Condition monitoring of rotary kiln with HD Technology

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Contents

1 Introduction ................................................................................................................................. 3
2 Conclusion and summary ............................................................................................................. 3
3 Application description ............................................................................................................. 4
4 System configuration ................................................................................................................. 6
  4.1 Measuring equipment ............................................................................................................. 6
  4.2 Measuring technique ............................................................................................................ 6
  4.3 Condmaster setup ................................................................................................................ 6
5 Case description: Gear, output shaft ....................................................................................... 7
  5.1.1 Ocular control of the gearbox ........................................................................................ 10
  5.1.2 Dismantling and bearing replacement .......................................................................... 10
6 Economic justification .............................................................................................................. 10
7 References ............................................................................................................................... 11
  7.1 Customer reference .............................................................................................................. 11
  7.2 SPM references ................................................................................................................ 11
1 Introduction

This case study describes the detection of a crack in a gear on the output shaft on a rotary kiln at Swedish forest group Södra’s pulp mill Södra Cell Värö. The rotary calciner is production-critical and in 2014, an online system was, therefore, installed to monitor the bearing and gear condition of the gearboxes. A breakdown of the gearboxes on the kiln would lead to significant costs for secondary mechanical damages.

Södra Cell Värö is one of Sweden's largest pulp mills with a production rate of 700,000 tons of pulp per year. The pulp mill is in operation 24/7 all year and unplanned downtime has major economic consequences.

Over the years, SPM has supplied some thirty online vibration monitoring systems as well as two portable vibration measurement systems of the Leonova Diamond model to Södra Cell Värö.

2 Conclusion and summary

Through measurements with the Intellinova Compact online system, a crack was detected in a gear on the output shaft of the gearbox (on the outside of the gearbox; marked with a red ring in Fig. 3). The gear, which has 21 teeth, in turn drives the rotation of the kiln (a ring gear with 175 teeth). The measurements showed a sharply increasing trend at the measuring point on the gearbox output shaft. At the same time, no fault symptoms were consistent with the gearbox's internal gears or bearings. The damage frequency was 21X, which coincides with the cogs on the gear mounted on the output shaft.

Initially, damage to the gear in question was considered unlikely. Instead, it was assumed that the rising shock pulse levels were caused by problems in the gearbox; this was due to the sound that could be heard while the gearbox was run at low speed and which seemed to propagate through the gearbox itself to a large degree.

The gearbox was, therefore, disassembled, but no damage was detected. The crack in the gear (with 21 teeth) was discovered as it was being heated before re-mounting on the output shaft following the re-assembly of the gearbox. The heat made the crack visible and also caused the oil/grease in the crack to seep out.
3 Application description

The kiln is a cylindrical, horizontal vessel, 110 m long and about 5 m in diameter. The fuel is fed into the cold upper end of the kiln, and at the opposite, hot end, the by-product is ejected. At the hot end, wood powder is fired together with a small proportion of methanol through a combination burner. It is also possible to burn boiler gas, strong gas from the evaporation, and methanol.

The combustion gas from the burners, having a temperature of about 1400 °C, flows through the kiln and out through the cold end. The energy in the combustion gases calcines and heats the fuel in the kiln. At the cold end, the gas temperature is about 450 °C.

The kiln is slightly inclined downwards to the hot end. Through the rotation, the material fed into the kiln moves toward its hot end. The rotation of the kiln is done through a ring gear attached to the kiln shell. Via the gearboxes, two electric motors drive the ring gear. When the kiln is hot and filled with lime, the rotation must not stop.

Fig. 1 Drawing of the rotary calciner.
Two gearboxes (see Fig. 2) rotate the kiln. If these gearboxes cannot fulfill the task of rotating the kiln, the result is a curvature of the tube, in which case the entire kiln must be scrapped.

*Fig. 2 Cross section of the rotary kiln and gearboxes.*

The measurement results are from shock pulse measurements on the drive of the output shaft. The gear in question has 21 cogs. The blue arrow in Figure 3 below indicates the location of the shock pulse transducer.

*Fig. 3 Drive on the output shaft.*
4 System configuration

4.1 Measuring equipment

The monitoring system consists of four shock pulse transducers (44000) and one vibration transducer (SLD144) on each gearbox. There are also two vibration transducers (SLD144) on each motor. All transducers are connected to the Intellinova Compact (INS18) online system.

4.2 Measuring technique

The mechanical condition of the gearboxes is monitored using the SPM HD measurement technology, which is very well suited for this low-RPM application.

4.3 Condmaster setup

The configuration of the measurement assignments in the analysis and diagnostic software Condmaster Ruby are as follows:

- 300 orders with 3200 lines, to cover cogs in outgoing gears in gearbox (68 cogs) with four harmonics.
- Symptom Enhancement Factor = 5
- Measurement interval = 4 hours
- No conditions or filters are set.
5 Case description: Gear, output shaft

During a capacity test, the output shaft speed was increased from 13.5 to 14.5 RPM. This test began on November 10, 2019. Soon thereafter, a rising trend was observed.

*Image 1*  Condition trend from the gearbox on the gearbox output shaft. The trend starts to rise shortly thereafter.

The trend in Figure 2 below shows the same development during the corresponding period of time. This trend is based on a floating average calculated on ten measurement results.

*Image 2*  Trend of measurement assignments with floating average calculation during the same period.
Image 3 Condition trend showing rising readings prior to gear replacement.

The following FFT shows 21 orders, which corresponds to the number of cogs on the gear in question.

Image 4 FFT with markers for harmonics at 21 X.
The time signal in Figure 5 is sharp and clear, showing 1X of the output shaft. The circular plot shows 21 teeth going in and out of a load zone, which in this case probably is because the ring gear is not fully centered.

**Image 5** Time signal with 1 order between markers.

**Image 6** Colored Spectrum Overview where the red color indicates rising shock pulse levels at 21 X.
5.1.1 Ocular control of the gearbox

Just over two weeks after the capacity test with the speed increase was initiated, the trend had not fallen. It was then decided to bring the gearbox down to crawl speed – corresponding to about 1 RPM on the output shaft - to be able to open the gearbox and perform troubleshooting.

A crackling sound could be heard in the gearbox about once per rotation. The sound seemed to come from the bearing on the output shaft. Two days later, a decision was made to start a coast-down of the kiln to remove the gearbox and replace the bearings on this shaft. Coast-down takes three days to complete.

5.1.2 Dismantling and bearing replacement

When dismantling the bearing, no defects were found. Nevertheless, the bearings on the output shaft were replaced. After the gearbox was re-assembled and the gear was to be mounted back onto the shaft, a crack was discovered between the cogs while heating the gear. An attempt was made to grind away the crack, but this was not possible as it was very deep.

As no spare gear was available, the decision was made to mount the gearbox with the damaged gear and order a new one as a spare.

In the spring of 2020, new, larger gearboxes were installed. In conjunction with this change, the gear ratio also changed, as did the gear on the output shaft which was changed to another dimension. At the same time, the monitoring system was changed from Intellinova Compact to Intellinova Parallel EN with sixteen channels, which makes it possible to make optimal use of measurements with time-synchronous averaging.
6 Economic justification

The lime kiln (tube) must not stop rotating while it is hot, as the heat will cause it to become "banana-shaped" if it stops rotating. If that were to occur, the entire kiln must be scrapped. In the event of a breakdown, where the gearboxes can no longer be used, large cranes must be hired to rotate the kiln during a cooling process that takes about three days to complete before gearbox repair or replacement can take place. Thus, a gearbox failure would cause significant economic costs and loss of production.

7 References

7.1 Customer reference

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