Effects of process variation on ring formation in lime kilns

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ABSTRACT: Operational data from different lime kilns were studied to find connections between process variations and the tendency for rings to form. Variations in lime mud dryness affect the kiln temperature profile, leading to recarbonation and ring formation. A mill trial indicated that it would be possible to reduce the fluctuation in lime mud dryness by measuring dryness in-situ with NIR spectroscopy. These measurements could then be used to determine how much water to add. Although kilns must be shut down to clean rings, mills can reduce ring formation by adding crushed limestone, by monitoring the shell temperature, by making short visual inspections frequently, and by using a power shot system that releases vaporized liquid carbon dioxide.

Application: Mills can reduce the operating costs associated with ring formation.

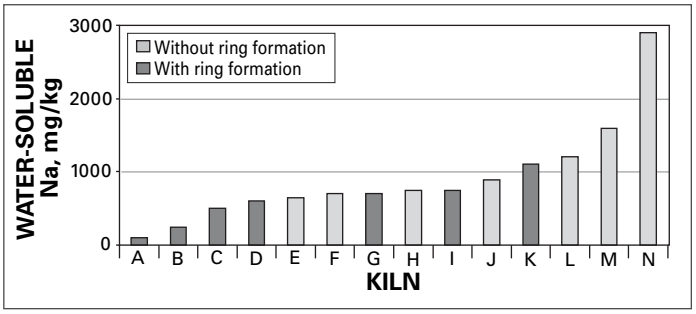
The production of lime is interrupted when rings cause unscheduled shutdowns for cleaning the kiln. Mid-kiln rings are thought to occur as a result of melting sodium compounds and an unstable kiln [1]. The ring starts to grow when melted sodium compounds allow lime mud or lime particles to become sticky and adhere to the kiln wall. The hardening of the ring is caused mainly by recarbonation, which occurs when the flue gas temperature falls enough to lower the temperature in the deposit below the calcination temperature. Repeated fluctuations in gas temperature allow the ring to grow thicker with time.

A survey was undertaken to compare ring formations in different kilns within Stora Enso. The survey focused on lime mud composition and the connection between different operational parameters and the tendency for rings to form. The study pointed to several practical ways to manage and reduce the effects of ring formation.

WATER-SOLUBLE SODIUM IN LIME MUD

Lime mud compositions were determined in samples taken at the entrance points of fourteen Stora Enso lime kilns. None of the kilns studied burn noncondensable gases. For the purposes of the study, kilns cleaned only once a year during scheduled annual maintenance were regarded as running without having problems with ring formation.

Half of the kilns studied had ring formations that required additional, unscheduled shutdowns, and the other half operated without ring formation problems. No correlation could be found between the tendency for rings to form and the lime mud washing efficiency. The washing efficiency was determined from the amount of water-soluble sodium left in the lime mud. As shown in **Fig. 1**, the amount of water-soluble sodium varied between 100 mg/kg and 3000 mg/kg.



1. Water-soluble sodium in lime mud. Lime mud washing efficiency decreases from left to right.

PROCESS VARIABILITY

What drives the recarbonation reaction that makes rings grow? The primary cause is a temperature fluctuation around 800°C [2]. Temperature variations in the kiln are caused by changes in operating parameters. Unstable operation of the lime mud filter, for instance, leads to fluctuations in temperature at the feed end. On the other hand, unstable burner operation will result in large variations in temperature at the front end.

Several operating parameters were considered in an effort to find correlations between process variability and the tendency for rings to form. These parameters include flue gas oxygen content, front-end temperature, and lime mud dryness.

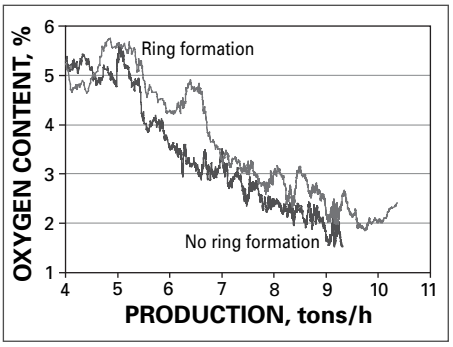
Oxygen content in flue gases

For a certain kiln, the O_2 content for a period when rings formed was compared against the O_2 content for a period without ring formation. The results are presented in **Fig. 2**, showing that the O_2 content at a specific production is higher when ringing is a problem.

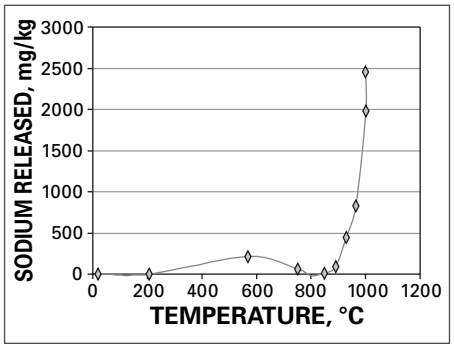
Front-end temperature

In a laboratory trial, lime mud was heated, and the remaining amount of sodium was measured. As **Fig. 3** shows, the release of sodium increased drastically at temperatures above 900°C. At 1000°C, the sodium release was 2500 mg per kilogram of dry mud, compared to a sodium release of less than 500 mg/kg at temperatures below 900°C. The released sodium is transported with the flue gases and can play an active role in ring formation earlier in the kiln. An increase in the sodium released will increase the sodium content in the kiln and may affect the ring formation.

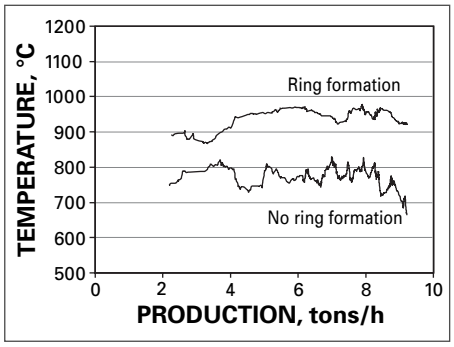
At a specific kiln, temperatures in the burner zone were compared for periods during which rings formed as opposed to periods without ring formation. **Figure 4** presents the results. During the period when the kiln was running at higher temperatures, and presumably with a higher release of sodium, three rings formed. During the period when the kiln was running at lower temperatures, no rings were formed.



2. Oxygen content in the flue gas, comparing four months without ring formation to four months when several rings formed. Oxygen content is higher when ringing is a problem.



3. Amount of sodium released from lime mud to flue gas.



4. Temperature in the burner zone, comparing a period without ring formation to a period when several rings formed.

Lime mud dryness

Lime mud dryness and variations in lime mud dryness during year 2000 were compared for different lime kilns with diameters ranging from 3.0 m to 3.3 m. Kiln H ran without rings and was cleaned only during the annual maintenance shutdown. Consequently, Kiln H was added as a reference for the others, which had more frequent ring formation. Kiln D had four unscheduled shutdowns, whereas Kilns A and C had eight unscheduled shutdowns each for cleaning rings that formed during the year.

Figure 5 compares these four kilns. Kiln H had the lowest dryness at 75% and the lowest variation at ±2.3% dryness. Kiln C had the driest lime mud at slightly above 80%, followed by Kiln A at slightly below 80%. Kilns A and C had large variations of about ±4% dryness. Kiln D had intermediate dryness at 77% and intermediate variation of ±2.8% dryness.

IN-SITU MEASUREMENT OF LIME MUD DRYNESS

Variation in lime mud dryness was identified as one of the main operating parameters affecting the temperature profile and therefore recarbonation and ring formation. The next step was to study the possibility of making an in-place measurement of the dryness. Laboratory measurements indicated that it would be possible to measure lime mud dryness in the mill with near-infrared spectroscopy (NIR).

A mobile NIR unit was installed at the Skoghall mill above the conveyor during the spring of 2003 to measure the dryness of lime mud entering the lime kiln. *In-situ* measurements were made every 5 min, and a graphical presentation of these measurements was included in the millwide control system. Figure 6 shows results over nine days in 2003.

Some practical problems arose during the measurement period. The NIR optic was covered with lime mud from time to time, which caused some deviation in the measurements. The final calibration to laboratory values gave a measurement accuracy of ±1.3 percent dryness. For this technology to be applicable, the optic needs to be kept clean from lime mud. One possible solution would be to place the NIR optic further away from the conveyor and shield it.

CONTROLLING LIME KILN RINGS

The Skutskär Mill has a systematic approach for reducing kiln ring formation and its associated costs. Crushed limestone is added on a continuous basis to rub the inside of the kiln and prevent the formation of rings. An infrared scanner is used to supervise the temperature profile along the kiln. Cooler areas indicate that material has built up and is insulating the shell. Once a week, the kiln is stopped for a short visual inspection for operators to identify the size and location of any ring.

The kiln is also equipped with a power shot system that has been used frequently since 2001. When necessary, the kiln is stopped, and the power shot system is fired to remove the ring. When the shot is detonated, vaporized liquid CO_2 is released, and part of the ring is removed. The remaining part of the ring falls out when the kiln is rotated. The kiln shutdown for this procedure takes about two hours.

These actions have reduced the number of times personnel have to enter the kiln and clean it manually by drilling. The kiln is now cleaned only during one shutdown for annual maintenance, as compared to the eight unplanned shutdowns during 2000.

CONCLUSIONS

Variation in lime mud dryness is an operating parameter that affects the kiln temperature profile and thereby the conditions under which recarbonation occurs and rings form. A mill trial indicates that it is possible to measure lime mud dryness with near-infrared spectroscopy.

A mill can reduce ringing problems by taking a systematic approach. Measures like adding crushed limestone, observing the shell temperature, making frequent, short visual inspections, and using a power shot system have proven effective in reducing the costs associated with ring formation. **TJ**

ACKNOWLEDGEMENT

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LITERATURE CITED

1. Tran, H., Mao, X., Barham, D., *1992 International Chemical Recovery Conference Proceedings*, TAPPI PRESS, Atlanta, p. 169.
2. Tran, H., Mao, X., and Barham, D., *J. Pulp Paper Sci.* 19(4): J167(1993).

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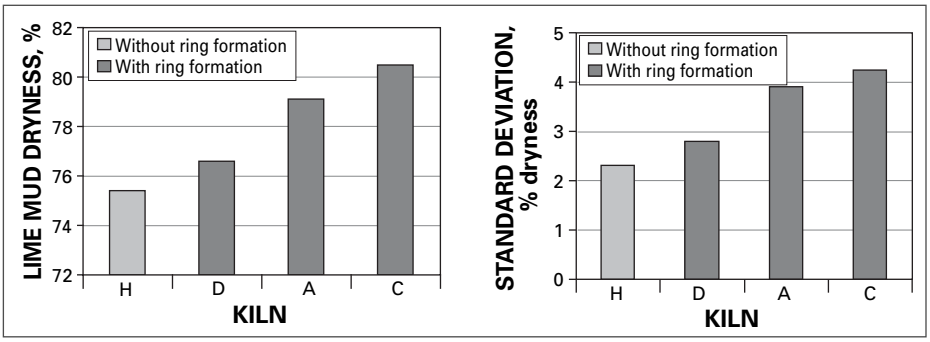
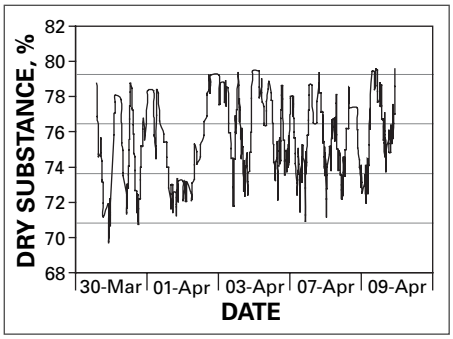


5. Annual averages (left) of lime mud dryness at four kilns and variations in dryness (right) expressed as standard deviations from the annual averages in units of percent dryness.



6. NIR in-situ measurements of lime mud dryness over nine days.

This paper is also published on TAPPI's web site <www.tappi.org> and summarized in the June *Solutions! for People, Processes and Paper* magazine (Vol. 88 No. 6).

INSIGHTS FROM THE AUTHORS

Lime kiln shutdowns are costly, but there are some practical ways to reduce ring formation. This study complements research work carried out by Honghi Tran at the University of Toronto. The most surprising result was the low correlation found between ring formation and the sodium content in lime mud. At Stora Enso, no further research is currently planned on lime kilns.

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