The role of the JPMA mill coupling in energy conservation

MS Sundaram, DS Nikam and SS Ghadge

J P Mukherji & Associates Pvt Ltd, Pune, Maharashtra, India; mssundaram@jpma.org.in

Abstract A conventional tail bar coupling can cause serious complications to the mill drive components. Misalignment between the mill and gearing, shaft cracks, thrust load, sluggish floating of the top roller, rounding of the shaft square ends, damage to the crown pinion, and damage to the last motion gear bearing due to excessive thrust are common problems associated with the tail bar coupling. The JPMA mill coupling is an alternative to the tail bar coupling that eliminates damage caused by misalignment between mill and gearing and reduces other problems caused by the tail bar coupling. This paper presents a study of the impact of the JPMA coupling during the 2014-15 crushing season. The primary objective of the study was to assess the effect on power consumption by replacing a tail bar coupling with the JPMA mill coupling. Data on axial thrust, power consumption, top roller lift, fibre % cane, primary extraction, pol % cane, and bagasse moisture were collected and analyzed. Strain gauges were used to measure axial thrust and torque. The measurements were carried out for 4 days and the comparative data recorded before and after the installation of the JPMA mill coupling are discussed and elaborated in this paper. Our study produced the following conclusions: average reduction in power consumption of 8% with peak reduction of 12%; reduction of axial thrust, reduction in torque demand and increased transmission efficiency; improved mill performance.

Key words JPMA mill coupling, tail bar coupling, energy conservation, axial thrust, torque, mill performance

INTRODUCTION

The sugar industry has been striving for energy conservation for improved environmental outcomes and to increase profit. The electrical power consumption pattern in the Indian sugar factories indicates that about 55% to 60% is consumed for running the juice extraction plant. Several efforts have been made to reduce the power consumption of the juice extraction section for higher energy efficiency. Installation of energy efficient motors and planetary gearboxes and automation of systems are some of the steps followed for energy conservation in the juice extraction section.

Replacing the tail bar coupling (Fig. 1) with a flexible rope coupling (Fig. 2) is emerging as a method of energy conservation. The flexible rope coupling was introduced to overcome troubles and limitations associated with the tail bar coupling (Tosio 1992).

Fig. 1. Tail bar coupling.
Initial installations of rope couplings were mainly aimed at elimination of roller breakages, absorption of misalignment, and reduction in maintenance costs (Mane and Murugkar 2003). Additionally, a reduction in power consumption was reported by the factory staff with results varying at different locations depending on preparation levels, mill settings and operating conditions. We know of no studies to determine the reduction in power consumption with the flexible rope coupling.

The paper presents the results from a factory trial undertaken to determine the reduction in torsional and axial torque and power consumption of the flexible rope coupling within a JPMA mill coupling. The coupling (Fig. 3) comprises two yokes with back sandwich plates, one on each shaft. The shafts are connected with a compression strut installed between the yokes in such a way that slings transfer the torque from the driving yoke via the compression strut to the driven yoke. This configuration allows both shafts and coupling to have lateral, axial and angular displacements, thus eliminating frictional resistance improving torque transmission efficiency with reduced axial thrust and bending moments on the shaft.

We had three objectives in this study:
- Level of energy conservation: The major objective was to determine the actual reduction in power consumption by replacing the existing tail bar coupling with a JPMA mill coupling, keeping all operating parameters unchanged.
- Influence on system efficiency: Due to their rigidity, tail bar couplings transmit an axial thrust which results in wastage of power. The rope coupling reduces axial thrust and transmits purely torque, which in turn increases efficiency of the transmission system. Hence, quantifying the reduction of thrust was part of this study.
Influence on performance of the mill: For constant top roll load and consistent extraction, free floating of the top roller is the main requirement for ideal milling operation and is thought to be the main advantage of the rope coupling over the tail bar coupling. The study was planned to measure the enhancement in mill performance by the replacement of coupling.

MATERIALS AND METHODS

Most of the earlier JPMA mill couplings were installed during expansion, modernization or during maintenance of the respective plants. Since pre-installation and post-installation parameters such as cane crush rate, prime mover rating and transmission systems were invariably changed, assessment of power consumption differences in such cases before and after installation of the mill coupling could not be attributed solely to the installation of the coupling.

It was, therefore, desirable to conduct the trial at a plant where replacement of the tail bar coupling with the JPMA mill coupling occurred during the crushing season, such that parameters such as crush rate, fibre content, prime mover rating and the rest of the transmission system were similar. Power consumption and changes in the system could then be compared for both couplings. Such an opportunity of replacing a tail bar with a JPMA mill coupling arose at M/s. Athani Sugars Ltd (ASL), Athani, Vishnuannanagar, Dist. Belgavi, one of their #1 mills during the 2014-15 season.

The trials were undertaken on the #1 mill. The mill size is Ø33x66. The mill has a 500 kW/1000 rpm/415 V DC motor with a Thyristor control drive and an individual drive of 200 kW/1000 rpm/415 V AC motor with a variable frequency drive for the GRPF. The transmission system for the mill consisted of a helical gearbox and one-stage open gearing. In the conventional (existing) arrangement, the open gearing and mill top roller were connected using a square coupling and tail bar.

A data acquisition system (DAS) (Fig. 4), with 16 channels for inputs in the form of 0 to 10 V DC signals, was used to read and store the data. The system was able to read and store 512 readings per second. However, readings during the study were stored at the rate of 100 readings per second for each channel.

The prime parameters measured were:

- Current of the electric motor for the mill was measured to determine power consumption so that the change in the power consumption with different couplings could be measured. The DC motor armature current signal from the Thyristor control panel provided the measurement.
- Speed of the electric motor measured to determine change in the speed with respect to power consumption. The DC motor speed signal from the Thyristor control panel was used.
- Axial Thrust and Torque were measured on both ends of the coupling to quantify the transmission efficiency of the coupling. Due to the large size of the shafts and constraints of the site conditions, measurement of axial thrust and torque in terms of actual load was not feasible. Instead, strain levels in the direction of loads, which are proportional
to axial thrust and torque, were used. Instead of absolute values, we decided to measure the relative values of the axial and torsional loads between the tail bar coupling and the JPMA mill coupling.

- Roller lift was measured on both sides of the mill roller to check the top-roller floating. Linear variable displacement transmitters (LVDT) were installed on both sides of the mill top roller to measure top roller lift. The signal was sent to the data acquisition system.
- Key Parameters – Since the coupling was replaced during the season, it was expected that the crush rate and fibre loading would be almost unchanged. Fibre% cane, pol % cane, preparatory index (PI), moisture % first mill bagasse and primary extraction (PE) were determined several times before and after installation as per standard prescribed methods (Verma 2005). Juice flow and crushing rates were recorded as per the methods followed by the factory.

The strain gauges were mounted in full Wheatstone bridge configuration on either end of the coupling. The locations of these bridges were selected in such a way that they did not need to be removed/relocated/replaced with the replacement of the coupling. Each bridge consisted of four strain gauges, two in the direction of axial thrust and two in the direction of torsional load. On the gear shaft side, the gauges were mounted on a step immediately after the bearing. On the mill top roller shaft, they were mounted on a step after the crown pinion.

Advanced Radio Frequency (RF) telemetry systems were used for wireless transmission of strain gauge data signals from rotating parts. Similarly RF telemetry systems were used to receive signal data, convert to volt signals and send to the data acquisition system. Figure 5 shows strain gauges on the mill side. Figures 6 and 7 show the telemetry transmitter and receiver, respectively.

![Fig. 5. Installation of strain gauges.](image)

![Fig. 6. Telemetry transmitter.](image)
Prior to the measurements, the tail bar was removed and the sensor mounting locations were cleaned properly. The required surface finish level to mount strain gauges was achieved with suitable chemical cleaning and machining. After completing the mounting of gauges and the instrumentation system, the tail bar coupling was assembled and the sensors and instrumentation system were checked at no-load conditions.

The initial measurements with the existing tail bar coupling were conducted on 8-9 April 2015. On 10 April 2015, the mill was stopped to replace the tail bar coupling with the JPMA mill coupling. Measurements with the JPMA mill coupling were conducted on 10-11 April 2015. Readings over about 15 hours for the tail bar and 10 hours for the JPMA mill coupling were recorded.

RESULTS AND DISCUSSION

A summary of the parameters observed and the analyzed results before and after replacement of the tail bar coupling by the JPMA mill coupling is given in Tables 1 and 2 and Figures 8-11.

Table 1. Key parameters and mill performance during the measurement period.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Tail bar coupling</th>
<th>JPMA mill coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crush rate*</td>
<td>t cane/h</td>
<td>160 ± 2</td>
<td></td>
</tr>
<tr>
<td>Fibre content</td>
<td>%</td>
<td>14 ± 0.1</td>
<td></td>
</tr>
<tr>
<td>Preparation level</td>
<td>%</td>
<td>85 ± 1</td>
<td></td>
</tr>
<tr>
<td>Hydraulic pressure</td>
<td>kg/cm²</td>
<td>190-crown side, 185-off side</td>
<td></td>
</tr>
<tr>
<td>Bagasse moisture (1st mill)</td>
<td>%</td>
<td>57 – 58</td>
<td>56 – 57</td>
</tr>
<tr>
<td>Primary extraction</td>
<td>%</td>
<td>71.40</td>
<td>71.88</td>
</tr>
</tbody>
</table>

*The plant was initially set to crush 210 t cane/h. However due to cane shortage, crushing was reduced to 160 t cane/h. Crush rate, fibre content and preparation level were relatively constant throughout the trial period.

Table 2 shows maximum, minimum, mean, range, Root Mean Square (RMS) and Standard Deviation (SD) of the strain, current and speed readings. Range values are an indication of the difference between maximum and minimum values and mean values are the statistical median of the readings. RMS is square root of the mean of the squares of the readings and standard deviation indicates the amount of variation or dispersion of the readings about the mean.
Table 2. Data analysis and statistical comparison.

<table>
<thead>
<tr>
<th>Channel</th>
<th>Units</th>
<th>Tail bar coupling</th>
<th>JPMA mill coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Strain – Torque</td>
<td>µstrain</td>
<td>83</td>
<td>0</td>
</tr>
<tr>
<td>Mill Side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain – Torque</td>
<td>µstrain</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>Gear Side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain – Axial</td>
<td>µstrain</td>
<td>273</td>
<td>0</td>
</tr>
<tr>
<td>Mill Side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain – Axial</td>
<td>µstrain</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>Gear Side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor current</td>
<td>A</td>
<td>917</td>
<td>0</td>
</tr>
<tr>
<td>Motor speed</td>
<td>rpm</td>
<td>942</td>
<td>831</td>
</tr>
</tbody>
</table>

*Zero indicates readings when mill is not operating

Figure 8 shows a cross plot of measured torsional strain on the mill side (y axis) against motor current (x axis). The relation between current and torsional strain is linear which indicates that torsional strain is related to torque. The slope of the curve is similar for both couplings indicating the change of coupling does not affect the mechanical torsional requirement of the mill.

The torsional strain values measured were an indication of the torque required (mill side) and torque supplied (gear side). Strain values on the mill side for both the couplings were varying within 20 to 80 µstrain, and mean value were 52 and 55 µstrain. These values indicate that the torque requirement of the mill in both cases was approximately the same. There is a 25% reduction in strain values with JPMA mill coupling compared to tail bar coupling. This reduction appears very high but can be attributed to the natural variability of the process and also experimental error. Further experiments are planned to verify these results.

Figure 9 shows a cross plot of measured axial strain on the mill side (y axis) against motor current (x axis), where separate trends for the tail bar coupling and the JPMA mill coupling can be distinctively identified. This difference indicates that thrust with the tail bar coupling is higher than with the JPMA coupling.

The axial strain values measured were an indication of the axial thrust on the mill side and gear side. These readings were reduced substantially for the JPMA mill coupling. Comparing the mean values for the JPMA coupling to the tail bar coupling, the axial strain was reduced by 36.64% on the mill side and 71.42% on the gear side. This result indicates the JPMA mill coupling significantly reduces the axial thrust.
During the trials, the motor speed was 855-856 rpm. The speed range for the JPMA mill coupling was reduced by 40 rpm, which was 35% less than that of the tail bar coupling. This result indicates that the fluctuations in the mill speed were reduced using the JPMA coupling.

The overall motor current readings for the JPMA mill coupling were reduced. With the JPMA mill coupling the mean current reduction was about 1.4% with a 15% drop in standard deviation. Figure 10 shows integration of the motor current for tail bar coupling and the JPMA mill coupling and it could be inferred from graph that current required with JPMA mill coupling was always less than tail bar coupling.

Figure 10 shows a cumulative distribution comparison of the motor current between the tail bar and JPMA mill coupling. It is seen from the graph that, for the tail bar coupling, the motor current was above 750 A for more than 20% of time; whereas, for the JPMA mill coupling, it was only above 750 A for 10% of time. This result indicates that, with the JPMA mill coupling, the number of occurrences of higher current were less than in comparison to the tail bar coupling.

Figure 11 shows the strain versus time graph for JPMA mill coupling (FC) and tail bar coupling (RC). It shows a period of stable operation of about 2 hours. A minimum reduction of 6.5-7.0% and a maximum reduction of 9% was recorded for the period of stable operation. An average reduction of about 8% was determined. The strain gauge measurements are directly proportional to torque (Kent et al. 2006). Since power is directly proportional to torque (Lewinski et al. 2010), a decrease in torque consumption would result in decrease in power consumption of the milling unit.
CONCLUSIONS

Conclusions that we drew from the factory trials are:

1. Improved performance of milling unit was measured with JPMA mill coupling.
2. With the JPMA mill coupling, axial thrust was reduced by 36.64% on the mill side and 71.42% on the gear side as compared to the tail bar coupling.
3. With the JPMA mill coupling, transmission efficiency of the system increased.
4. With the JPMA mill coupling, the reduction in power consumption was observed at about 8 % as compared to the tail bar coupling.
5. Assessment of system performance at full rated capacity of the milling plant will help in assessing the actual quantity of reduction in power consumption with the installation of the JPMA mill coupling.
6. Further studies with different cane characteristics and mill locations with AC VFD and planetary gearboxes are planned in order to better assess the benefits of the system.

ACKNOWLEDGEMENTS

We thank the management of JPMA Pvt Ltd for the permission to publish the paper, the Automotive Research Association of India (ARAI) for the assistance during the factory trials and fruitful discussions and advice with the results analysis, and the management of M/s Athani Sugars Ltd for their permission to undertake trials on the milling unit and the assistance provided during the trials.

REFERENCES


La contribution d’un dispositif d’accouplement de moulin JPMA en matière d’économie d’énergie

Résumé. Un accouplement conventionnel par pièce de même section carrée (tail-bar) peut poser des problèmes graves aux éléments d’entraînement d’un moulin à broyer. Parmi les complications les plus fréquentes, il faut citer le désalignement de l’entraînement et du...
moulin, les fissures de l’arbre moteur, le balancement désordonné des cylindres supérieurs, l’arrondissement des parties carrées des extrémités de l’arbre et les dommages causés à la couronne d’entraînement et au roulement du dernier engrenage. Le dispositif d’accouplement de moulin conçu par JPMA offre une solution alternative à l’utilisation d’une tail-bar et permet d’éliminer les dommages causés par le désalignement entre l’entraînement et le moulin tout en réduisant les autres conséquences négatives de l’accouplement par tail-bar. Cet article présente les résultats d’une étude sur les effets du dispositif d’accouplement de JPMA durant la saison de broyage 2014-2015. L’objectif principal de ce travail était d’évaluer les incidences sur la consommation électrique du remplacement d’un accouplement par tail-bar par un dispositif d’accouplement JPMA en se fondant sur la collecte et l’analyse de plusieurs données : poussée axiale, consommation électrique, lever des cylindres supérieurs, pourcentage de fibre de la canne, extraction primaire, pourcentage de richesse (pol) de la canne et humidité de la bagasse. Des jauges de contrainte ont été utilisées pour mesurer la poussée axiale et les couples pendant 4 jours. Nous avons également examiné et analysé les données comparatives recueillies avant et après l’installation du dispositif d’accouplement de moulin JPMA. Notre étude présente les conclusions suivantes : réduction moyenne de 8 % de la consommation électrique avec un pic de réduction de 12 % ; réduction de la poussée axiale ; réduction de la demande de couple et efficacité accrue de la transmission ; amélioration du rendement du moulin.

Mots-clés: Accouplement de moulin JPMA, accouplement par tail-bar, économie d’énergie, poussée axiale, couple, rendement du moulin

Relevancia del acoplamiento para molino JPMA en la conservación de energía

Resumen. El acoplamiento de barra de cola convencional puede causar graves complicaciones en los componentes de la transmisión del molino. Una mala alineación entre el molino y los engranajes, grietas en el eje, sobrecarga del empuje, flotación pesada del rodillo superior, desgaste de los extremos cuadrados de eje, daños en el piñón de corona, y daños en el último rodamiento del engranaje debido a un empuje excesivo son problemas comunes asociados al acoplamiento de barra de cola. El acoplamiento para molino JPMA es una alternativa al acoplamiento de barra de cola que permite eliminar los daños causados por una mala alineación entre el molino y el engranaje, y reducir otros problemas causados por el acoplamiento de barra de cola. En este documento se analiza el impacto del acoplamiento JPMA durante la temporada de triturado de 2014-15. El objetivo principal del estudio fue evaluar el efecto sobre el consumo de energía reemplazando un acoplamiento de barra de cola por el acoplamiento para molino JPMA. Se recopilaron y analizaron los datos relativos al empuje axial, consumo de energía, levantamiento del rodillo superior, fibra % caña, extracción primaria, pol % caña, y humedad del bagazo de caña. Se utilizaron extensómetros para medir el empuje axial y el torque. En este documento se incluyen y discuten los datos comparativos registrados antes y después de la instalación del acoplamiento para molino JPMA, tras cuatro días de mediciones. Las conclusiones de nuestro estudio son las siguientes: promedio del 8% de reducción en el consumo de energía, con un pico máximo de reducción del 12%; reducción del empuje axial, reducción en la demanda de torque y mayor eficacia de la transmisión; mejora en el rendimiento del molino.

Palabras clave: Acoplamiento de molino JPMA, acoplamiento de barra de cola, conservación de energía, empuje axial, torque, rendimiento del molino