Trouble shooting of mill operation by analysing the torque distribution between the rollers

Juliusz Lewinski¹, Paulo Grassmann², Mattias Fredriksson¹ and Tomas Kallin¹

¹Bosch Rexroth, Sweden; jlewin@prodigy.net.mx
²Bosch Rexroth, Brazil

Abstract Individual electrohydraulic drives allow constant measuring of the torque in each roller during milling operations. The automation of each mill operation and of the whole tandem allows working with the optimum torque in each mill, giving the maximum extraction. During optimum four-roller mill operation, the top roller takes the same portion of the torque related to the inferior rollers and additionally the input torque, if the fourth roller is moved by the top roller. The torques in each roller should be kept uniform but, in case of any mechanical problems inside the mill, the total torque or the torque in the individual roller will vary, giving information that something has to be corrected. This paper presents the analysis of the milling operation in four-roller mills in Brazil, Mexico, Belize and the USA, where the torque in each roller of the mill was measured. The rollers of the mills were driven individually by electrohydraulic drives, thus allowing for easy continuous measurements of the torque and speed in each mill. The fourth roller was driven by the top roller, except in the USA, where the fourth roller was equipped with an additional individual drive. Analysis of the torque distribution in each roller allowed for detection of various mechanical problems inside the mill, including the wear of roller surfaces and also determining the torque in the fourth roller, which was found not to be higher than 5% of the total mill torque. The possibility of continuous torque measurement in each roller was found to be an excellent mill operation predictive maintenance and troubleshooting tool.

Key words Hydraulic, mill, drive, independent, torque, speed

INTRODUCTION

The use of individual drives to operate sugar mills gives an opportunity to determine the torque and power consumption in each roller. In the case of four-roll mills, the fourth roller is driven mainly by the top roller through pinions. In some cases the fourth roller is moved from the cane roller through a chain transmission, but, in the case of individual drives, where we have the opportunity to change the speed of the cane roller in relation to the top roller, the use of chain transmission to move the fourth roller is not recommended. In some sugar mills, the fourth roller is moved separately by an individual drive and, in this case, there is the possibility to measure the torque consumed by the fourth roller.

Kent and McKenzie (2001) and Lewinski et al. (2013), in analysing and measuring torque distribution, reached the conclusion that in a three-roll mill the top roller consumes the same portion of the torque as that consumed in the cane and bagasse rollers together and that the torque in the top roller is 50% of the total torque. There are some reports about the torque measurements in four-roll mills using electrohydraulic drives and it is concluded that in the four-roll mill the top-roller torque oscillates between 50 and 55% of the total torque (Lewinski et al. 2013). The possibility of continuous measurement of the torque in each roller and the analysis of the torque distribution amongst the rollers allows the determination of the torque in the fourth roller and the potential to detect problems inside the mill, such as problems with the adjustment of the trash plate, adjustment or failure in scrapers, wear of the roller surface, incorrect mill settings and also incorrect configuration and use of controls when the mill operation is automated.

FOURTH-ROLLER TORQUE

The common question is still how much torque is generated in the fourth roller during stable mill operation and if it is really necessary to drive it separately, considering power consumption.

Following the papers mentioned above, in four-roll mills, when the fourth roll is moved by the top roll, the top-roll torque equals the sum of the torques in the inferior rollers plus half of the intake torque between the top roll and the fourth roller, giving the following formula:
The best results from the mills are obtained when mills are operated with optimum torque, as stable as possible. This can be achieved by automating the operation of the mills using variable-speed drives. The electrohydraulic drive is a very good option, as the moment of inertia of direct electrohydraulic drives is 100 to 1000 times lower than the moment of inertia of hydraulic drives.

TORQUES IN FOUR-ROLL MILL ROLLERS AND THEIR DISTRIBUTION

From Tables 1 and 2 we conclude that the torque in the fourth roller during correct mill operation (torque stable in all the rolls) is less than 5% of the total torque, which means that the maximum inlet torque is not higher than 10% of the total torque in the mill. This means that when the fourth roller is moved by the top roller, the torque in the top roller is at a maximum 10% higher than the sum of torques in the inferior rollers. It can be concluded that the individual drives can be selected for the same capacity (two drives for the top roll and one for each inferior rollers) and it is not really necessary to drive the fourth roller individually. Discrepancies in some results arise from problems inside the mill, incorrect mill settings and control configuration, which will be discussed below.
other high torque variable speed drives (individual drives, top-roll drives). The first mill regularly works with constant speed and the optimum torque is maintained by controlling the chute level in an optimum range. It is done by changing the speed of cane feeding to the first mill, which may be either manually or automatically. The other mills are set for the speeds corresponding to milling capacity and the corresponding settings, and their speed is manually or automatically changed to maintain the chute level within the defined optimum ranges. During the operation of the mill tandem, the operator can change the speed setting of each mill, when it is necessary to lower milling capacity due to, for example, high level of the juice in the tank. When this is done manually, the operator can monitor the chute level on the control desk, as well as pressures in the hydraulic motors and, thus, decide what set speed should be adjusted for each mill.

The automation of mill operation can also be done using speed-pressure control by maintaining the pressure in the hydraulic motors as constant as possible, which is very useful when mills are not equipped with chute level sensors. Full automation is achieved when the set speed of the mills and the speed of the intermediate carriers change automatically due to a change in milling capacity as a result, for example, of high level of the juice in the tank. The first mill will still work at constant speed and the feeding to the mill is automated by controlling the chute level. The mill operator can monitor on the control-desk display the pressures and speeds of hydraulic motors installed on each roller and, thus, determine if the work of the mills is stable and if all the rollers are participating in mill operation in the optimum way. The pressures and speeds of each hydraulic motor can be stored in the local memory of the control desk or in an external memory and then analysed, presenting the graphics of torques. The graphics of torque distributions provide immediate information that something is not correct in the mill operation. When the mill works correctly, the top-roller torque is the sum of the torques of the inferior rollers plus the input torque between the top and the fourth roller and as mentioned before, the top-roller torque is always 50% of the total torque in three-roll mills and no more than 55% in four-roll mills.

When the work of the mills is fully automated, then the variation of the pressures and speeds is very small, as in Figure 1 and 2, where pressures in the hydraulic drives of the rollers and torque distribution are presented for mill 1 and 5.

**Fig. 1.** Stable operation of mill 1: (a, left) pressures in the rollers’ hydraulic drives; (b, right) torque distribution.

**Fig. 2.** Stable operation of mill 5: (a, left) pressures in the rollers’ hydraulic drives; (b, right) torque distribution.
When the torque in the mill is not stable but the pressures in the rollers are changing in the same way, it means that all the rollers are still working with minimum slippage (Fig. 3) but the average torque is very low and the juice extraction is strongly affected. Pressure variation provides information about incorrect configuration of controls or failures of the sensors, mainly related to chute level. Figure 3a shows the pressures in the rollers’ hydraulic drives of the first mill in a sugar factory where the rollers seem to work without slippage but the operation of the mill is very unstable and the speed of the top roller is varying. The unstable operation of the mill is also reflected in the torque distribution shown on Figure 3b.

**Fig. 3.** Incorrect operation of mill 1: (a, left) pressures in the rollers’ hydraulic drives of the first mill; (b, right) torque distribution.

Figure 4a shows pressures on the hydraulic drives in mill 6 of the same tandem, where again pressures are not stable but the torque distribution is very stable, which means that the slippage of the rollers is really quite small and this can be seen in Figure 4b. On this figure it can also be observed that the mill operator adjusted the setting for the bagasse roller very tight, looking for the lowest moisture contents in the bagasse. In this case, the total torque is increasing and the risk of slippage is high, but Figure 4b shows that the torque distribution is rather uniform. Variation of pressures is the result of the use of the speed pressure control that is here not correctly configured. Mill 6 has no chute-level sensors.

**Fig. 4.** Unstable operation of mill 6: (a, left) pressures in the rollers’ hydraulic drives of mill 6; (b, right) torque distribution.

When pressures are not changing in a similar way (one of the pressures is lower than expected and without changes), it shows that the corresponding roller has a slippage and is not working properly. Other rollers are loaded in excess and the total torque is increasing due to losses provoked by the slippage (Fig. 5). The operator can confirm the slippage of the roller by trying to manually increase the speed ratio between the rollers. If the speed ratio between the inferior rollers and the top roller is increasing, the torque in the inferior roller should increase. If this does not occur, then the inferior roller is
slipping. This is quite common for the bagasse roller, where application of welding is more difficult. Roller slippage is generally the result of roller surface wear or of incorrect adjustment of the corresponding scraper, but if it happens suddenly, it shows that the scraper has a failure and the grooves will be immediately filled by bagasse. Figure 5a shows the graphs where the bagasse roller and top roller are slipping and Figure 5b shows torque distribution for this mill, which seems rather stable, but the main job is done by the top and the cane roller.

![Image](image.png)

**Fig. 5.** Slippage of the bagasse and top roller: (a, left) pressures in the rollers’ hydraulic drives of mill 5; (b, right) torque distribution.

Figure 6 shows how the problem in the top roller of a sugar mill was detected and corrected. The top-roller drive pressure was rather low in the first hours. The operator first stopped the mill to find out the cause for the low pressure in the top roller and found that the top-roller’s surface was full of bagasse. At about 14:00 hours the operator started to adjust the top roller scraper and the pressure in the top-roller drive increased, showing that the top roller was now properly cleaned by the scraper.

![Image](image.png)

**Fig. 6.** Work of the top roller before and after the scraper adjustment at about 14:00 hours.

Another problem that can be detected in the mill, especially after maintenance, is the incorrect adjustment of the trash plate or the scrapers. If operation conditions are the same and cane quality is the same but the torque in one of the rollers is much higher than before, then the trash plate or the scrapers are pushing the corresponding rollers excessively.
Furthermore, when the trashplate is adjusted too close to the top roller, it generates higher torque and the operator can see higher flotation of the top roller.

In mill 2, where the wet bagasse from the juice strainer is returned by the corresponding conveyor, there is a possibility of additional slippage of the rollers (mainly cane roller) due to higher moisture content of the fed bagasse and it can be detected by observing the cyclical oscillation of pressures (Fig. 7a) and torque ratios (Fig. 7b).

**Fig. 7.** Slippage of the rollers in mill 2: (a, left) pressures in the rollers’ hydraulic drives of mill 2; (b, right) torque distribution.

The wrong configuration of controls also affects the work of the mill and it can be immediately detected by analysing torque distribution (Figs 8a and 8b).

**Fig. 8.** Unstable operation of the mill due to wrong configuration of controls: (a, left) pressures in the rollers’ hydraulic drives of mill 4; (b, right) torque distribution.

Figure 9 shows the speed ratio between the inferior rollers and the top roller, for the case of Figure 8. The ratio is changing automatically due to a wrong configuration of controls. The interesting observation is that the total torque is rather stable in this mill operated in an unstable way (Fig. 10).
The wear of welding on the rollers can be easily detected by a gradual reduction of the operating pressure that reflects torque reduction on individual electrohydraulic driven rollers. In Usina Ferrari in Brazil, this control is done on a regular basis to determine the exact time to re-weld the rollers. On one hand, the mill avoids reduction of production due to slippage on the rollers, and, on the other hand, they avoid excessive welding.

A long-term follow-up of pressure relations between the rollers also helps to make better decisions regarding when a roller needs to be replaced or if diameter reduction can still be compensated by an increase in speed.

CONCLUSIONS

Electrohydraulic individual drives allow constant measuring of the torque in each roller during milling operation. The possibility of continuous measurement of the torque in each roller and the analysis of the torque distribution among the rollers allows to determine the torque in the fourth roller and the detection of problems inside the mill, such as problems with adjustment of the trash plate, adjustment or failure in scrapers, wear of the roller surface, incorrect mill settings and also incorrect configuration and use of controls when mill operation is automated. The continuous measurement of torque in each roller was found to be an excellent mill operation predictive maintenance and troubleshooting tool.

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REFERENCES


Résolution des problèmes d’exploitation du broyeur en analysant la répartition du couple entre les rouleaux

Résumé. Les entraînements électro hydrauliques individuels permettent d’obtenir une mesure constante de couple dans chaque rouleau pendant les opérations de broyage. L’automatisation du fonctionnement de chaque broyeur et du tandem complet permet de travailler avec un couple optimal dans chaque broyeur, ce qui donne une extraction maximale. Pendant le fonctionnement optimal du broyeur à quatre rouleaux, le rouleau supérieur prend la même partie de couple lié aux rouleaux inférieurs et aussi le couple d’entrée, si le quatrième rouleau est déplacé par le rouleau supérieur. Les couples de chaque rouleau doit rester uniformes, mais en cas de problèmes mécaniques à l’intérieur du broyeur, le couple total ou le couple sur les rouleaux individuels peut varier, donnant des informations que quelque chose doit être corrigé. Dans cet article on présente l’analyse de l’exploitation de broyage a quatre rouleaux au Brésil, au Mexique, au Belize et aux États-Unis, où des mesures de couple ont été effectuées sur chaque rouleau du broyeur. Les rouleaux des broyeurs ont été opérés individuellement par les unités électro hydrauliques, permettant des mesures en continu en couple et la vitesse de chaque rouleau. Le quatrième a été tiré par le rouleau supérieur, sauf aux États-Unis, où le quatrième rouleau a été équipé d’une seule unité supplémentaire. L’analyse de la répartition du couple dans chaque rouleau a permis de détecter divers problèmes mécaniques à l’intérieur du broyeur, dont l'usure de la surface des rouleaux et on a déterminé aussi le couple dans le quatrième rouleau, qui a été jugée non supérieure à 5% du couple total du broyeur. On a constaté que la possibilité de mesure en continu du couple dans chaque rouleau peut être un excellent outil pour la maintenance prédictive et la résolution des problèmes d'exploitation du broyeur.

Mots-clés: Hydraulique, broyeur, entraînement, indépendant, couple, vitesse

Solución de problemas de operación del molino mediante el análisis de la distribución del torque entre las mazas

Resumen. Los accionamientos electrohidráulicos individuales permiten obtener una medida constante del torque en cada maza durante las operaciones de molienda. La automatización de la operación de cada molino y de todo el tándem permite trabajar con el torque óptimo en cada maz, dando la máxima extracción. Durante la óptima operación del molino de cuatro mazas, la maza superior toma la misma porción del torque relacionado a las mazas inferiores y, además, el torque de entrada, si la cuarta maza es movida por la maza superior. Los torques en cada maza deben mantenerse uniformes, pero en caso de cualquier problema mecánico en el interior del molino, el torque total o el torque en las mazas individuales pueden variar, dando información de que algo debe corregirse. En este trabajo se presenta el análisis de la operación de molienda en los molinos de cuatro mazas en Brasil, México, Belice y los EE.UU., donde se realizaron mediciones del torque en cada maza del molino. Las mazas de los molinos fueron accionadas individualmente por las unidades electrohidráulicas, permitiendo así mediciones continuas del torque y la velocidad de cada maza. La cuarta maza fue accionada por la maza superior, excepto en los EE.UU., donde la cuarta maza estaba equipada con una unidad individual adicional. El análisis de la distribución del torque en cada maza permitió la detección de diversos problemas mecánicos en el interior del molino, incluyendo el desgaste de las superficies de las mazas y también determinó el torque en la cuarta maza, que se encontró que no era mayor al 5% del torque total del molino. Se encontró que la posibilidad de medición continua del torque en cada maza puede ser una excelente herramienta de mantenimiento predictivo y resolución de problemas de operación del molino.

Palabras clave: Hidráulica, molino, unidad, independiente, par, velocidad