A First-Ever innovative brown-field modification in conservative cement industry - de-risked by smart simulation

Martin Weng, Matthias Schumacher
**portfolio**

- **Simulation Services**
  - CFD process simulation
  - *SolidSheet* process modeling
  - process optimisation

- **Digital Solutions**
  - aixProM software platform
  - aixProM i-sensors
  - aixProM Big Data Analytics

- **Engineering & Products**
  - cyclones
  - advanced flow equipment
  - basic & detail engineering

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- **established 2001**
  - by Dr. Martin Weng, Markus Hufschmidt
- **owner-operated**
- **located in Aachen / Germany**
- **25 staff**
  - 16 process engineers
  - 9 data & ML specialists
Kiln 4:
- Capacity: 1500 tpd
- Kiln: Ø 3.2/3.8 x 48 m, Polysius, modified in 1980
- Preheater: 1 string, 5 stages, Polysius, 1980
- Cooler: IKN/CPAG, 1980
- Filter: Baghouse, RD42, 2018
- Fuels: Lignite, RDF, solvents

Kiln 8:
- Capacity: 3700 tpd
- Kiln: Ø 4.55 x 58 m, FLSmidth, 2001
- Preheater: 2 strings, 6 stages, FLSmidth, 2001
- Cooler: IKN, 2001
- Filter: Baghouse, RD42, 2018
- Fuels: Lignite, RDF, solvents, wet sewage sludge
Calciner designed for lignite-firing
- Short calciner with low retention time (2-3 s)
- Exceptional CO-emission under injection of typical fluffy calciner RDF
- Moderate, but still elevated CO-emission under injection of “expensive” pelletized and pre-ground RDF
- Coal-free calciner operation not possible

Make the calciner ready for 100% TSR with low CO emissions
Size of Alternative Fuels
Pre-ground RDF Pellets

Zig-Zag-Sifter

Class 1
Class 4
Class 5
Class 6

$V_{\text{gas}} = 16.0 \text{ m/s}$
$V_{\text{gas}} = 14.3 \text{ m/s}$
$V_{\text{gas}} = 10.1 \text{ m/s}$
$V_{\text{gas}} = 7.8 \text{ m/s}$
$V_{\text{gas}} = 5.8 \text{ m/s}$
$V_{\text{gas}} = 2.5 \text{ m/s}$
Size of Alternative Fuels
RDF Pellets vs Fluffy RDF

PRE-GROUND PELLETS

Class 1
Class 2
Class 3
Class 4
Class 5
Class 6

FLUFFY RDF

Class 1
Class 2
Class 3
Class 4
Class 5
Class 6
Pre-ground pellets require higher minimum gas speed for safe pneumatic transport

Coarse particles burn slower and produce more CO than fine ones

Why is this particular calciner producing less CO with the pellets?
CFD-Analysis of the current operation
Fired with pre-ground RDF Pellets

Motion of the Pellets

- „Easy to suspend“
- „Hard to suspend“
- Terminal velocity
- Time: 0.000s

CO concentration

- Fuel rain out into the kiln inlet
- Fluidized bed of the pelletized particles in the inclined part
- CO is permanently produced from the layer at the bottom
- CO/O₂ stratification in the riser
- CO oxidation in the double deflector
- CO Emission >1000 mg/Nm³
Combustion of RDF particles
Lab furnace tests

Sample 1
Type: 2D
Size: 25 x 25 mm
Weight: 12 mg

Sample 2
Type: 3D
Size: 30 x 5 mm
Weight: 140 mg
Development of a smart retrofit concept

Brainstorming phase

- CO emissions can be reduced by
  - Increasing temperature
  - Improving oxygen availability for the fuel
  - Enhancing retention time for the fuel

- Fluffy RDF is carried straightly through the calciner – limited by retention time

- Coarse high-dense particles are producing high CO emissions due to local lack of oxygen – limited by mixing

- Concept as developed by the Lengerich engineers
  Installation of a pre-combustion chamber to increase retention time and to improve mixing
CFD-Evaluation of the future operation
Fired with pre-ground pellets

- Fuel particles swirl in the pre-combustion chamber
- Fuel particles remain in the hot bottom section
- Reduced fall-through, only very coarse particles rain into kiln inlet
- CO Emission reduction by >70% compared to today's operation
CFD-Evaluation of the future operation
Fired with fluffy RDF

- Introduction of fluffy RDF is technically feasible
- CO emission slightly increases with typical RDF again
- Still significant reduction of CO emissions compared to today (>60%)
- Fuel cost expenditures drastically reduced
CFD-Evaluation of the future operation
Flight through the calciner
Operational experience

Monthly average CO-Emission in mg/m³

Emission reduced by 70-80% after start-up
Further improvements

Gas temperature

Hot spot at the roof

Injection of cooling meal
Economical Benefits

- Increase of the total substitution rate (TSR) by 22 %-points
- Reduction of the fuel costs through substitution of lignite by RDF (1.40 €/ton clinker)
- Additional reduction of the fuel costs due to elimination of the pre-ground pellets (1.00 €/ton clinker)
- Total fuel cost savings: 2.40 €/ton clinker
- Return on investment in less than 6 months
Take-Home Messages

• Our CFD studies have proven to be exact in a way to project the effect of future plant modifications – even for minority components like CO (measured in ppm)

• Due to the lack of reference experience for comparable modifications only detailed modeling and simulation could check the viability for this unique optimization proposal

• The proposed unconventional retrofit has proven to be successful and the project objectives could be reached

• Additional benefit could be generated by downgrading the alternative fuel quality leading to substantial fuel cost savings without jeopardizing operational stability

• Careful engineering and simulation has led to total project success with an RoI < 6 months