SUGAR MILL OPERATION WITH INDIVIDUAL DRIVES

By

JULIUSZ LEWINSKI[1], PAULO GRASSMANN[2] and TOMAS KALLIN[3]

[1]*Consultant:* jlewin@prodigy.net.mx
[2]*Hagglunds Drives, Brazil:* paulo.grassmann@br.hagglunds.com
[3]*Hagglunds Drives, Sweden:* tomas.kallin@se.hagglunds.com

KEYWORDS: Hydraulic, Mill, Drive, Independent, Torque, Speed.

Abstract

THE TERM 'Individual drives' refers to the process of separately moving each roll of the mill with independent drives. This way of mill operation is rather new and knowledge regarding how to set and operate the mills with individual drives is very limited. This paper describes tests made with a complete tandem (four mills) driven by electro-hydraulic independent drives. The first mill was driven at a constant top roll speed, and the feeding was adjusted automatically to keep the chute level within the determined range. The rest of the mills were automatically changing speed, keeping the chute level of the corresponding mills within the pre-established range. Three scenarios were analysed in the first tests: speed ratio between side and top rolls varied to keep the same pressure in all hydraulic systems (torque distribution 50, 25, 25% between top, cane and bagasse rolls respectively), speed ratio to keep the same peripheral speed for each roll and rotational speed ratio equal to 1 as is often the case with conventional drives. For each scenario, the torque and power distribution were measured. The main conclusions found were that the total torque required doesn't depend on the speed of the mill for constant mill pressure and that the distribution of the torque in the four-roll mill can be 50, 25, 25 for higher speed of the cane roll and lower speed of the bagasse roll than the top roll speed. This scenario is best from a mechanical and operational point of view.

Introduction

The term 'Individual direct drives' refers to the separate propulsion of each mill roll by a drive placed directly on the shaft of each roll.

The first mill drive using this method was reported in Cuba (Abon, 1986) where the torque distribution between the rolls, depending on the relative speeds of the side rolls compared to the top roll, was presented.

This installation was the result of the collaboration of MINAZ (Ministry of Sugar) and the Hägglunds company, starting with the introduction of the first high torque hydraulic motors in Cuba in 1976.

For that first installation, the drive was formed by combining Hagglunds hydraulic motors with two-stage planetary gearboxes of the Thyssen company.

This concept gave rise to the 'Hydrodrive' of the Mannesmann Rexroth company, where high speed hydraulic motors and three-stage planetary gearboxes were combined.

A similar installation was analysed in Mexico 10 years later (Muñoz and Lewinski, 1996) and important research about the torque distribution in three-roll sugar mills was carried out in Australia (Kent and McKenzie, 2001).

In the 1980s, Hägglunds developed higher torque hydraulic motors, allowing mill rolls to be driven individually, and eliminating the need for planetary gearboxes.

At the same time, the German company Flender, well known manufacturer of gearboxes, presented a ‘Hydrex – Planurex’ system, combining a high torque hydraulic motor of their own manufacture and a one-stage planetary gearbox.

These high torque hydraulic motors, with and without planetary gearboxes, were very well received in the marketplace, due to the following advantages:

1. Partial or full elimination of conventional gears and crown gears.
2. Elimination of the tail bar.
3. Less space required.
4. Reduction of loads on roll shafts.
5. No foundation required.
6. Maximum torque over the full speed range; from zero to maximum speed.
7. Reversible movement.
8. Continuous speed variation in each roller.
9. Protection against overloading and almost immediate interruption of mill operation.
10. Simplifies automation of the milling process.
11. Measurement of the torque for each roller.
12. Easy maintenance.
13. Greatly reduced size and weight.
14. Power savings (high efficiency in transmission, use of electric power, load reduction in journal bearings).
15. Increased extraction (optimisation of the extraction process).

The main advantage is the independent variable speed of each roll, which allows for the optimisation of the mill’s operation from a mechanical (torque distribution) and operational point of view (extraction, pol in bagasse, moisture in bagasse) (Lewinski, 2005; Vivas *et al*., 1998)

A more recent alternative for fitting individual drives to sugarcane mills has been the use of planetary gearboxes engaged directly to or through the cardan shaft with AC electric and variable frequency motors, a well known solution in the sugarcane industry for driving cane conveyors.

Currently the following options are commercially available for mill operation on an individual basis.

1. Electro-hydraulic drive – high torque, low speed hydraulic motor
2. Electro- hydraulic – mechanical drive (high torque, low speed hydraulic motor connected to a one-stage planetary gearbox)
3. Electro – hydraulic – mechanical drive (medium speed hydraulic motor with a two-stage planetary gearbox)
4. Electro – hydraulic – mechanical drive (high speed hydraulic motor with a three-stage planetary gearbox)
5. Electro mechanical drive (planetary gearbox driven by an AC variable frequency electric motor.

At present, options 1 and 5 are the most common ones in the market.

Although 20 years experience has been gained operating mills with direct, individual drives, there is no published information on how to operate these mills (torque distribution, speed distribution, mill adjustments, etc.). This work aims to answer some of these questions.

Description of the testing methodology

Tests were conducted on a mill tandem driven by high torque electro-hydraulic drives, without planetary gearboxes.

Each mill was driven by four high torque hydraulic motors of the same size, directly placed on the mill's rolls (two motors on the top roll and one on each side roll) (Figure 1).

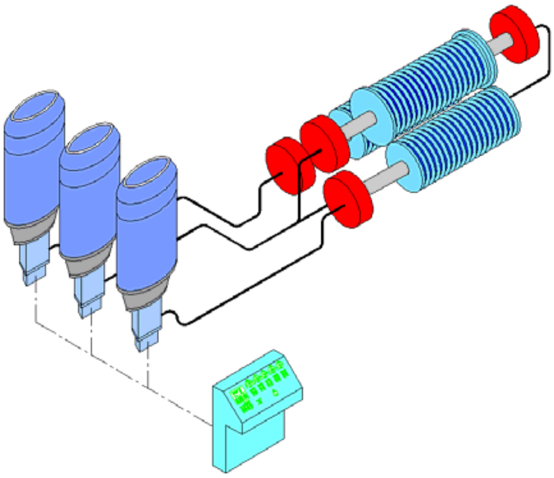

Fig. 1—Individual direct electro-hydraulic drive.

Each hydraulic motor was powered by an electric motor which drove a variable flow hydraulic pump, allowing for the operation of the motors at rated torque over the whole speed range. The flow was transmitted to the motors through piping, which allowed for great flexibility of positioning for the power units (electric motor, pump and accessories) in relation to the hydraulic motors. The tandem was made up of four mills and was located in the Santa Isabel sugar mill, in Brazil (Figure 2).

Fig. 2—Santa Isabel milling tandem with individual drives.

Mill 1 had a length of 2134 mm and the remaining mills were 1981 mm in length. The mills were set for a cane rate of 550 t/h and operated at constant first mill speed, usually 6 r/min. The tandem was automated (Figure 3).

The feed of mill 1 was controlled to maintain the level of the chute in the determined range and the other mills varied their speed automatically to maintain the level of their chute within the predetermined ranges. Measurements included the torque on each mill's shaft (continuous pressure measurement for each hydraulic system) and speed (sensors placed directly on the hydraulic motors).

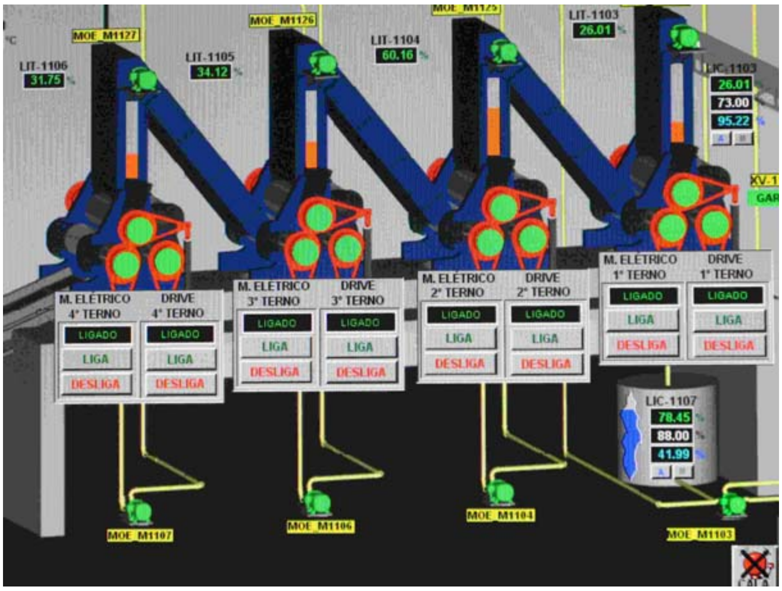

Fig. 3—Display of the control system in Santa Isabel.

Desired results were:

1. Torque distribution.
2. Speed distribution (ratio of speed of the side rolls in relation to the top roll).
3. Distribution of power on the mill's rolls.
4. Total power consumed by each mill.

In the first tests carried out in 2008 in Santa Isabel Sugar Mill, three different scenarios were analysed for the mill settings defined by the manufacturer.

1. Distribution of torque 50%, 25%, 25% between the top, cane and bagasse rolls respectively - providing optimal capacity performance of the hydraulic motors (equal pressure on all hydraulic systems of the mill). For this scenario, the speed ratios were experimentally determined).
2. Equal peripheral speeds for all mill rolls – a case considered by several researchers as optimal for mill operations.
3. Equal rotational speed for all mill rolls – as is often the case of mills with conventional transmissions equipped with pinions.

Further tests were carried out in 2009 in Santa Isabel for the purpose of measuring the torques and powers in all mills of the tandem. These tests were conducted for the first scenario of equal pressures in all hydraulic systems.

Results

Measurements were taken during two test periods, identified as Test 1 and Test 2. Within these periods, each of the three scenarios was used. The periods for the individual measurements are shown in Table 1.

Table 1—Test conditions for the 2008 measurements.

Test	State	Scenario	Mill 1 speed (r/min)
1	I	1	4
	II	1	5
	III	2	5
	IV	3	5
2	I	1	6
	II	1	5
	III	2	5
	IV	3	5
	V	1	5

As an example of the results, Figure 4 shows the results for mill 1 for Test 1 and Figure 5 shows the results for mill 4 for Test 2. In the legends for these two figures, ‘TR’ refers to top roll, ‘CR’ refers to cane roll and ‘BR refers to bagasse roll while ‘r.p.m.’ refers to speed and ‘Bar’ refers to hydraulic motor pressure.

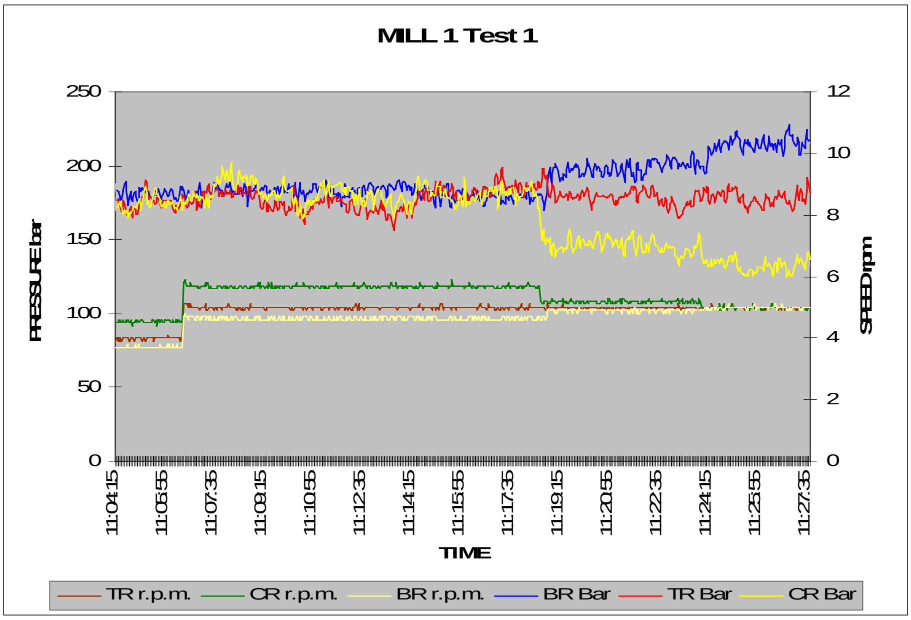

Fig. 4—Measurements for the mill 1 Test 1. State I: Time 11:04 – 11:06, State II – Time 11:06 – 11:18, State III – Time 11:18 – 11:24, State IV – 11:24 – 11.27.

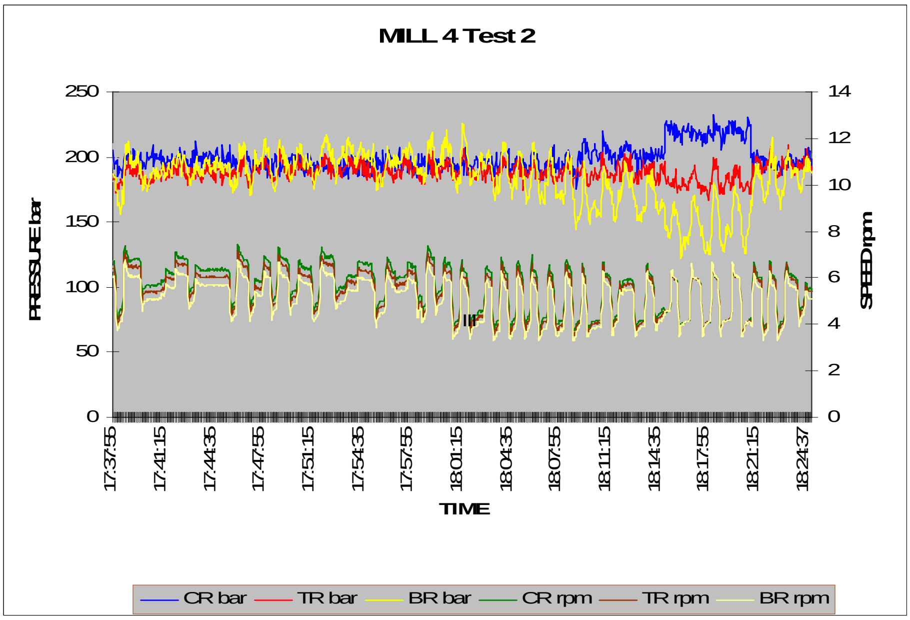

Fig. 5—Measurements for mill 4 test 2. State I – time 17:38 – 18:00, State II – time 18:00 – 18:08 State III – time 18:08 – 18:15 , State IV– time 18:15 – 18:20, State V – time 18:20 – 18:24.

Table 2 presents the mean results for each state for each mill. ‘SR’ in the title refers to speed ratio of the nominated roll to the top roll. Table 3 presents the mean power for each mill and each state with a mill 1 speed of 5 rpm.

Table 2—Mean results for the 2008 tests.

	State	Pressure			Speed			Torque				Power			
		TR BAR	CR BAR	BR BAR	TR R/min	SR CR	SR BR	Total Nm	TR %	CR %	BR %	Total kW	TR %	CR %	BR %
MILL 1	1	174	174	181	4.0	1.14	0.93	1499606	49%	25%	26%	636	49%	28%	24%
	11	178	181	182	5.0	1.14	0.93	1532374	49%	25%	25%	814	49%	28%	23%
TEST 1	111	179	146	197	5.0	1.04	0.98	1493417	51%	20%	28%	781	51%	21%	28%
	IV	178	133	214	5.0	1.00	1.00	1497009	51%	18%	31%	781	51%	18%	31%
MILL 1	II	188	184	172	6.0	1.15	0.95	1564145	51%	25%	24%	1006	50%	28%	22%
	II	186	172	176	5.0	1.15	0.95	1537882	52%	24%	24%	821	51%	27%	23%
TEST 2	IN	197	135	188	5.0	1.04	0.98	1529224	55%	19%	26%	800	55%	19%	26%
	IV	195	121	203	5.0	1.00	1.00	1521231	55%	17%	28%	793	55%	16%	29%
	V	187	180	184	5.0	1.15	0.95	1577250	51%	24%	25%	843	50%	27%	23%
MILL 2	II	195	194	190	6.7	1.03	0.97	1107455	50%	25%	24%	777	50%	26%	24%
	II	198	185	189	5.6	1.03	0.97	1101944	51%	24%	25%	643	51%	25%	24%
TEST 2	III	190	189	193	5.5	1.06	0.98	1090592	50%	25%	25%	635	49%	26%	25%
	IV	192	162	201	5.6	1.01	1.00	1067541	52%	21%	27%	630	52%	22%	27%
	V	197	186	193	5.7	1.03	0.98	1106938	51%	24%	25%	660	51%	25%	24%
MILL 3	II	198	203	192	6.0	1.03	0.95	1135501	50%	26%	24%	715	50%	27%	23%
	II	194	199	195	5.2	1.03	0.95	1120708	50%	25%	25%	615	50%	26%	24%
TEST 2	111	192	186	197	5.0	1.03	0.95	1097073	50%	24%	26%	572	50%	25%	25%
	IV	188	171	212	5.1	1.01	0.98	1084312	49%	22%	28%	584	50%	23%	28%
	V	194	194	202	5.2	1.02	0.97	1125784	49%	25%	26%	618	50%	25%	25%
Mill 4	II	189	194	196	5.8	1.05	0.94	1098780	49%	25%	26%	669	49%	27%	24%
	II	190	192	195	5.0	1.05	0.94	1095205	50%	25%	25%	570	50%	26%	24%
TEST 2	111	188	175	198	4.8	1.04	0.95	1069083	50%	23%	27%	539	50%	24%	25%
	IV	185	159	210	4.9	1.02	0.98	1052240	50%	21%	29%	546	50%	22%	28%
	V	189	170	206	5.1	1.02	0.97	1076250	50%	22%	28%	572	50%	23%	27%

Table 3—Mean power for the whole tandem.

R/min	State	Power kW					
		Mill 1	Mill 1	Mill 2	Mill 3	Mill 4	Total tandam
5.0	II	814	821	643	615	570	2649
5.0	III	781	800	635	572	539	2546
5.0	IV	781	793	630	584	546	2553
5.0	V		843	660	618	572	2693

Laboratory results for the day in which Test 1 and Test 2 were conducted were as follows: cane rate 572 t/h and extraction 95.65%.

The first scenario where the speed ratio was adjusted to keep the same pressure in all hydraulic systems was assessed to be the most suitable, taking into account the optimal use of the drives, as well as the distribution of speed. In this tandem, the cane roll always rotates at a higher speed helped by the better feed and the bagasse roll usually rotates at a lower speed. The torque on the top roll was generally constant, independent of the speed variations of the mill and the speed ratios and, as a result of the control scenario, was 50% of the total torque generated.

Table 4 presents results of measurements carried out in Santa Isabel in 2009. Both tests used scenario 1 with equal pressure in all hydraulic systems – torque distribution 50, 25, 25.

Figure 6 shows the mill 1 results for Test 2 and Figure 7 shows the mill 4 results for Test 2.

Table 4—Numerical mean results for the whole tandem in 2009.

Mill number	Test	Pressure			Speed			Torque				Power			
		TR Bar	CR Bar	BR Bar	TR r/min	F CR	F BR	Total Nm	TR %	CR %	BR %	Total Kw	tr %	CR %	BR %
1	1	156.2	164.5	165.9	6.5	1.04	0.92	1391719	49	26	26	910.0	49	27	24
	2	158.1	162.0	155.5	6.5	1.03	0.91	1370462	50	25	25	894.0	51	27	22
2	1	156	158	169	6.60	1.05	0.90	922561	49%	25%	26%	617	49%	26%	24%
	2	162	156	162	6.70	1.05	0.89	927151	50%	24%	25%	627	51%	26%	23%
3	1	156	162	169	6.20	0.99	0.82	896636	47%	26%	27%	541	49%	27%	24%
	2	153	161	155	6.30	0.98	0.80	895730	49%	26%	25%	543	52%	27%	21%
4	1	157	149	164	6.10	1.05	0.92	904055	50%	24%	26%	558	51%	25%	24%
	2	156	155	161	6.10	1.06	0.91	903403	50%	25%	26%	558	50%	26%	24%
Total tandem	1											2626			
	2											2622			

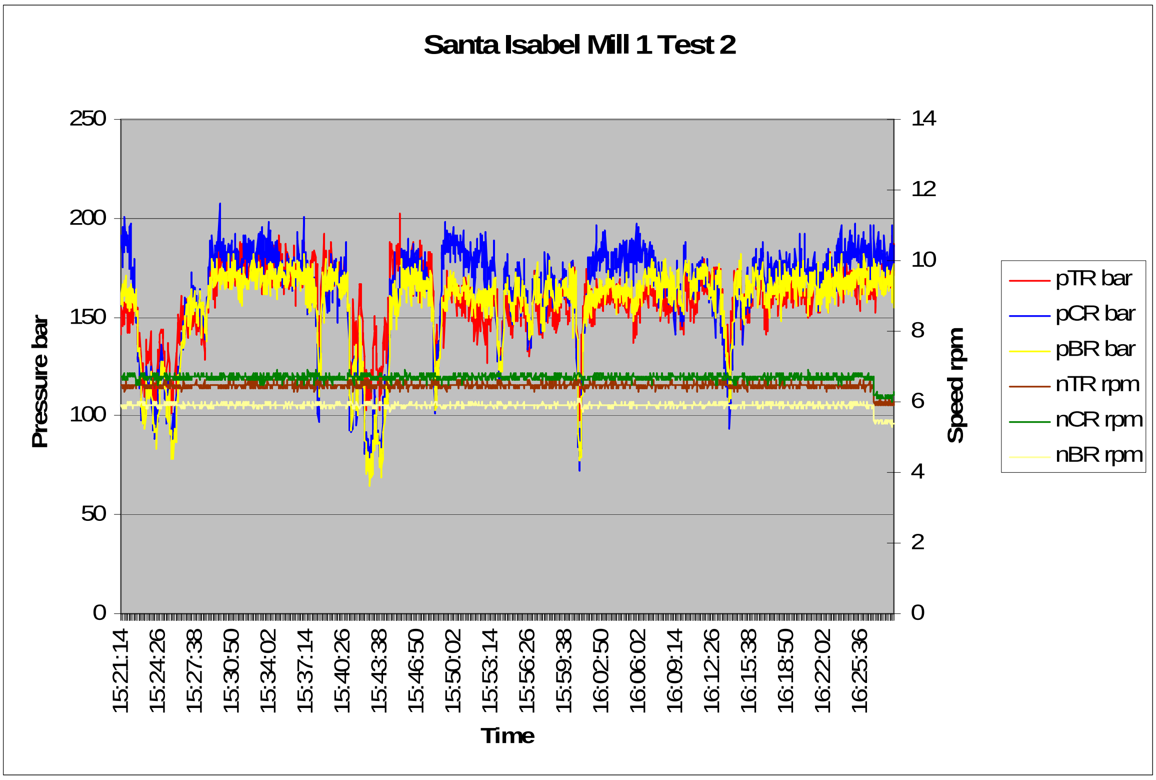

Fig. 6—Mill 1 Test 2 results from the 2009 tests.

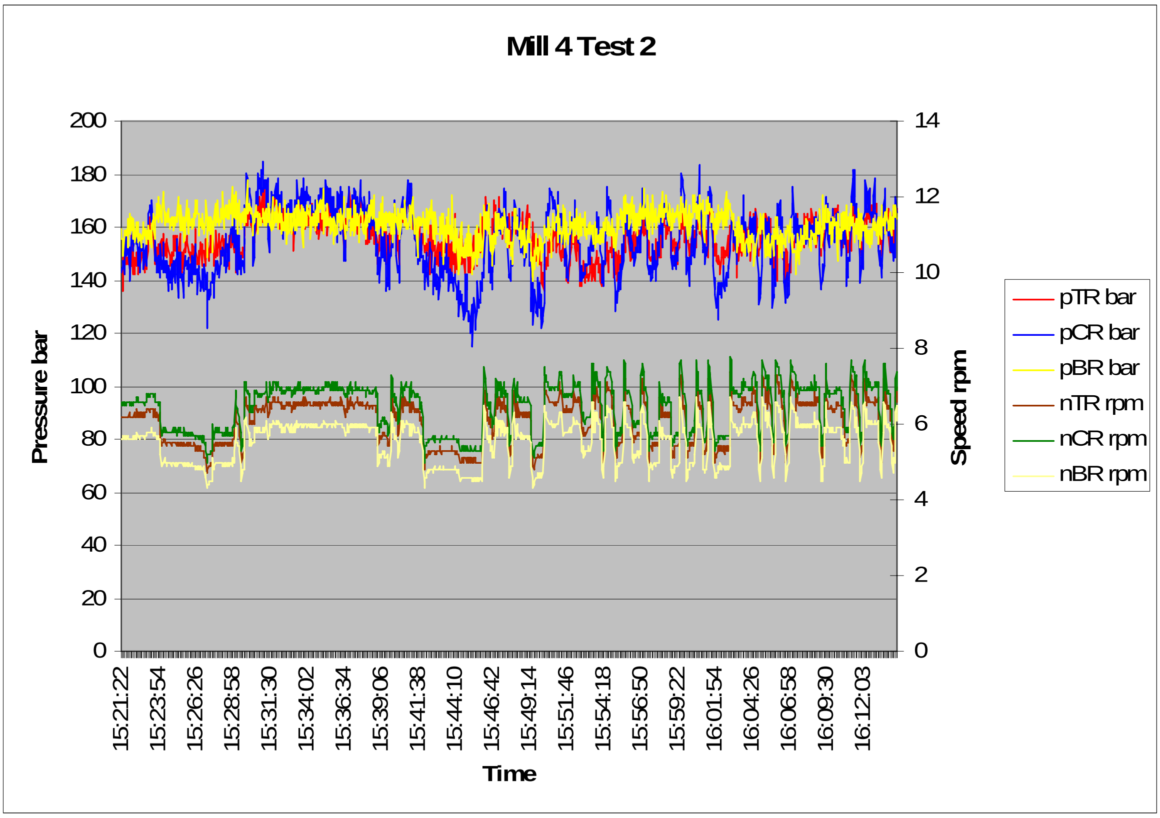

Fig. 7—Mill 4 Test 2 results from the 2009 tests.

The laboratory results demonstrated higher milling capacity (cane rate 591.3 t/h) and higher extraction (96.76%) in comparison with the 2008 results with very similar or even slightly lower total power consumed by the tandem. The extraction only from the Mill 1 was close to 84%. In comparison with 2008, all the rolls were machined reducing their diameter by 30 mm, the mill pressure was kept at the same level, and the settings of the mills were made very close to the values from the year 2008. The mill rotational speed was higher to maintain similar tangential speed of the rolls as in 2008 (Sato, 2009).

Conclusions

With the individual drives, mills can be operated at different speed distributions, giving the possibilities to drive the mill with the same tangential speed of the rolls, the same rotational speed as in conventional mills and changing the ratio between side and top rolls looking for the higher cane roll speed (for better feeding) and lower bagasse roll speed (for lower reabsorbtion).

This last option was achieved for similar mean pressures in all hydraulic motors, resulting in the same torque applied on the end of all the shafts. For this option all hydraulic drives can be operated at their maximum capacity, maximising the mill torque, avoiding the hydraulic system overloading, giving the same stresses on the end of all the shafts.

At Santa Isabel Sugar Mill, the use of the equal pressure control scenario helped to give better milling results than the previous year. The tandem of four mills is now achieving a cane rate close to 600 t/h and extraction of 97%, with extraction from mill 1 close to 84%. These better results were achieved with total mill power consumption about the same as in the previous year.

Acknowledgements

The authors would like to express their gratitude to the companies Hagglunds Sweden and Hagglunds Brazil for the interest in this research and the corresponding economical support. Thanks to Santa Isabel Sugar Mill people for their support and great cooperation in making possible this research. Thanks to Mr Mario Sato for the permission to use his settings in Santa Isabel Sugar as reference. Special thanks to Geoff Kent for his very valuable comments and observations and for great help in interpreting the results and preparation of the last version of this paper.

REFERENCIES

Abon, J.F. (1986). Utilisation of hydraulic motors for the individual drive of sugar-cane rollers. Their results after three sugar-cane crops. Proc. Int. Soc. Sugar Cane Technol. 19: 850–859.

Kent, G.A. and McKenzie, N.J. (2001). The distribution of torque in a three-roll mill. Proc. Int. Soc. Sugar Cane Technol., 24: 220–225.

Lewinski, J. (2005). Electro-hydraulic assist drives for sugar mills. ISJ, 107: 532–538.

Muñoz, G. and Lewinski, J. (1996). Analysis of the mechanical performance of a sugar cane mill. ISJ, 98: 574–578.

Sato, M. (2009). Projeto de Regulagem de Moenda da Inovatech Engenharia, reproduced with permission.

Vivas, A.L., Giron, J., Figueroa, F., Caicedo, G., Plata, A.M., Echeverri, L.F. and Gomez, A.L. (1998). Performance of a last mill with assist drive. Proc. Int. Soc. Sugar Cane Technol., 23: 194–201.

OPÉRATION DE MOULINS À SUCRE AVEC COMMANDE INDIVIDUELLE

Par

JULIUSZ LEWINSKI[1], PAULO GRASSMANN[2] et TOMAS KALLIN[3]

[1]*Consultant:* jlewin@prodigy.net.mx
[2]*Hagglunds Drives, Brazil:* paulo.grassmann@br.hagglunds.com
[3]*Hagglunds Drives, Sweden:* tomas.kallin@se.hagglunds.com

MOTS-CLEFS: Hydraulique, Moulin, Commande, Indépendant, Couple, Vitesse.

Résumé

LE TERME « commande individuelle » indique que chaque rouleau du moulin est conduit indépendamment. Ce mode de fonctionnement est nouveau et les connaissances le concernant sont très limitées. Ce document décrit les tests réalisés sur un tandem complet (quatre moulins) conduit par des moteurs indépendants electro-hydrauliques. Le premier moulin a été conduit à une vitesse constante pour le cylindre supérieur et l'alimentation a été ajustée automatiquement pour maintenir le niveau de la goulotte dans la plage déterminée. Le reste des moulins modifient leurs vitesses automatiquement pour maintenir le niveau des goulottes correspondantes dans les plages préétablies. Trois scénarios ont été analysés dans les premiers tests: le rapport des vitesses cylindres de côté et supérieur est varie pour maintenir la pression constante dans tous les systèmes hydrauliques (distribution du couple 50, 25, 25% entre les rouleaux supérieur, canne et bagasse respectivement), rapport de la vitesse sélectionne pour conserver la même vitesse périphérique pour chaque rouleau et le rapport de la vitesse de rotation égal à 1 comme c'est souvent le cas avec les conduites conventionnelles. Pour chaque scénario, le couple et la distribution de la puissance ont été mesurés. Les principales conclusions trouvées étaient que le couple total requis ne dépend pas de la vitesse du moulin a une pression constante et que la répartition du couple dans un moulin avec quatre cylindres peut être 50, 25, 25 pour une vitesse supérieure du cylindre canne et une vitesse inférieure pour le cylindre bagasse compare à la vitesse du cylindre supérieur. Ce scénario est le meilleur d'un point de vue mécanique et opérationnel.

OPERACIÓN DE MOLINOS DE CAÑA CON ACCIONAMIENTOS INDIVIDUALES

Por

JULIUSZ LEWINSKI[1], PAULO GRASSMANN[2] y TOMAS KALLIN[3]

[1] *Consultor:* jlewin@prodigy.net.mx
[2] *Hagglunds Drives, Brasil:* paulo.grassmann@br.hagglunds.com
[3] *Hagglunds Drives, Suecia:* tomas.kallin@se.hagglunds.com

PALABRAS CLAVE: Hidráulica, Molino, Accionamiento, Torque, Velocidad.

Resumen

EL TÉRMINO accionamiento individual se refiere al movimiento de cada maza de un Molino de caña con accionamientos independientes. Esta forma de operación es relativamente nueva y el conocimiento sobre cómo ajustar y operar estos molinos es limitado. Este trabajo describe las pruebas efectuadas con un tándem completo (cuatro molinos) movido por accionamientos electro-hidráulicos independientes. El primer molino fue accionado a velocidad constante de la maza superior y la alimentación se reguló automáticamente para mantener la altura de la caña preparada en la tolva del molino dentro del rango determinado. El resto de los molinos operaron con velocidad variable para mantener la altura de bagazo en la tolva de cada Molino dentro del rango especificado. Tres escenarios fueron analizados en las primeras pruebas: la razón de velocidades entre maza superior y las inferiores se varió para mantener la misma presión en todos los sistemas hidráulicos (distribución de torque de 50, 25, 25% entre mazas superior, cañera y bagacera respectivamente), la razón de velocidades para mantener la misma velocidad periférica para cada maza y razón de velocidades igual a 1 como es a menudo el caso en accionamientos convencionales. Para cada escenario, se midieron el torque y la distribución de potencia y las principales conclusiones encontradas fueron que el torque total requerido no depende de la velocidad del molino para presión de molienda constante y que la distribución porcentual del torque en un molino de cuatro mazas puede ser 50, 25, 25 para relaciones de velocidad entre maza cañera y superior mayores que 1 y entre maza bagacera y superior menor que 1. Este escenario es el mejor desde un punto de vista mecánico y operacional.