JM

Johnson Matthey
Inspiring science, enhancing life

SCR catalyst technology

Conference "Ashes from Power Generation"– Krynica-Zdrój
16-18 October 2018

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Outline

Johnson Matthey Group

A speciality chemicals company and a world leader in sustainable technologies

Origins date back to 1817, floated 1942, FTSE 100 company since June 2002, ranked 79

Gross R&D spend £193.0 million

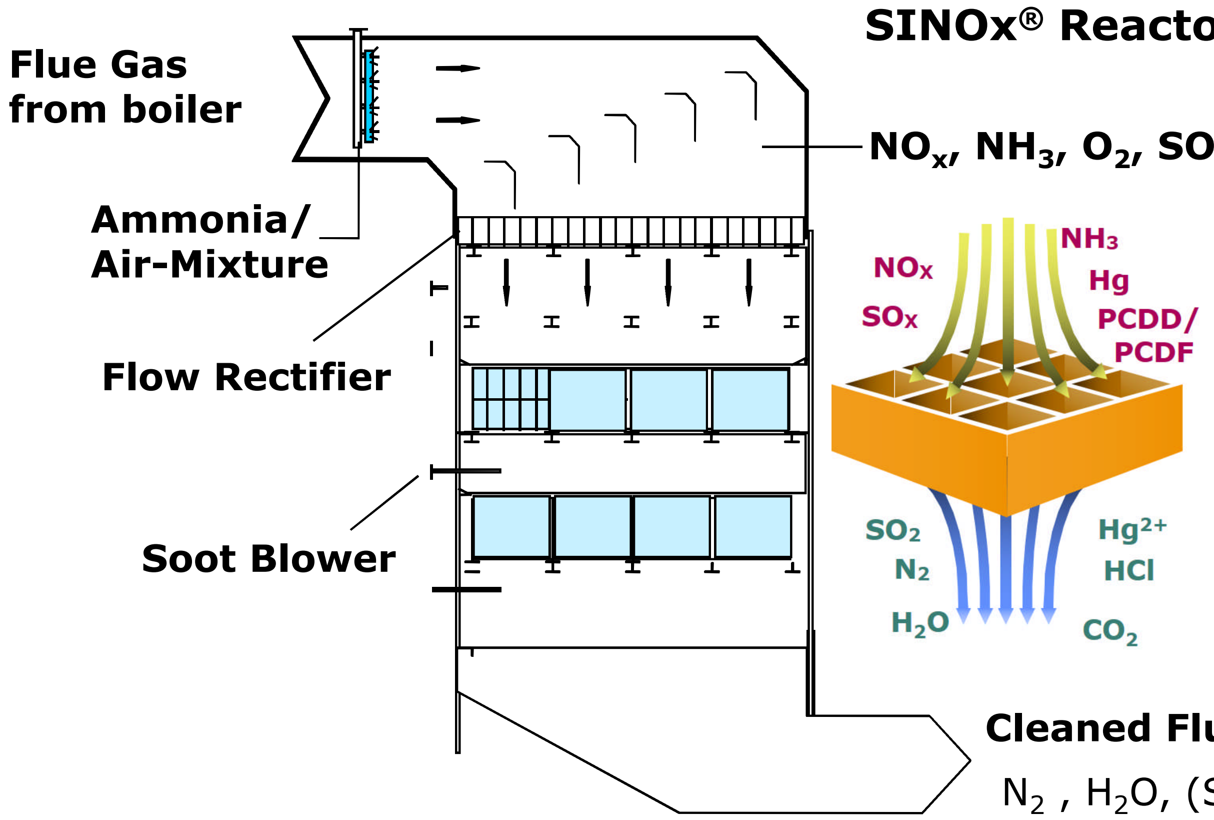
£3,846 billion revenue and underlying profit before tax* of £525.0 million for year ended 31st March 2018

Operations in over 30 countries with around 14,000 employees

Leading global market positions in all its major businesses

* Before amortisation of acquired intangibles, major impairment and restructuring charges, profit or loss on disposal of businesses, significant tax rate changes and, where relevant, related tax effects

Selective Catalytic Reduction of NOx



Desired reactions

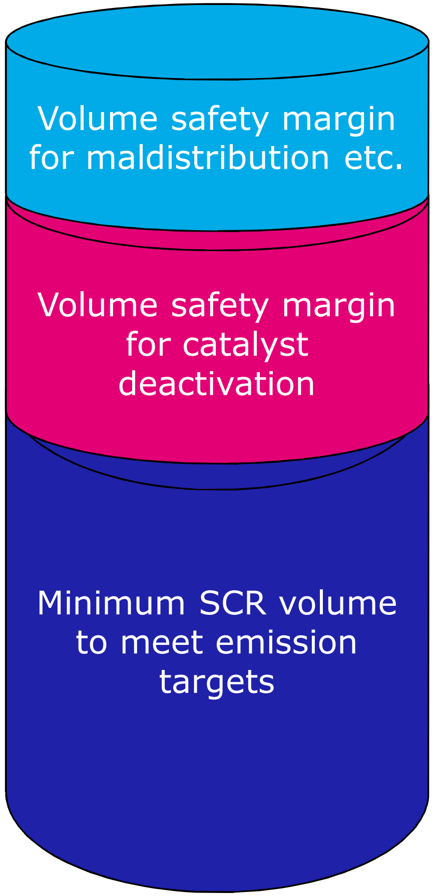
1) $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$
2) $2NO + 2NO_2 + 4NH_3 \rightarrow 4N_2 + 6H_2O$
3) $Hg + 2HCl + \frac{1}{2}O_2 \rightarrow HgCl_2 + H_2O$
4) $\text{Dioxin} + O_2 \rightarrow CO_2 + HCl + H_2O$
5) $CH_2O + \frac{1}{2}O_2 \rightarrow CO + H_2O$

Undesired reactions

6) $SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$
7) $NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$
8) $4 NH_3 + 3 O_2 \rightarrow 2 N_2 + 6 H_2O$

Catalyst design

Basic considerations



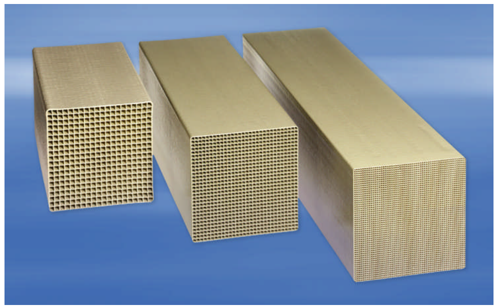
maldistributions (flow, NH_3/NOx)
catalyst erosion

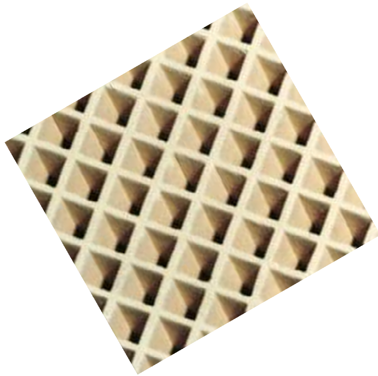
fuel (hard coal, lignite, biomass, etc.)
catalyst poisons
deactivation mechanism

application (high dust, low dust)
% NOx reduction requirement
NH3 slip requirements
max % SO_2-to-SO_3 conversion
chemical warranty
pressure drop limitation
space limitations (reactor layout)
flue gas data: volume flow, temperature, pressure, NOx, O_2, H_2O, SO_2

Catalyst types and selection – Honeycomb Catalysts

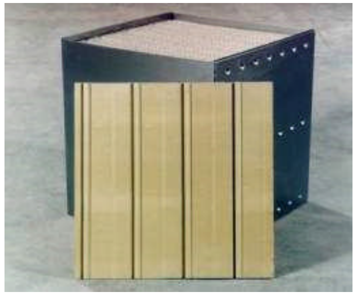
- High specific surface area
- High SCR activity, low SO_2 oxidation
- Optimized pressure drop
- Variable length and number of cells (5-300 cpsi)
- Low to medium-dust flue gas applications
  (high-grade coal, oil, gas, diesel or WtE applications)

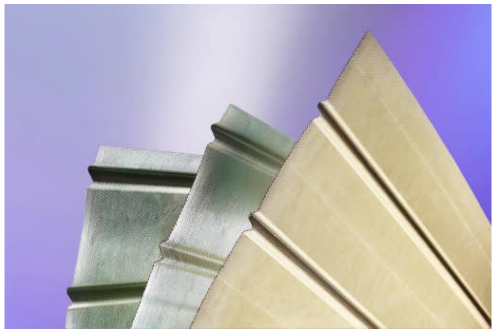


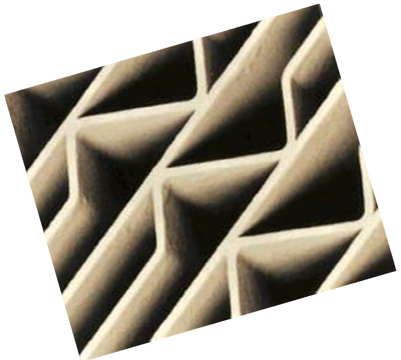


Catalyst types and selection – Plate Catalysts

- Variable pitch, minimal dust deposition
- High SCR activity, low SO_2 oxidation
- High erosion and poison resistance
- Low pressure drop
- Plate-to-plate clearance, variable Specific Surface Areas
- High-dust flue gas and special applications (coal-fired, biomass incineration, industrial processes & refinery power plants)

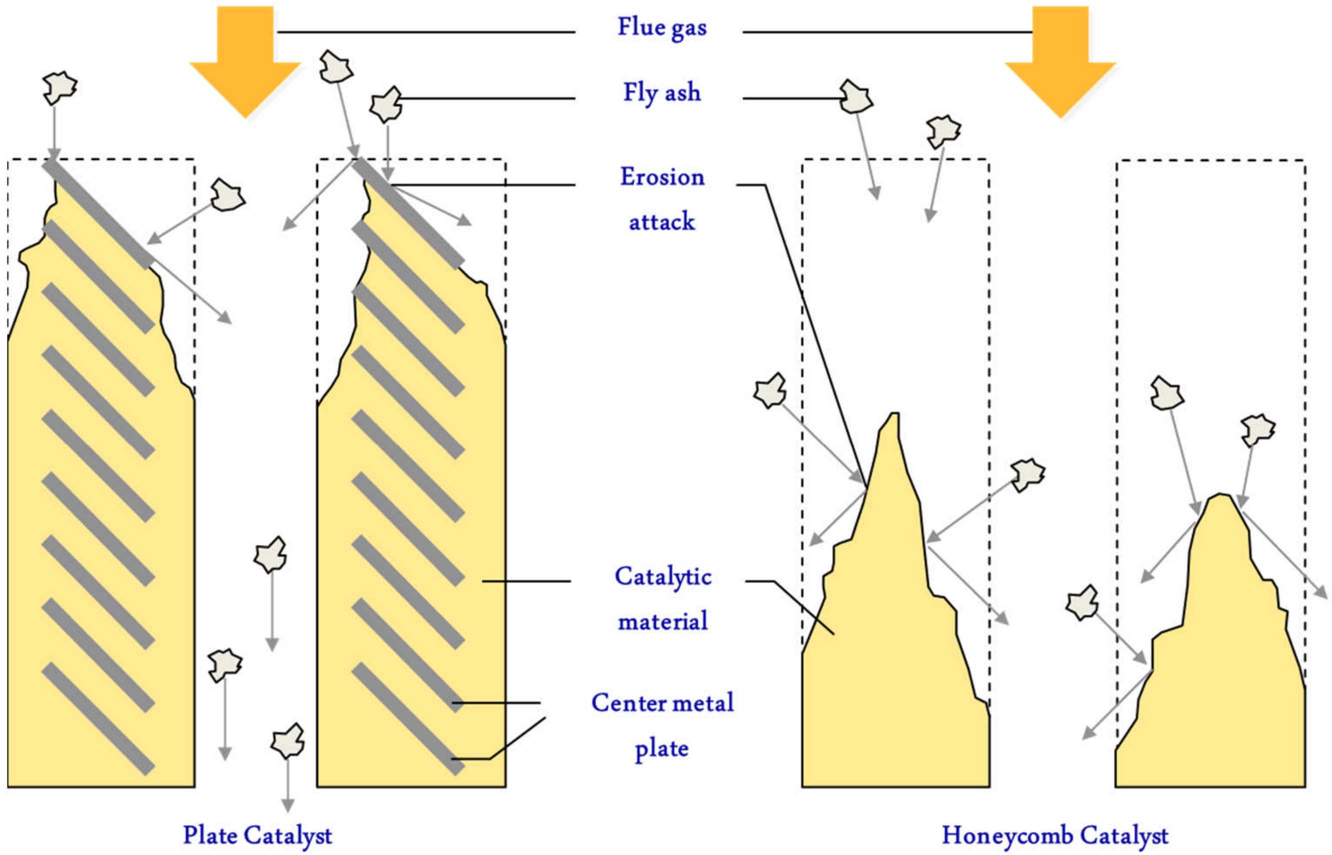




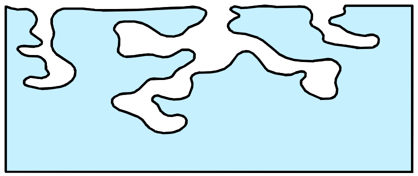


Catalyst selection

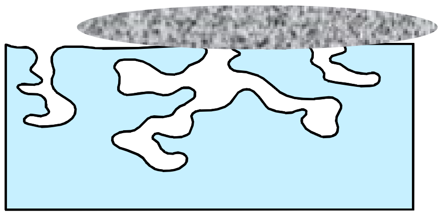
Erosion resistance



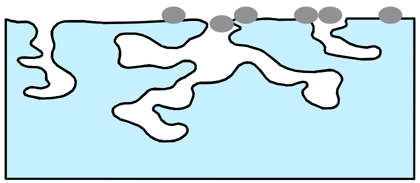
Catalyst deactivation mechanism



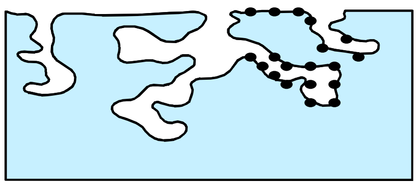
Fresh Catalyst



Masking
Reactive particles grow on the catalyst surface
Promoting conditions: CaO in ash > 20%, high SO_2, dew point conditions, excessive humidity



Plugging
Fly ash particle diffusion into catalyst pores
Catalyst micropore system is plugged mechanically



Poisoning
Three main kinds of catalyst poisoning:
1) Reaction of alkaline metals with acidic sites
2) Reaction of phosphorus with active centers
3) Reaction of arsenic with active centers

Formation of sulfates

Deactivation by Ammoniumsulfate (AS) or Ammoniumhydrogensulfate (ABS) from SO_3

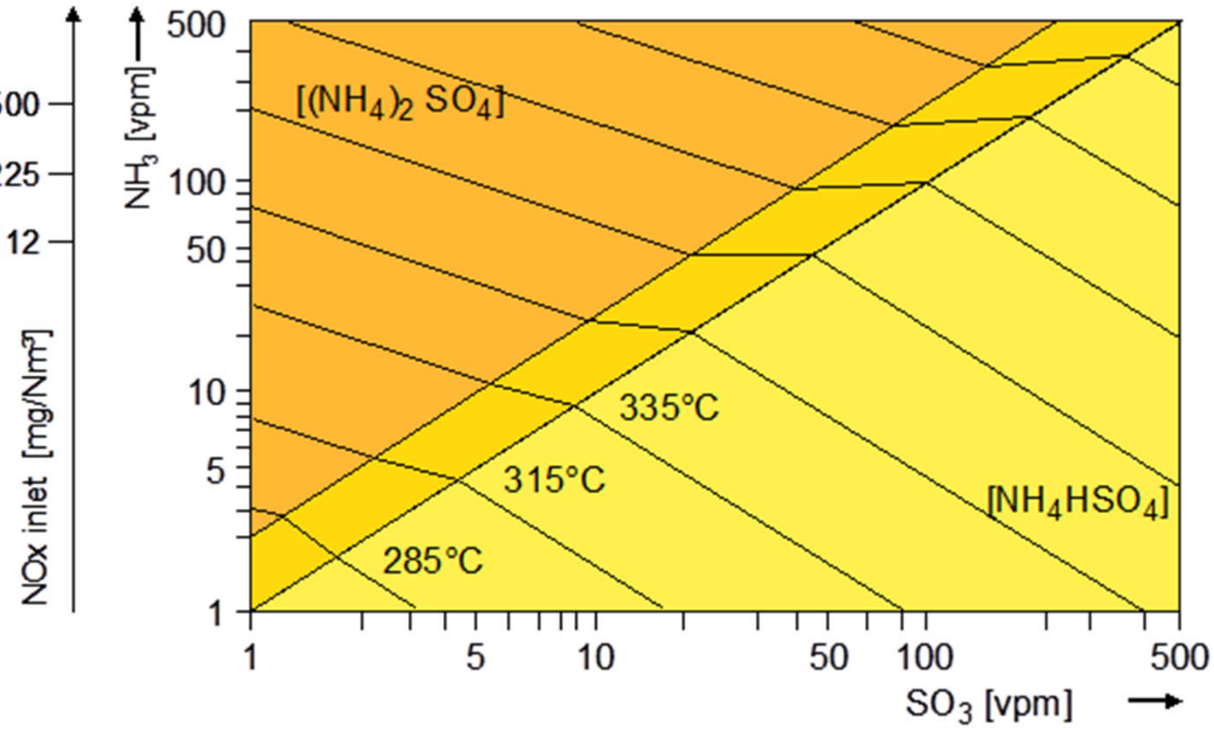
$$SO_2 + 0{,}5\ O_2 \leftrightarrow SO_3$$

$$H_2O_{(g)} + SO_{3(g)} + NH_{3(g)} \leftrightarrow NH_4HSO_{4(s)}$$

$$H_2O_{(g)} + SO_{3(g)} + 2NH_{3(g)} \leftrightarrow (NH_4)_2SO_{4(s)}$$

- Mechanism: Pore blockage
- > 300 °C: thermodynamic limitation of AS/ABS formation
- Very high SO_3-concentrations in the exhaust gas may lead to an increase of the condensing temperature (capillary condensation) $\Rightarrow$ salt formation

Formation of sulfates



Ammonium Sulfate Formation inside Catalyst

Catalyst flue gas flow distribution

Required flow conditions at catalyst inlet (maximum deviation from the mean)

<u>Velocity distribution:</u>

± 15%

<u>NH3/NOx distribution:</u>

± 7,5%

<u>Temperature distribution:</u>

± 10°C

<u>Dust distribution:</u>

± 10%

Angle of flow at the catalyst face:

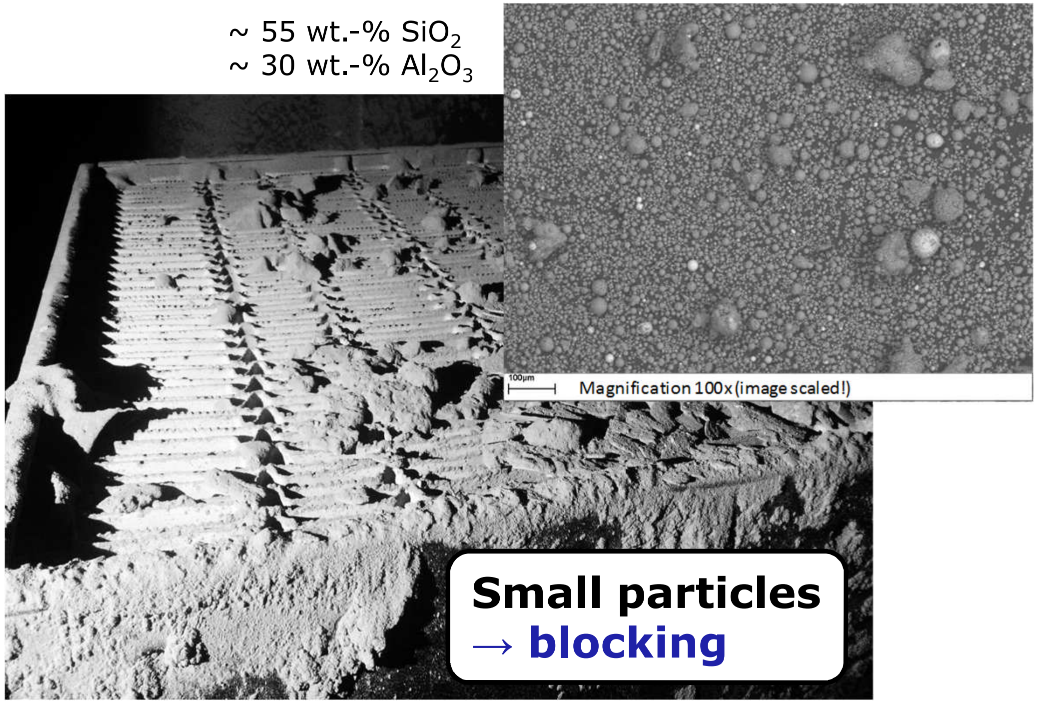
< 15°

Erosion

Influence on fly ash particle size

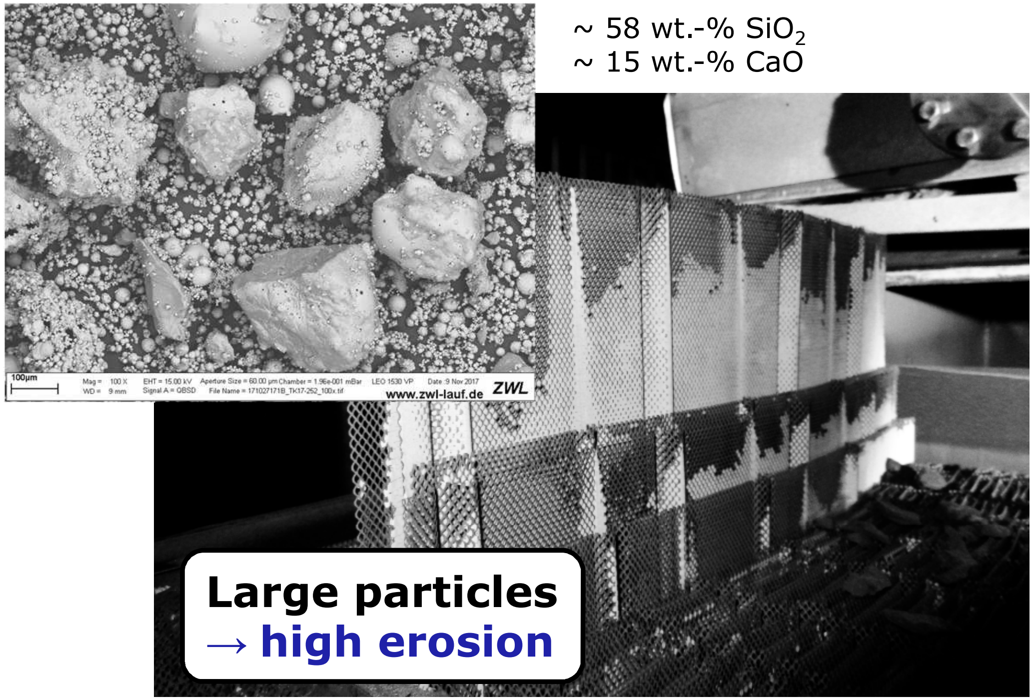
Lignite ash / ~30 µm particles

~ 55 wt.-% SiO_2
~ 30 wt.-% Al_2O_3



Lignite ash / ~250 µm particle

~ 58 wt.-% SiO_2
~ 15 wt.-% CaO



Large particles have large erosion impact – also on standard high dust suitable plate type catalyst

Erosion

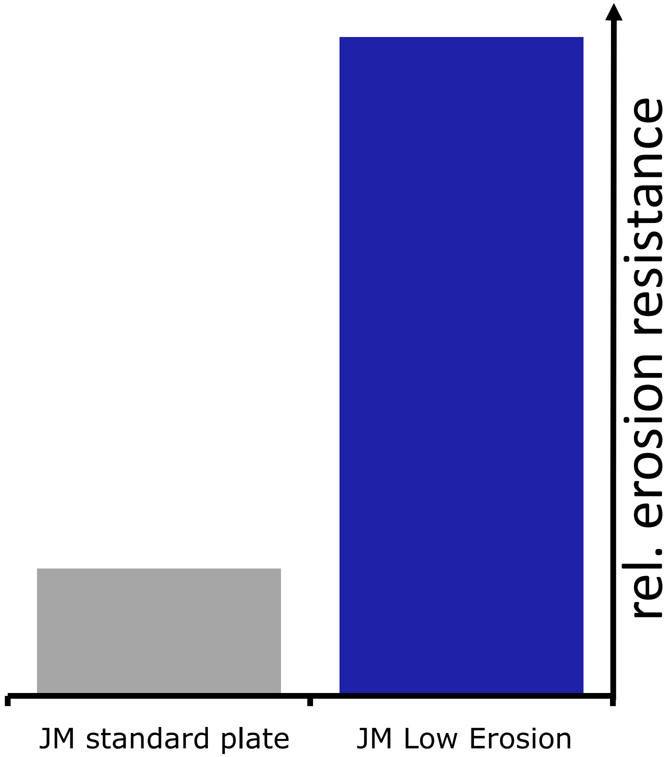
New plate catalyst development with high erosion resistance

JM standard plate catalyst

- high erosion resistance compared to honeycombs

JM Low Erosion – highly erosion resistant catalyst

- Erosion resistance boosted significantly
- Formulation optimized for high mechanical resistance

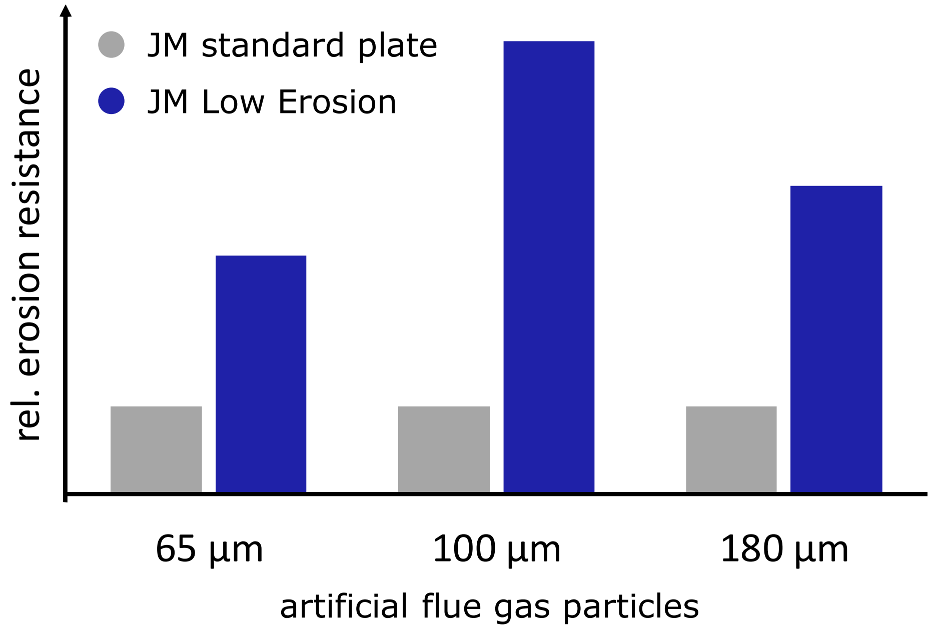


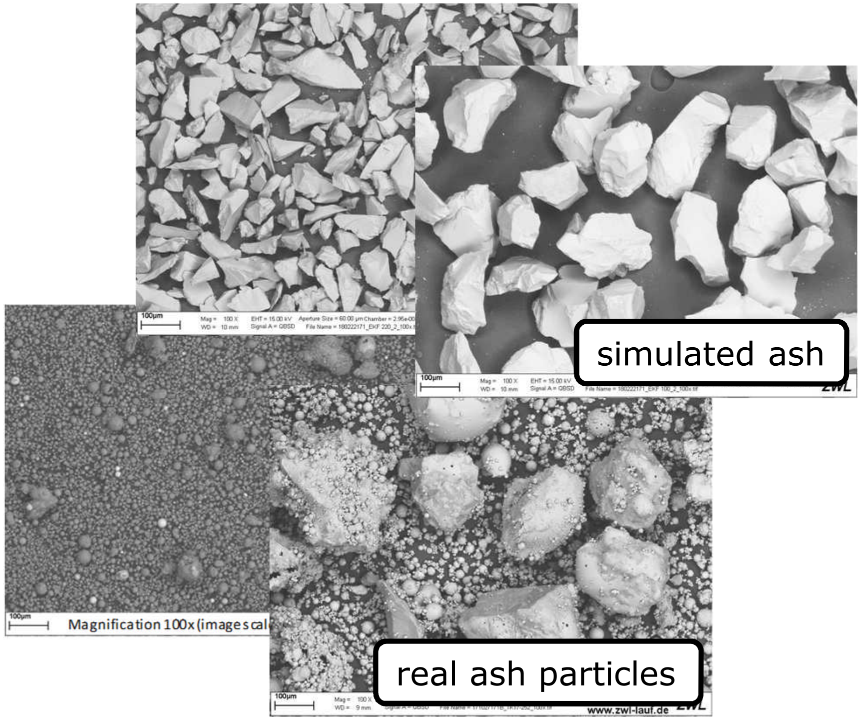
@ standard test conditions

Accelerated test was developed to achieve within one hour similar erosion as years in application

Erosion

New plate catalyst development with high erosion resistance





New catalyst shows superior erosion resistance even at large particle size (simulated ash particle)

Conclusion

Catalyst has a high contribution to low NH_3-content in fly ash under main prerequisites like

- Correct temperature window
- Correct flue gas distribution
- Correct catalyst selection and design

Required concentration of ammonia in fly ash of 50 mg/kg can be kept for e. g. under following conditions

- Fly ash 30 g/Nm³
- Ammonia slip < 2ppm (end of guarantee)

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Thank you for your attention!

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