

Online Image Analysis of Nodule Particle-size Distribution for the Control of Lime Kiln Operation

Erik Berg¹, Sven Hermansson^{*2}, Jonas Wetterling², Peter Lingman¹, Richard Nordenskjöld¹, Anders Åkesjö²

1. Optimization AB, Box 27, SE-941 21 Piteå, Sweden

2. Södra skogsägarna ekonomisk förening, SE-351 89 Växjö, Sweden.

^{*}Corresponding author, sven.hermansson@sodra.com, +46-340-633468



optimization



Background

- The reactivity of the lime has been shown to be coupled to the size of the lime nodules that are formed in the lime kiln. Nodules in the range of 10-15 mm diameter have been shown to yield higher reactivity than fine particulate reburned lime (dust). Several factors affect the nodule size.
- By keeping track of the particle-size distribution, a control routine could be established that would automatically steer the operation towards optimal lime reactivity, low dusting behavior and, consequently, low energy use.



Mr Henric Dernegård



Prof Honghi Tran



Prof Hans Theliander



[1]. Dernegård, H (2019)



Objectives

The main objectives of the study was to

- investigate online measurement of particle-size distribution of the reburned lime, as a possible input parameter to the control system of a lime kiln.
- quantify the influence of flue-gas temperature, lime temperature and residence time on the particle-size distribution of the reburned lime and, as an extension, the resulting lime reactivity
- contribute to an increased general understanding of how the operation of a lime kiln affects the particle-size distribution of the produced lime.



Methodology



Mönsterås Kraft mill 750 000 ADT

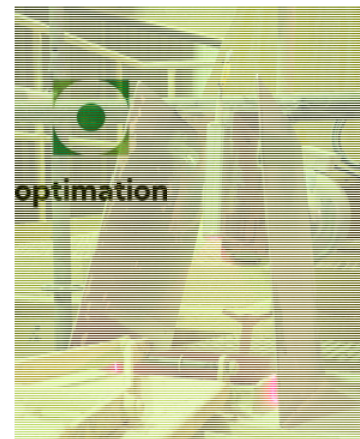


optimization

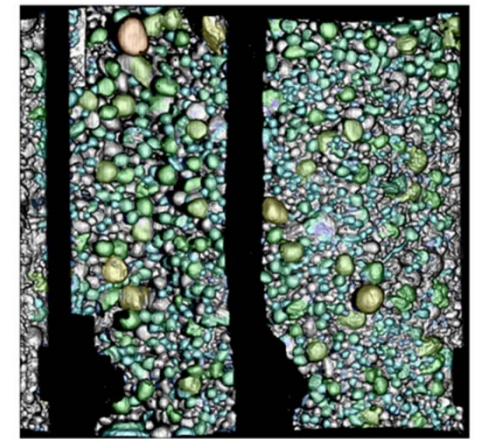
3DPM®

Particle-size distribution

Laser technology triangulation,
validated in harsh environment



Measurement set-up



Example of particle-size plot



Methodology

- Experimental trials of three (3) different operational parameters
- One (1) additional trial to eliminate effect of methanol incineration
- Online measurement of process parameters and with 3D camera
- Validation by sampling of lime screening (particle size) and residual carbonate analyzer

Trial no	Variation of condition	Validation
1. a, Lime temperature	850 -> 760 -> 810 -> 850°C	Screening, residual carbonates
b. Lime temperature	850 -> 760 -> 850°C	No screening, residual carbonates
2. Flue-gas temperature	613-640°C	Screening, residual carbonates
3. Kiln rotational speed	1,2 -> 1,0 -> 1,25 rpm	Screening, residual carbonates



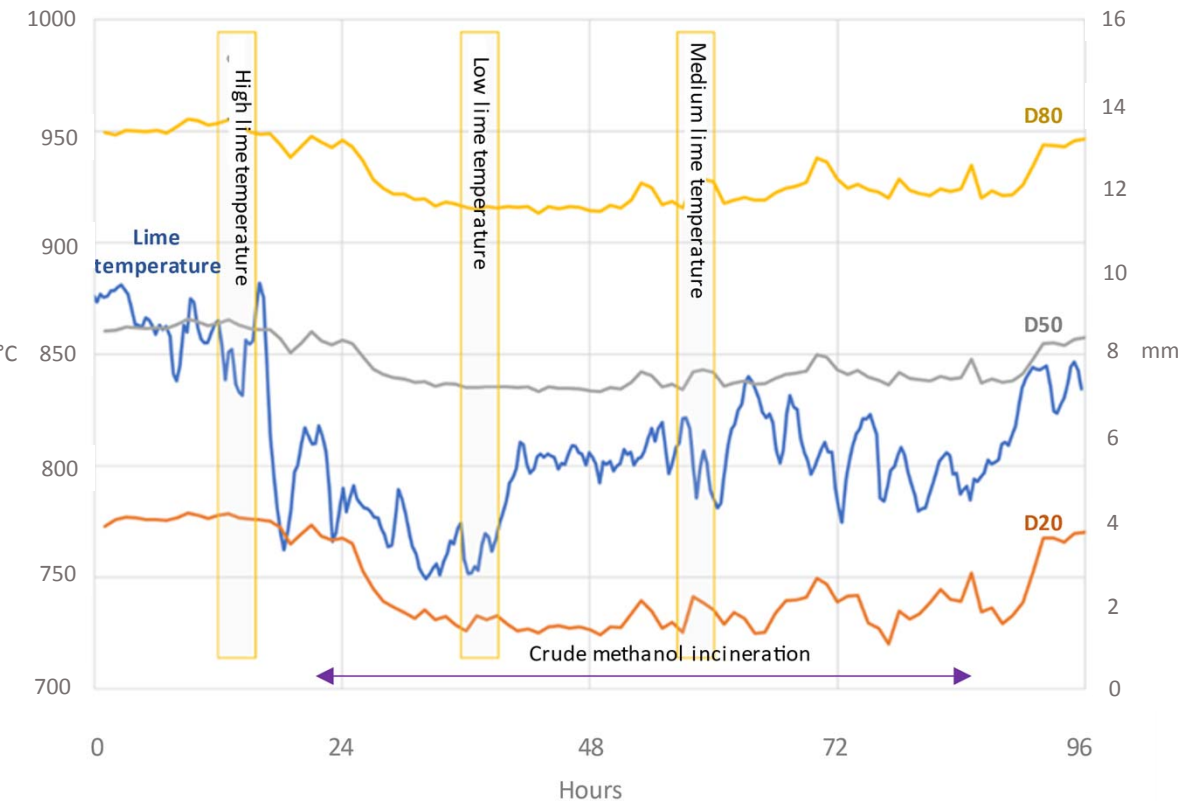
Mönsterås Lime Kiln No 2
275 tonnes of lime per day,
dried bark powder and bio-oil



Results – Lime Temperature - Trial 1a

On-line monitoring

Mean values of D20-80

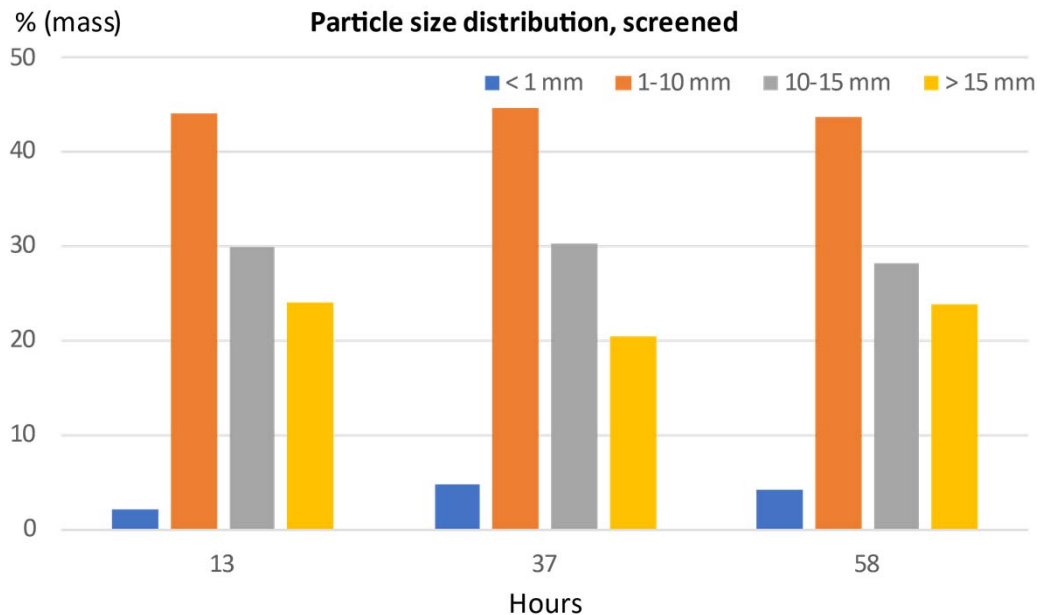


Interval	D20 (mm)	D50 (mm)	D80 (mm)
High temperature	4,5	9	13,5
Low temperature	1,5	7,5	11,5
Medium temperature	2	7,5	12,5



Results – Lime Temperature - Trial 1a

Validation by sampling of lime and screening



Carbonate analyzer:

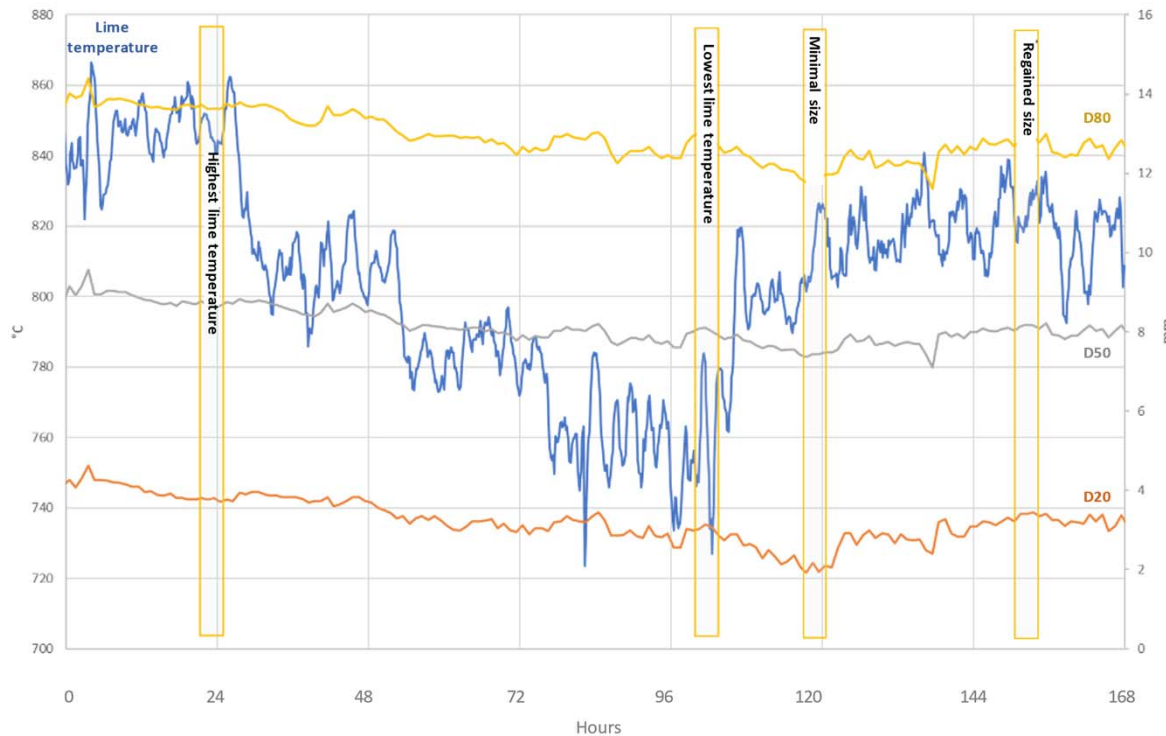
No significant difference in residual carbonate

On-line monitoring captures the trends!
High lime temperature → larger nodules!
however,
possible influence of methanol...?



Results – Lime Temperature - Trial 1b (No MeOH!)

On-line monitoring



Mean values of D20-80

Interval	D20 (mm)	D50 (mm)	D80 (mm)
High temperature	3,8	8,7	13,6
Lowest temperature	3,0	8,0	12,9
Minimal size	2,0	7,4	11,9
Regained size	3,4	8,2	12,9

Trend is consistent!

High lime temperature → larger nodules

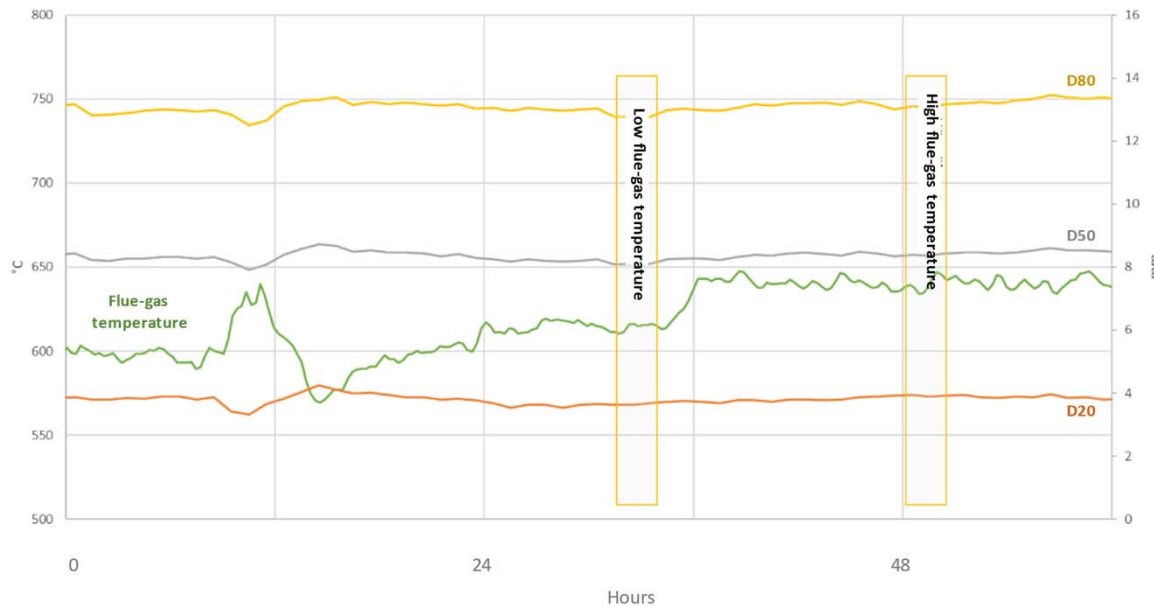
However,

Reaching high enough lime temperature (>810 °C) seem to be crucial to regain nodule size



Results – Flue-gas Temperature - Trial 2

On-line monitoring



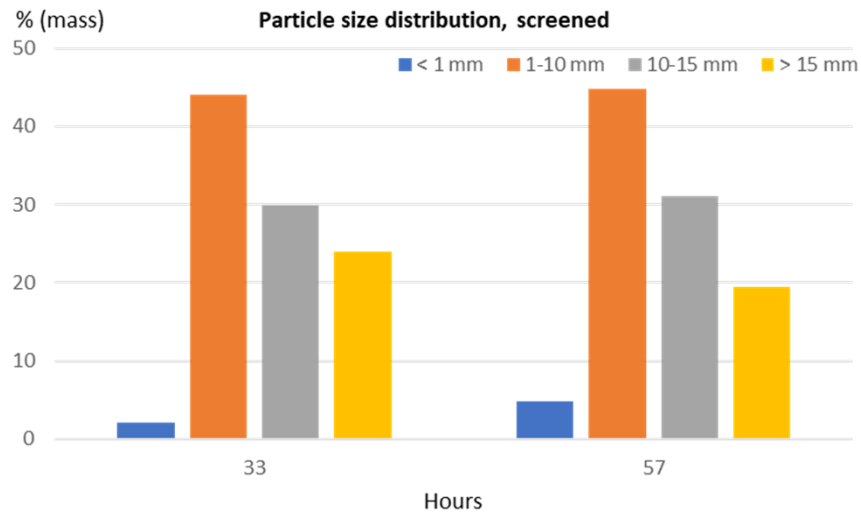
Mean values of D20-80

Interval	D20 (mm)	D50 (mm)	D80 (mm)
Low temperature	3,7	8,1	12,8
High temperature	4,0	8,6	13,4



Results – Flue-gas Temperature - Trial 2

Validation by sampling of lime and screening



Carbonate analyzer:

No significant difference in residual carbonate

On-line monitoring measures robustly!

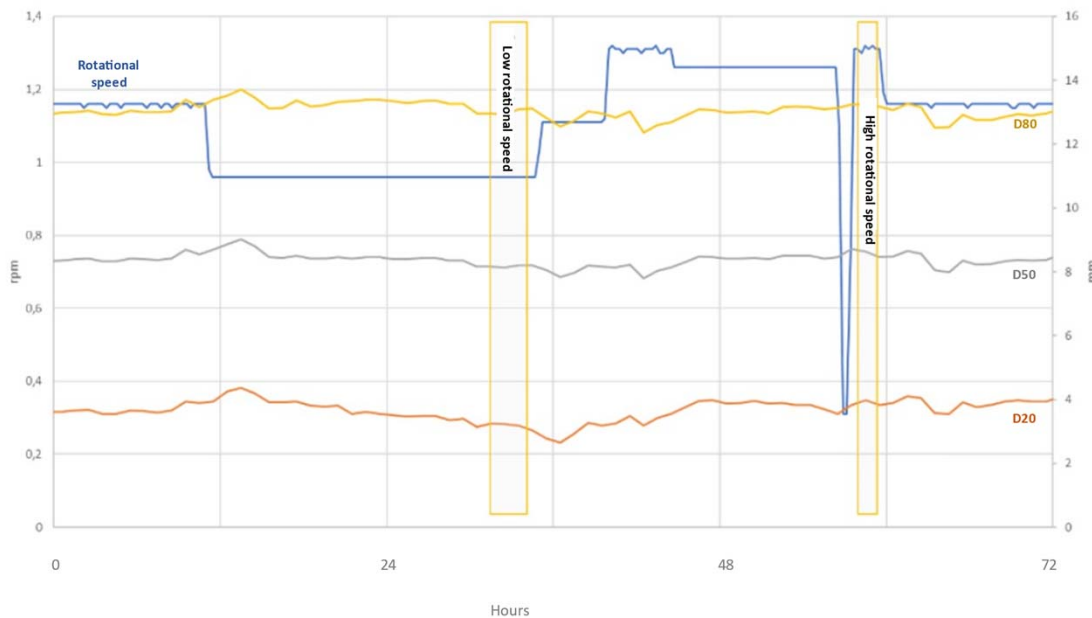
However,

Span of temperature too small to achieve a possible significant response in nodule size



Results – Rotational Speed of the Kiln- Trial 3

On-line monitoring



Mean values of D20-80

Interval	D20 (mm)	D50 (mm)	D80 (mm)
Low rotational speed	3,3	8,2	13,1
High rotational speed	3,8	8,6	13,2

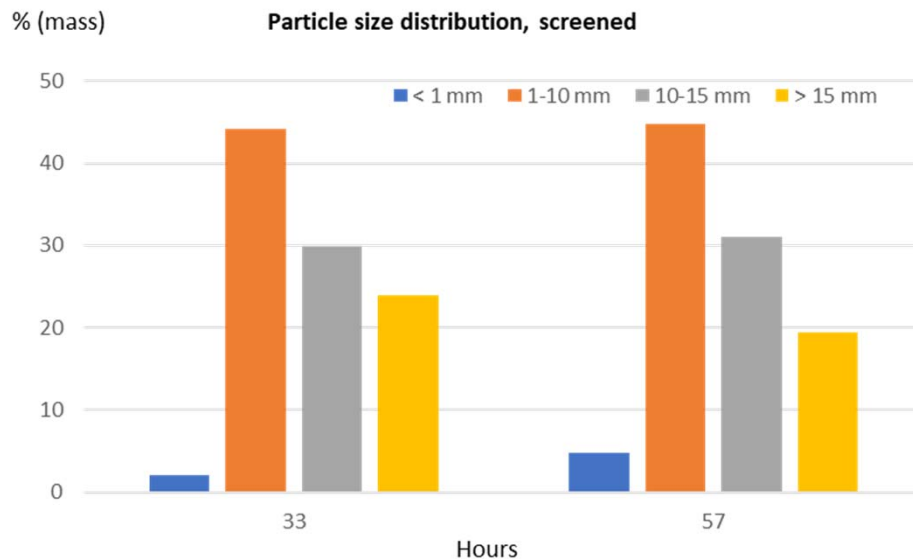


Results – Rotational Speed of the Kiln- Trial 3

On-line monitoring

Carbonate analyzer:

No significant difference in residual carbonate



On-line monitoring measures robustly!

Low speed → smaller particles (week trend)

However,

Clear coupling with specific energy consumption!

Low speed → high load → improved heat transfer



Conclusions

- Online measurement using 3D camera for identifying particle size groups, can be used as a stable tool for the monitoring of particle-size distribution of the reburned lime from a lime kiln
- Lime temperature had a significant effect on the nodule particle-size distribution of the reburned lime.
 - validated by the screening of manual lime samples.
 - could be achieved at basically constant specific energy consumption since the lime cooler could recover the increase in excess heat.
- Rotational speed of the lime kiln and flue-gas temperature at the end of the kiln, did not have any significant effect on the particle-size distribution
- Rotational speed of the lime kiln had significant effect on the specific energy consumption.
 - low rotational speed increases the level-load of lime in the kiln, which increases the heat transfer.



Recommendations for future work

- *A soft sensor for the lime composition.* Indirect monitoring the effect of Na, P and Cl, on the dusting in a lime kiln along with the nodule size. Eg demonstrating the effect of purging of virgin lime.
- *Evaluation tool for the firing of biomass powder in lime kilns.* Coupling the particle-size measurement with the heat-transfer between the flame and the lime bed.
- *Evaluation tool of the firing of sulfuric fuels in lime kilns.* Crude methanol of high sulfur content could have interfered with the nodule formation. Could this be reproduced, and also for other fuels, e.g. PET coke and kraft lignin?



Acknowledgements

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Thank you!

