can be increased by additionally installing a cane roll drive as was achieved, for example, in Monte Rosa, Nicaragua.

Quantitative advantages

The extent of the quantitative advantages will depend upon diverse factors such as cane preparation, number of mills, mill sizes and mill settings, imbibition, the shape of the roll’s surface, etc, which are not normally reported by users.

For this reason, numerical results can be subject to many speculations. In order to avoid this, the author will limit himself to comment on the results reported by some of the users in their formal technical presentations.

Cifuentes (2002) reports the results from La Union Sugar mills. In this sugar mill, the cane roll Assist Drives were installed on all six mills of the tandem.

The roll length was 1.98 m (6.5 feet). Figure 8 presents the tandem with the feed roll drives installed.
The figure also provided information about power consumption in the cane roll drives in comparison with the total power consumption. Data were taken from the screen of a monitor connected to the sugar mill control system. From Figure 8, one can see that the feed roll’s power consumption can be between 30% and 40% of the total power driving each mill, depending on the relative speed of the feed roll in relation to the top one. This means that we can reduce the power transmitted by the conventional drive in the same proportion or we can add between 42 to 66% of extra power to the existing conventional drive.

La Union started using the cane roll drives in 1998, first locating the hydraulic motors on mills 1, 3 and 6. In 1999, they were added to mill 5, followed in 2001 by mill 2 and finally, in 2002, on mill No. 4. The order followed in installing the cane roll drives was determined, first, by the importance of the mill in the tandem (first and last mills) and then, by the physical condition of the remaining conventional transmissions. The main innovations, besides the application of the cane roll drives, were, at the same time, the installation of a Lotus top roll on mills 1 and 2 and the use of the crowns with different numbers of teeth between the top roll and the discharge roll of mills 5 and 6, in order to reduce the surface speed of the discharge roll relative to the top roll.

Cifuentes (2002) reports that the use of cane roll drives provided an increase in milling capacity. The cane roll drive has greatly reduced the wear on the mill rolls which, in earlier years, was of 12 mm (0.5 inches) or more per year. The feeding of the mill, with the feed roll rotating at a higher speed than the top roll, resulted in correct floatation of the mill, thus permitting higher extraction. Increasing the feed roll angular speed by 5%, relative to the top roll, produces an increment of 3% in the milling capacity.

Cifuentes also reports very important advantages in changing the speed ratio of the differential crowns between the top and discharge rolls. It would not have been possible to operate correctly the mill when changing this speed ratio without the use of the cane roll drives. The ratio was such that the speed of the feed roll was higher than the top roll speed. These advantages are:
1. Power consumption in mills 5 and 6 was reduced by 10–12%. 
2. Imbibition water could be reduced to 380 Lpm or less, with the same pol in bagasse as a result.

Numerical results in the mill performance are:

1. Milling capacity increased from 9350 to 10 900 tonnes per day (10 300 to 12 000 short tons per day) (see Figure 9)
2. Reduced extraction increased from 94.80% to 96.84% (Figure 10)
3. Pol in bagasse reduced from 2.45% to 1.66% (Figure 11)
Gonzalez (2002) reports the results obtained in Taboga Sugar Mill in Costa Rica. The tandem consists of 5 mills of 1.98 m (6.5 feet) roll length. During the 2000–2001 season, cane roll drives were installed on mills 1 and 5 and during the 2003–2004 season, an additional motor was installed on mill No. 4. Again, the installation order started by the first and the last mills, and ended with the mill having the weakest mechanical transmission.

Results are shown in Table 1 and again we can observe important improvements in mill performance. Results from 2000–2001 to 2002–2003 are related to the incorporation of the cane roll drives, as well as to the change in the roll surface shape and the installation of juice drainage devices.

However, the last season’s results must be primarily attributed to the installation of the additional cane roll drive. The user also found that, considering the maximum power consumption by the hydraulic motor and the highest extraction level, the optimum feed roll speed is 15% higher than that of the top roll.

The high power consumption of the hydraulic motor is a very important parameter, as the assist drives are mainly installed to reduce the load in mechanical conventional transmissions.

Relevant results are also available from El Potrero sugar mill in Mexico (Anon., 2003, 2004). Motors were installed here on the feed roll of the first and sixth (last) mills of the tandem of 2.14 m (7 feet) rolls length.

The main purpose of installing these motors was to increase the milling capacity of tandem B, in order to achieve a milling throughput equal or higher than the one achieved with the two original tandems A and B combined, thus permitting the removal of tandem A from the operation.
Another objective here was to improve the mill tandem performance. Data reported were as follows:

1. The medium milling capacity of tandem B increased from 389 tonnes cane per hour for the 2002–2003 season to 483 tonnes per hour for the 2003–2004 season. The maximum daily milling capacity of tandem B when equipped with cane roll drives was of 511 tonnes per hour.

2. Pol in bagasse was reduced from 2.35 to 2.21%

3. Reduced extraction (12.5% of fibre) increased from 95.190 to 95.692% with a maximum value during the 2003–2004 of 95.939%

4. Moisture content in bagasse was reduced from 52.40% to 51.25%

The factory is now milling, with one tandem, the amount of cane that would previously be milled with two tandems and yet the operation results are better than before. The main economic advantage here was to fully eliminate the whole of one tandem’s maintenance costs.

Conclusions

The use of electro-hydraulic assist drives allows for gradual modernisation of conventional mill transmissions. The possibility of increasing the power transmitted to the existing mills makes it possible to continue using the conventional transmissions without the need to reinforce them. The incorporation of additional power into the mill through the use of electro-hydraulic drives is also a more economical option than that of modifying the conventional transmissions. The application of the assist drive on the feed roll, called the cane roll drive, is now the most common way to modernise the sugar mill transmission, having a great world-wide acceptance. By this solution, additional power is introduced, the conventional drive loads are reduced, milling capacity and extraction can be increased and moisture content and pol in bagasse can be reduced. The numerical advantages will of course depend on many factors, such as cane preparation, number of mills, mill sizes and mill settings, imbibition etc, but the electro-hydraulic assist drive is definitely an excellent tool to modernise the milling section and to improve mill performance.

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ENTRAÎNEMENT ELECTRO-HYDRAULIQUE DES MOULINS
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Résumé
LA MODERNISATION de l’entraînement des moulins se fait souvent par l’application de systèmes électro-hydrauliques. Ce papier décrit ces systèmes, leurs origines, opérations, et leurs avantages et désavantages. Des résultats sont aussi donnés, bases sur l’opérations de ces systèmes aux sucreries de La Union Sugar Mill au Guatemala, de Taboga Sugar Mill au Costa Rica, et de El Potrero au Mexique ; l’auteur présente aussi ses expériences personnelles qui comprennent la première installation dans le monde. Les systèmes électro-hydrauliques permettent une modernisation graduelle de l’entraînement des moulins ; on peut alors augmenter la puissance et se servir des transmissions conventionnelles, sans renforcements. L’augmentation de la puissance aux moulins grâce aux systèmes électro-hydrauliques est aussi plus économique quand on la compare à la modification des transmissions conventionnelles. On a remarque une augmentation de la capacité aux moulins avec les systèmes électro-hydrauliques et l’extraction est améliorée ; le pol et l’humidité de la bagasse sont aussi réduits.

ACCIONAMIENTOS ELECTRO-HIDRÁULICOS ASISTIDOS PARA LOS MOLINOS AZUCAREROS
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Resumen
LA APLICACIÓN del accionamiento electro-hidráulico asistido a una maza cafetera, también llamado accionamiento asistido de la maza cafetera es ahora la manera más frecuente de modernizar las transmisiones de los molinos azucareros. Este documento describe los accionamientos electro-hidráulicos asistidos, su historia, operación, ventajas y resultados cualitativos y cuantitativos, basándose en información proporcionada por algunos usuarios, tales como el Ingenio La Unión en Guatemala, el Ingenio Taboga en Costa Rica, y El Potrero en México, así como en la experiencia personal del autor, desde la primera instalación en el mundo. El uso de los accionamientos electro-hidráulicos asistidos permite una modernización gradual de las transmisiones convencionales de los molinos. La posibilidad de incrementar la potencia transmitida a los molinos existentes hace posible continuar usando las transmisiones convencionales sin necesidad de reforzarlas. La incorporación de potencia adicional en el molino a través del uso de los accionamientos electro-hidráulicos es, además, una opción más económica que la de modificar las transmisiones convencionales. Todos los usuarios reportan un incremento en la capacidad de molienda, mayores porcentajes de extracción y una reducción en el contenido de humedad y pol en el bagazo.