IBAAS 2026
TECHNICAL LECTURE SERIES

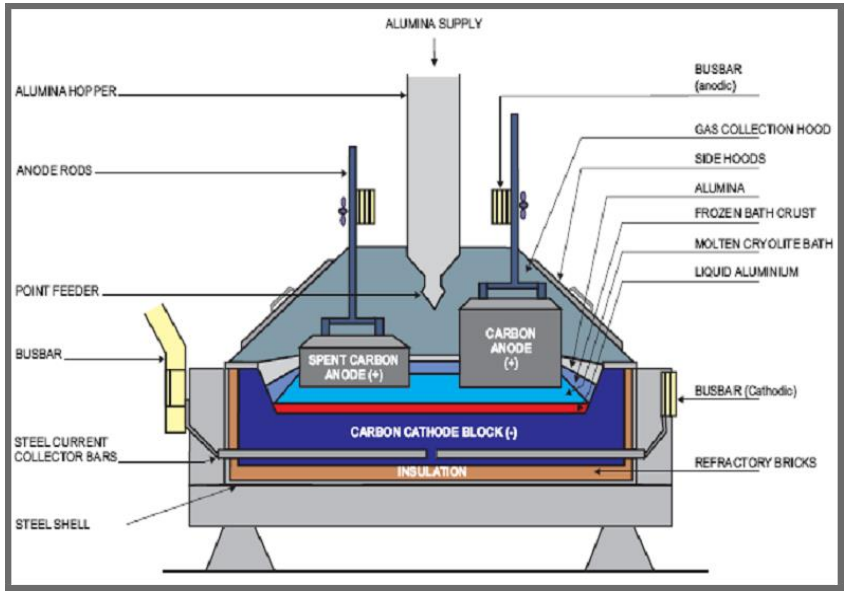
ANODE QUALITY OPTIMIZATION

K.M.KHAJI

Anode Quality Optimization

Primary aluminium is produced by electrolysis of alumina

Carbon blocks are used in electrolysis cells as anodes



Anode Quality Optimization

- About 410-430 kg of carbon anodes are consumed to produce 1 mt aluminium metal

- Functions of carbon anodes are:

  - Conduct electricity into electrolytic pots for electrolysis of alumina

  - Supply carbon for reaction with oxygen
    $2\ Al_2O_3 + 3C = 4\ Al + 3\ CO_2$

Anode Quality Optimization

Carbon anodes are required to have:

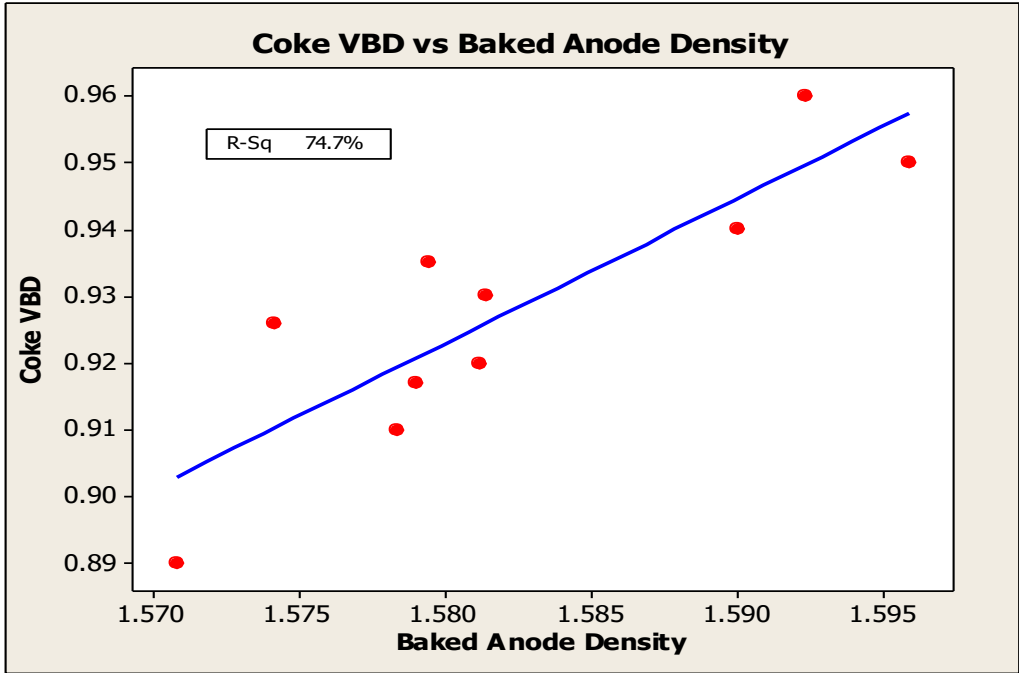
- Good apparent density
- Resistance to thermal shock
- Electrical resistivity
- Minimum chemical reactivity
- High mechanical strength
- High chemical purity
- No physical defects

Anode Quality Optimization: Baked Anode Density

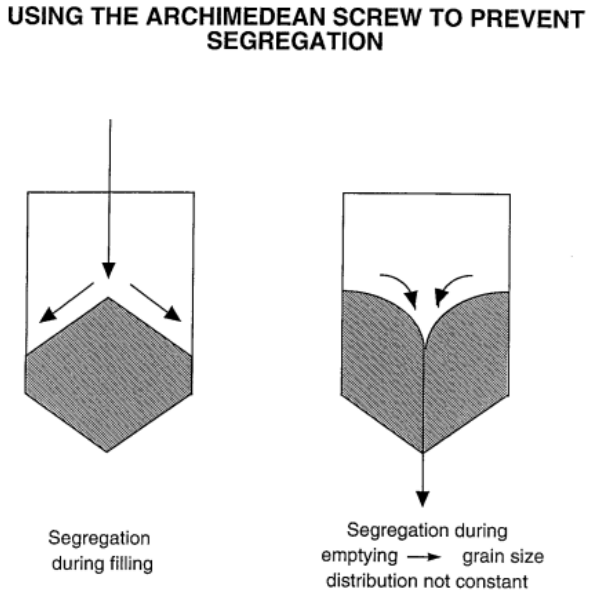
Baked Anode Density

Anode Quality Optimization

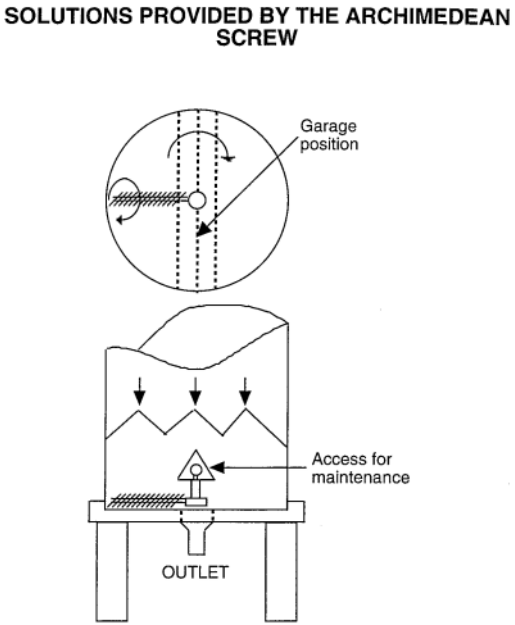
Coke VBD vs. Baked Anode Density



Segregations in Storage Silos



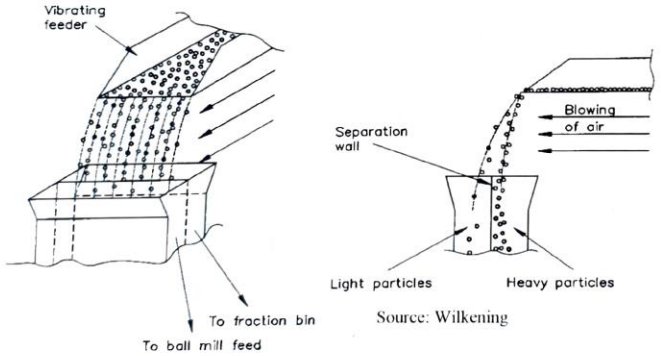
Extraction of Coke from Silos



Selective Processing of Coke

Plant improvements that helped maintain anode performance:

- Selective processing of aggregate:
  - Specific feeding of materials into the circuit:
    - Low density coke to Ball Mill
    - High density coke to coarse fractions
  - Separation and specific processing of light and dense aggregate particles



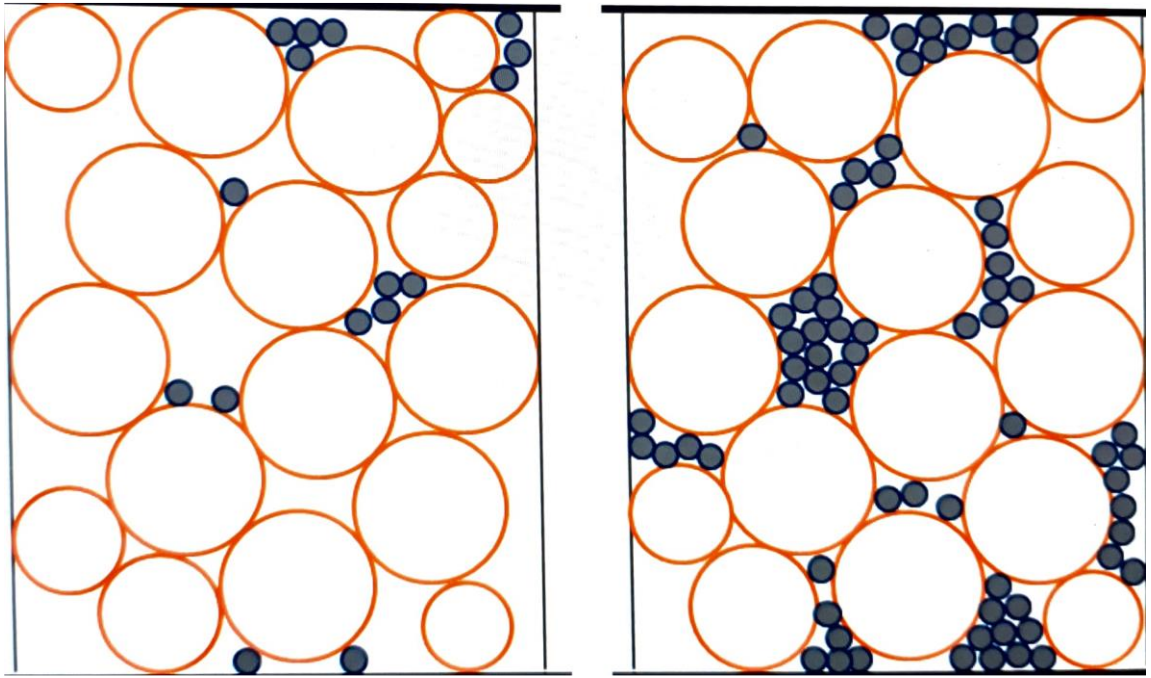
Source: Wilkening

Selective Crushing of Coke

- Selective “packed bed” crushing:
  - Softer, lower density particles are preferentially crushed into finer fractions
  - Roll crushers
  - New crusher variants

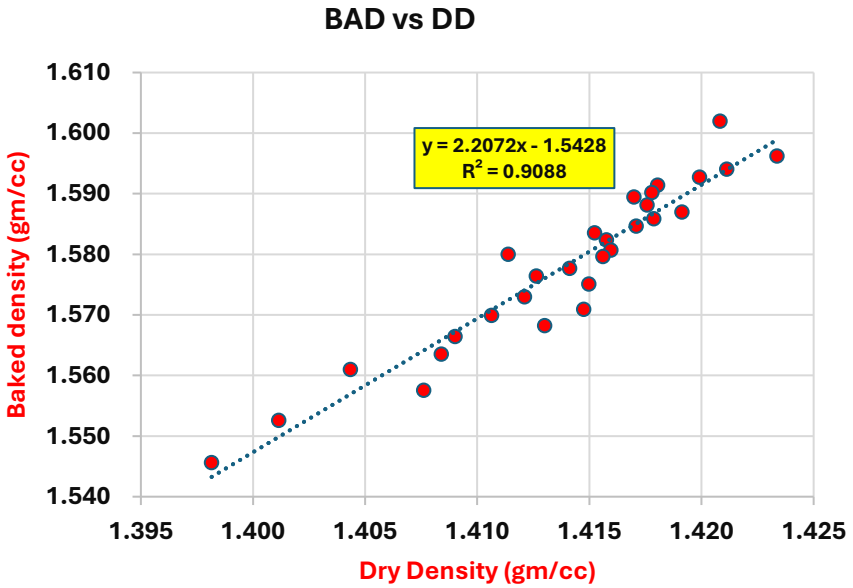
Anode Quality Optimization

Dry Aggregate Bulk Density



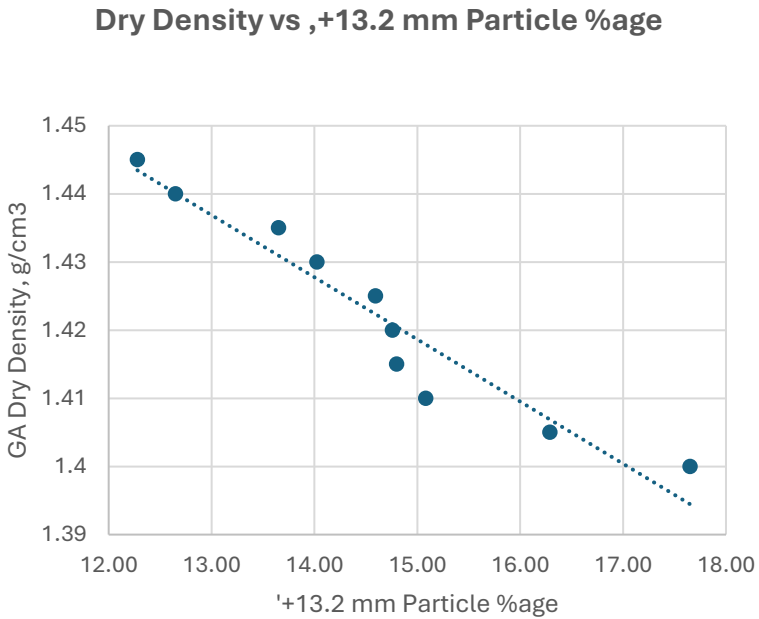
Anode Quality Optimization

Baked Anode Density vs. Dry Density



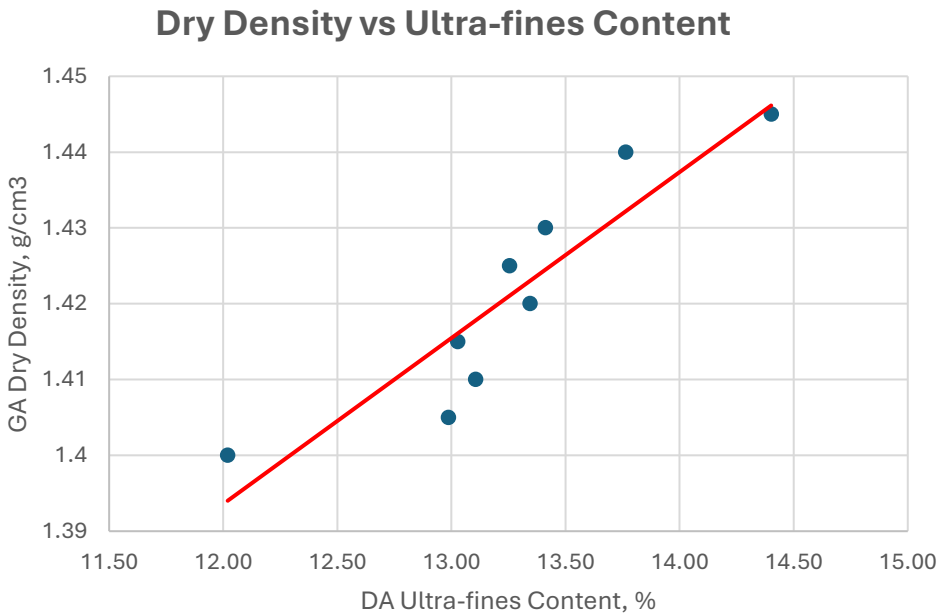
Anode Quality Optimization

Dry Density vs. +13.2 mm Particle %age

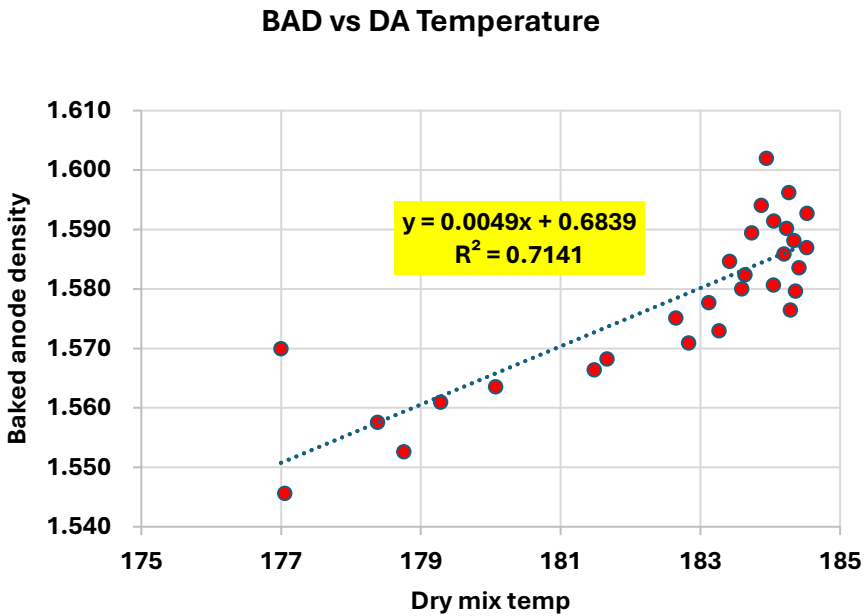


Anode Quality Optimization

Dry Density vs. Ultra-fines Content

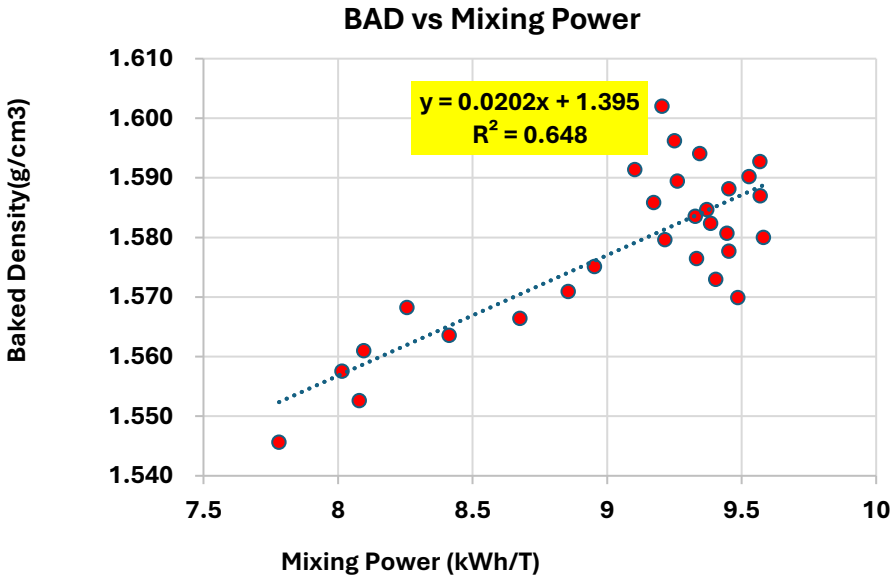


Baked Anode Density vs. Dry Mix Temperature



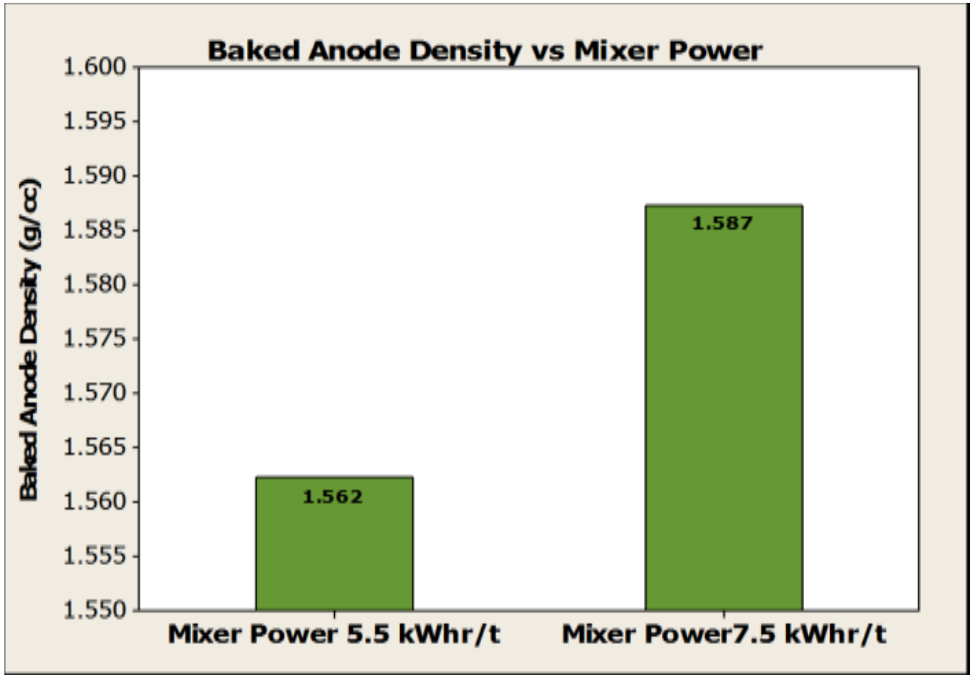
Anode Quality Optimization

Baked Anode Density vs. Mixing Power



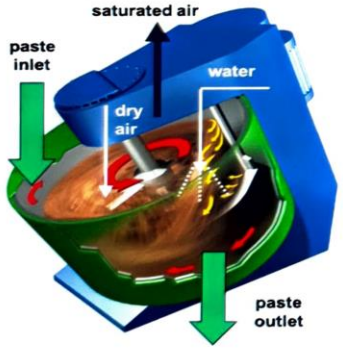
Anode Quality Optimization

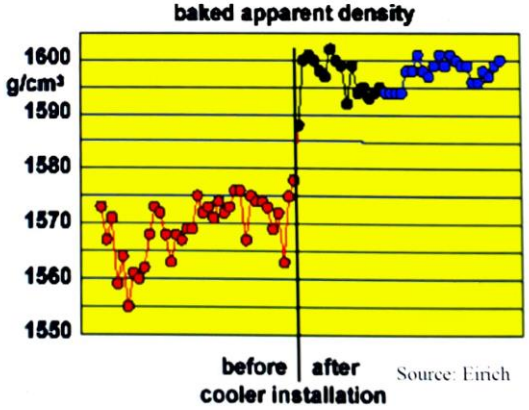
Paste Mixing Energy



High Temperature Mixing

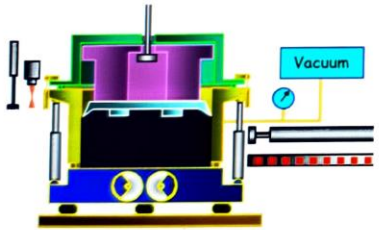
- Higher temperature processing to help achieve target anode properties (e.g. density):
  - Paste cooling to allow higher mixing temperatures
  - Vacuum to allow anode forming at higher temperatures

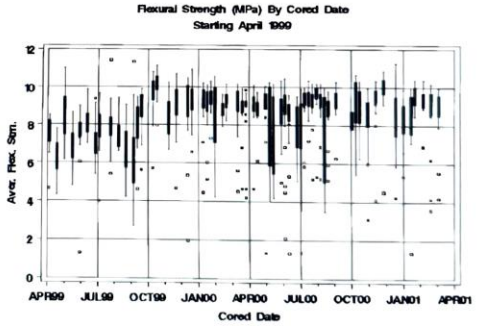




Vacuum Vibro-compacting

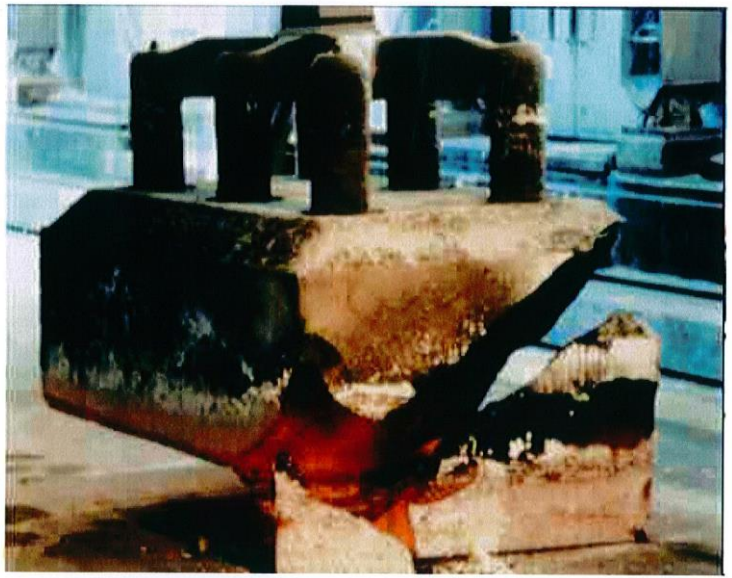
- Higher intensity processing to help achieve target anode properties (e.g. density):
  - Vibroformer coverweight pressure
    - Very high green anode density possible but with increasing risk of internal anode cracking
  - Vacuum vibroforming
    - Increases density, strength, and significantly reduces permeability





Thermal Shock Resistance

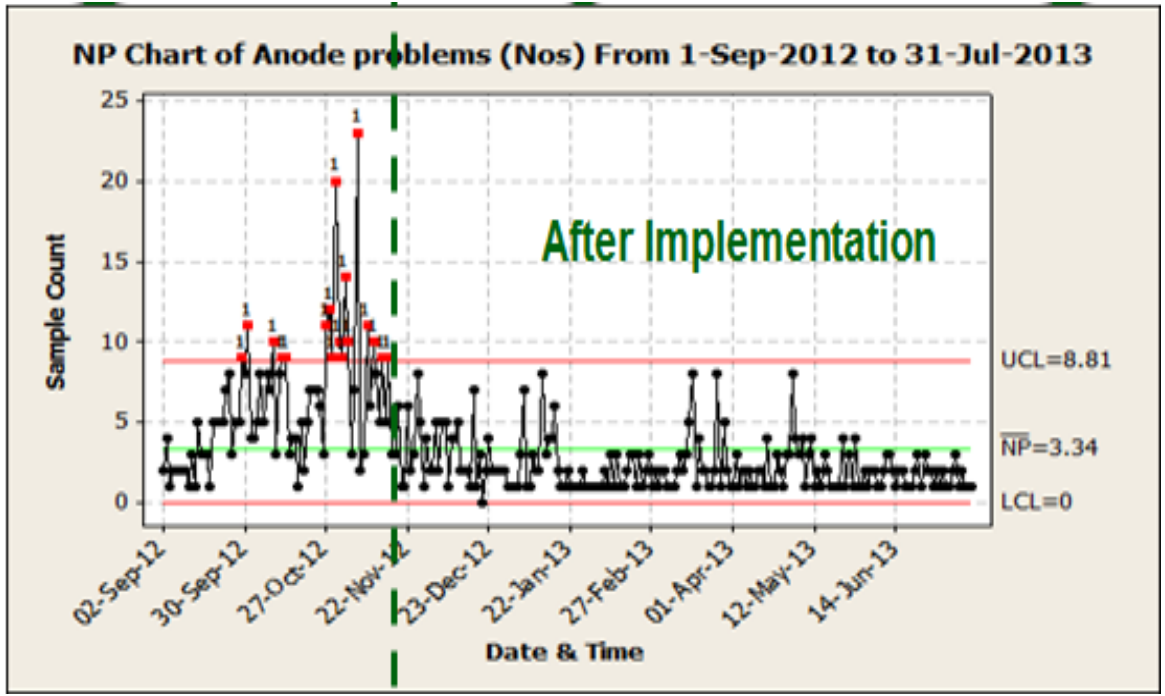
Thermal Shock Anode Cracking



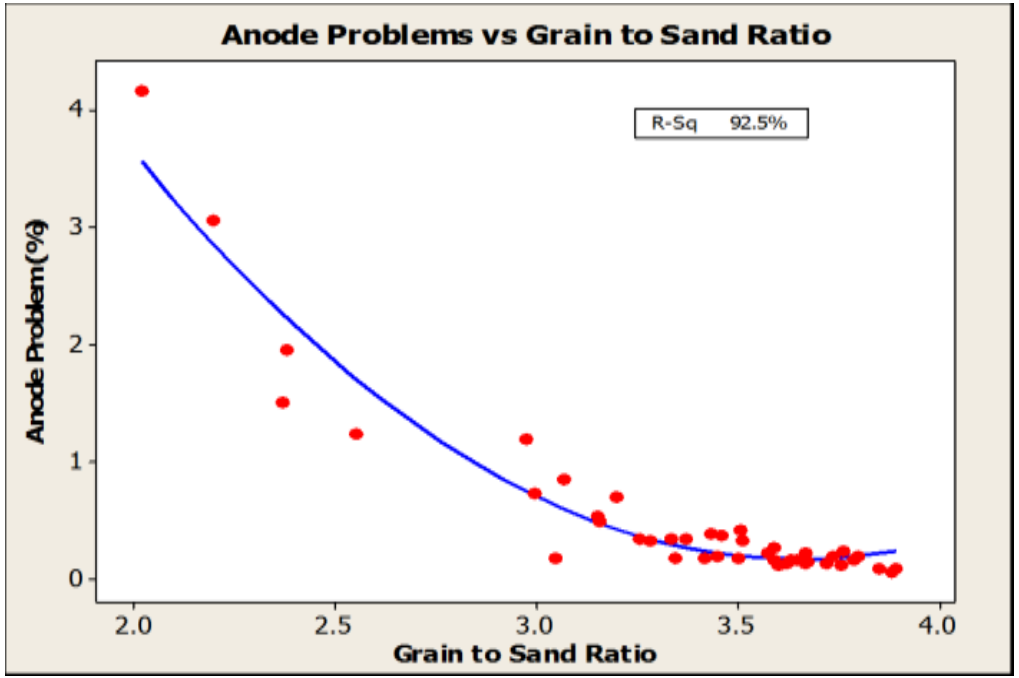
CORNER FRACTURE

Anode Quality Optimization

Anode Thermal Shock Cracking



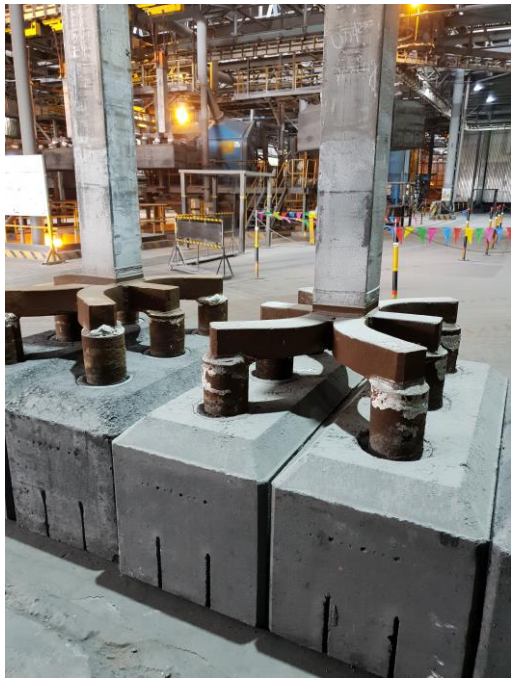
Thermal Shock Cracking vs. Grain to Sand Ratio



Slots for Thermal Shock Resistance

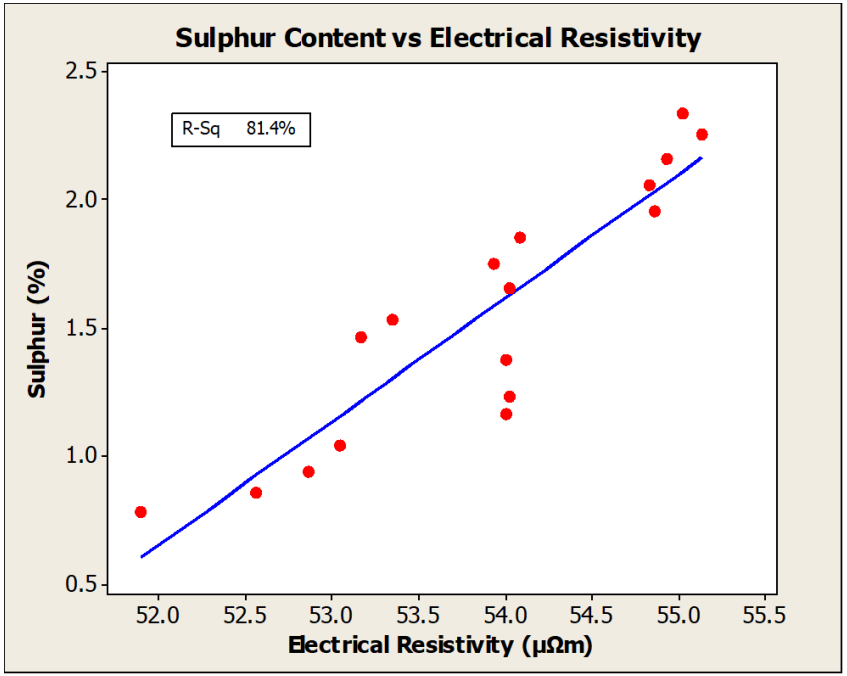
- Slots are made by sawing baked anodes or during vibro-compacting of green anodes
- Sawing gives better slot quality
- Forming is cheaper, but introduces heterogeneities around slots
- Depending on anode size, 1 – 3 slots are made
- Slots reduce bubble induced turbulence and oscillations of metal pad
- They reduce thermal stress and prevent thermal shock in newly changed anodes

Slots for Thermal Shock Resistance

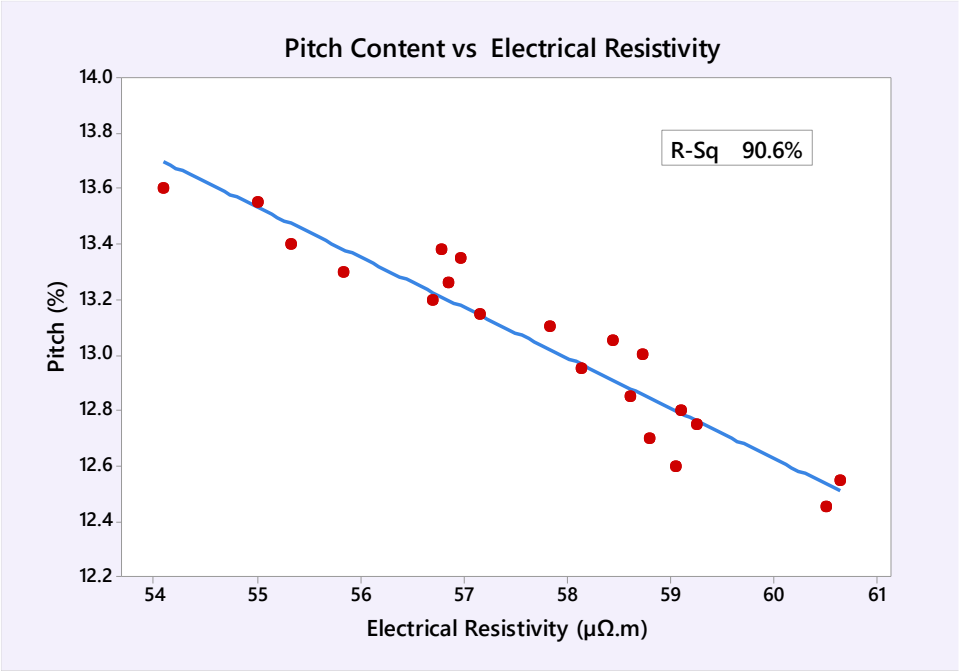


Electrical Resistivity

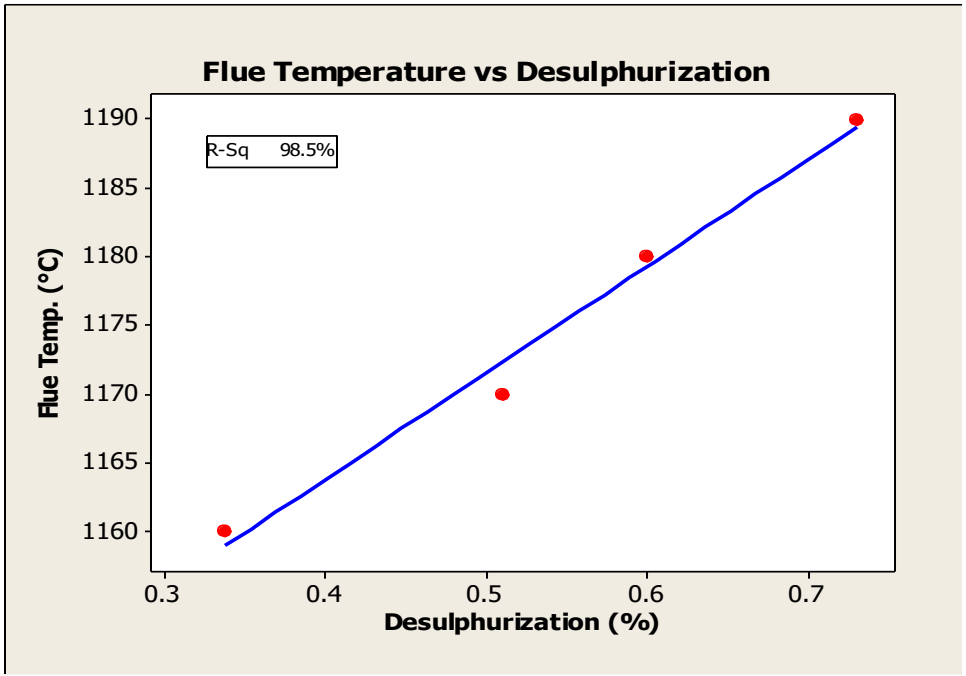
Impact of Sulphur Content on El. Resistivity



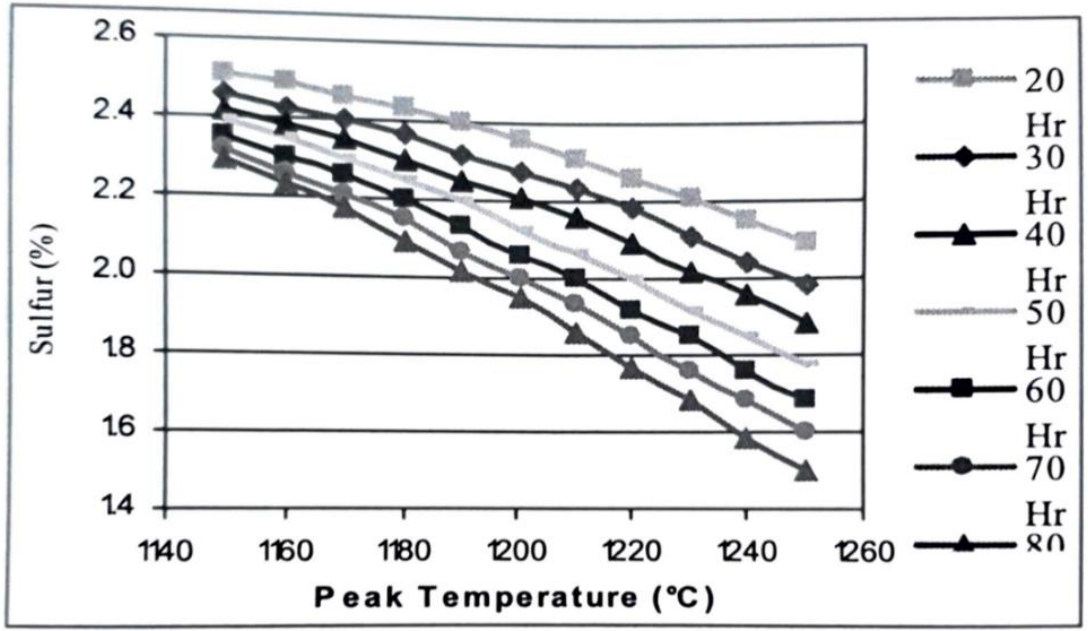
Impact of Pitch Content on El. Resistivity



Desulphurization during Baking

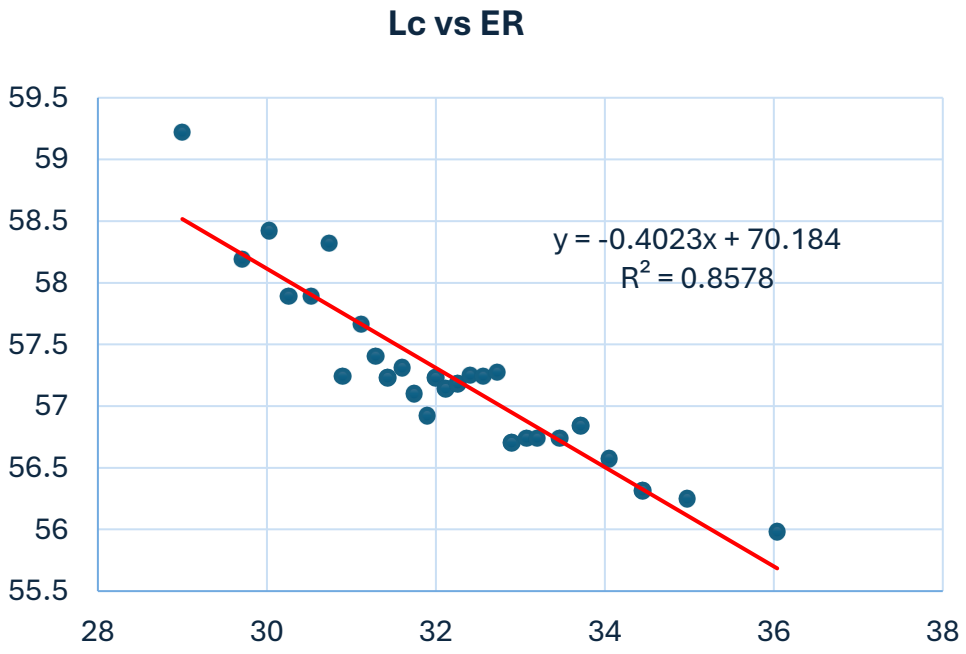


Desulphurization during Baking

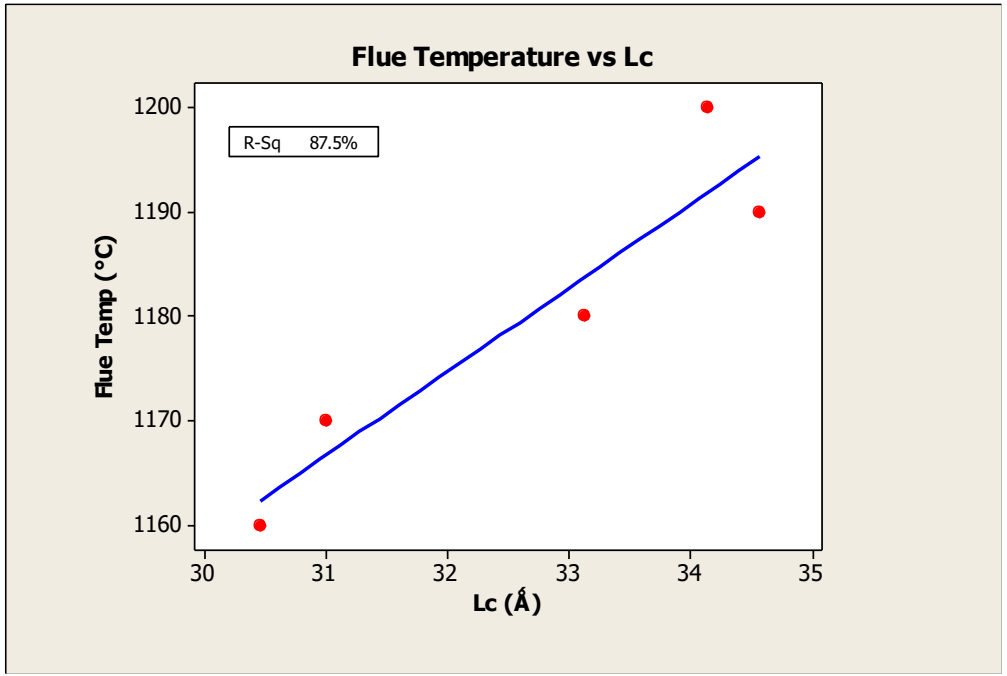


Anode Quality Optimization

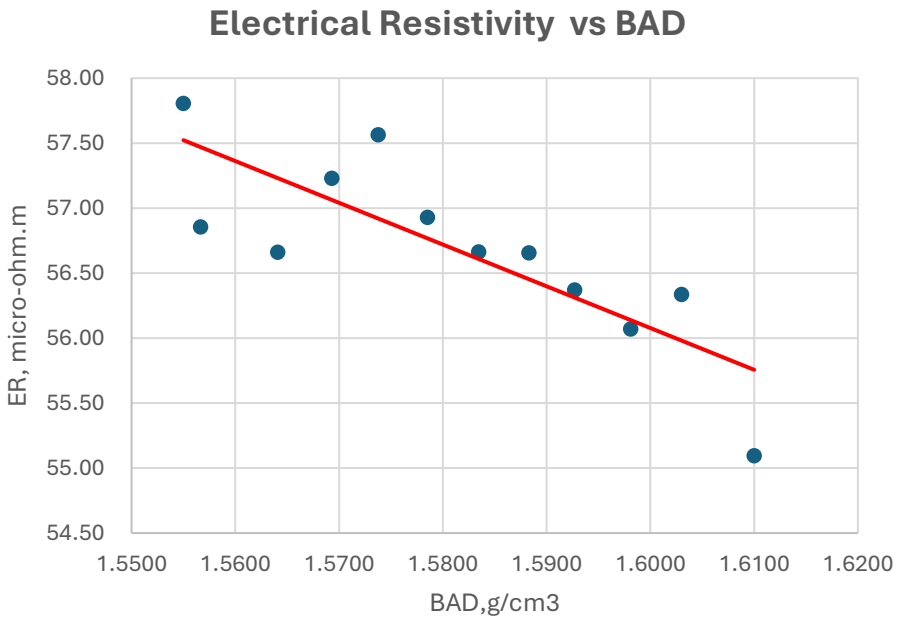
Anode Electrical Resistivity vs. L_c



Peak Flue Temperature vs. Baked Anode L_c

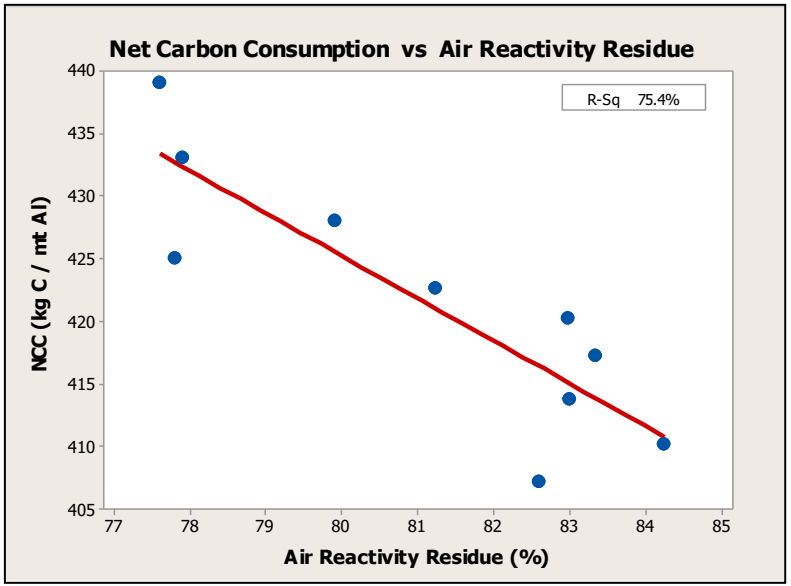


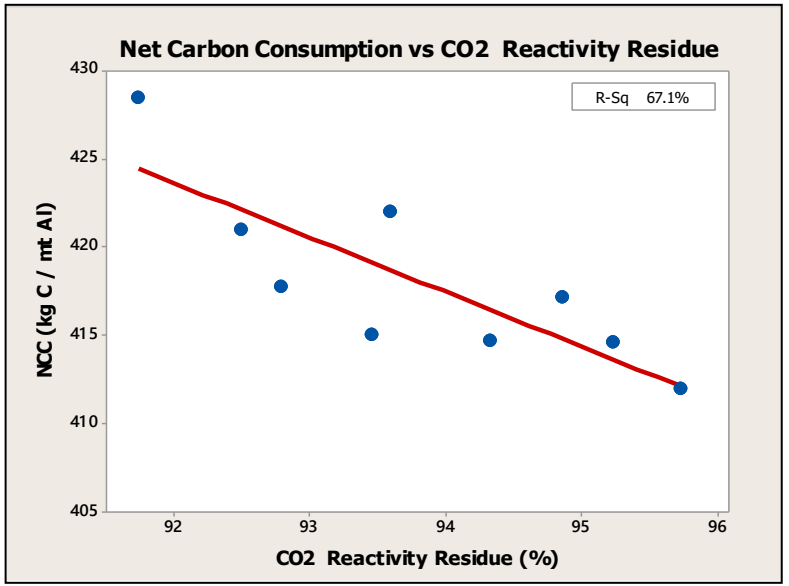
Electrical Resistivity vs. Baked Anode Density



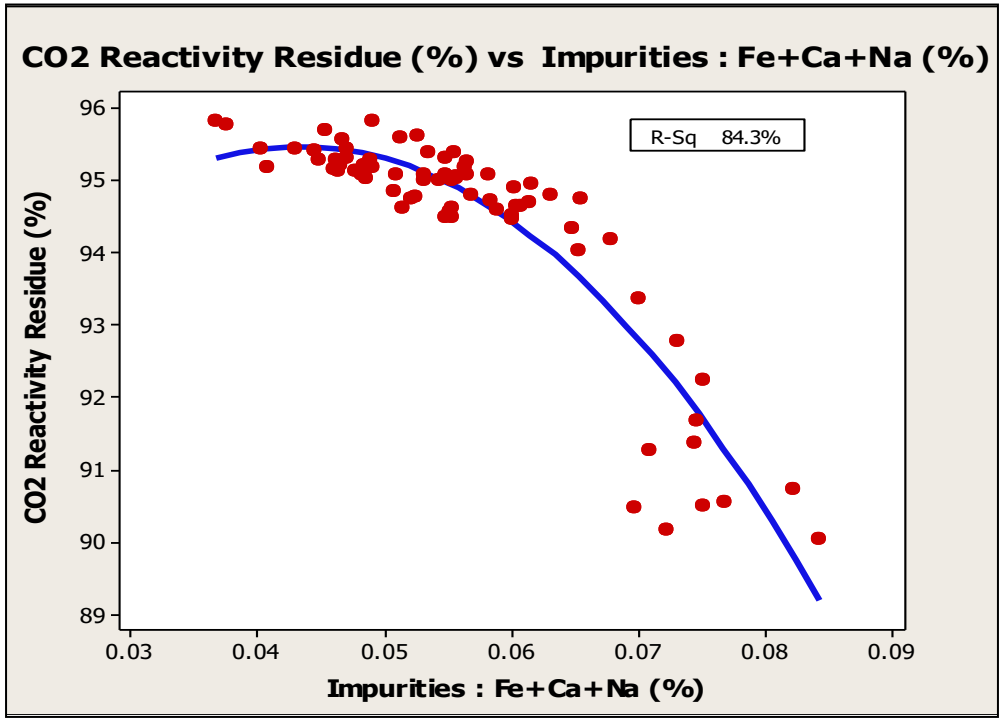
Chemical Reactivity

Net Carbon Consumption



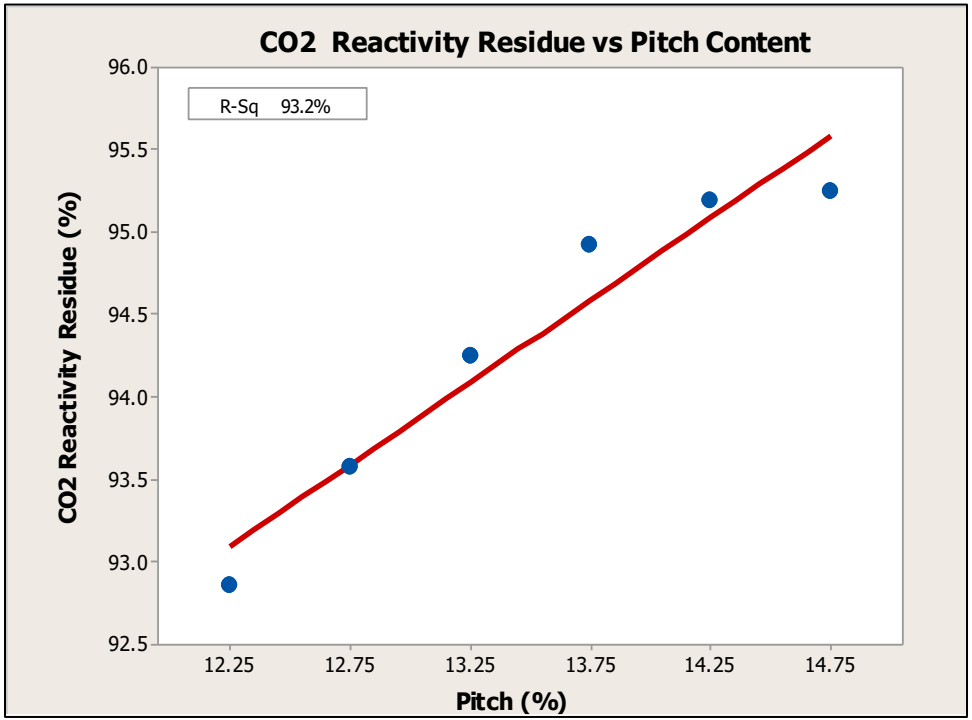


Impact of Anode Impurities

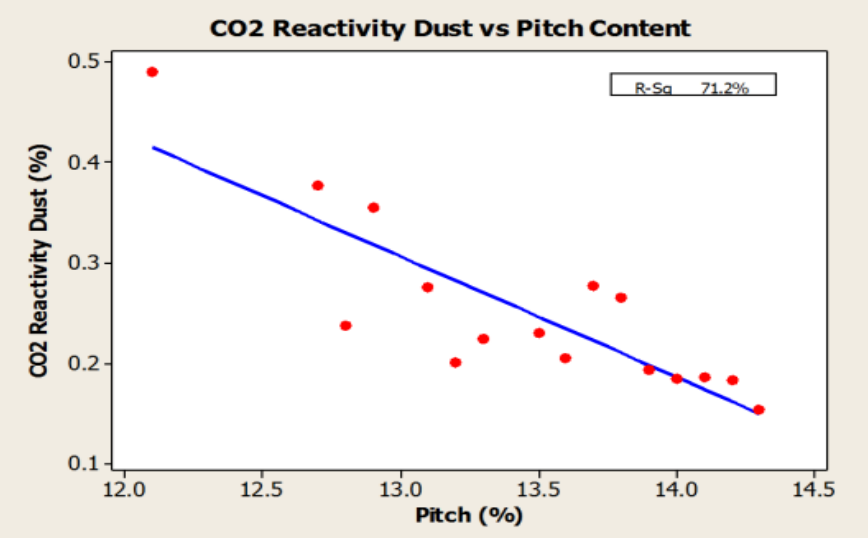


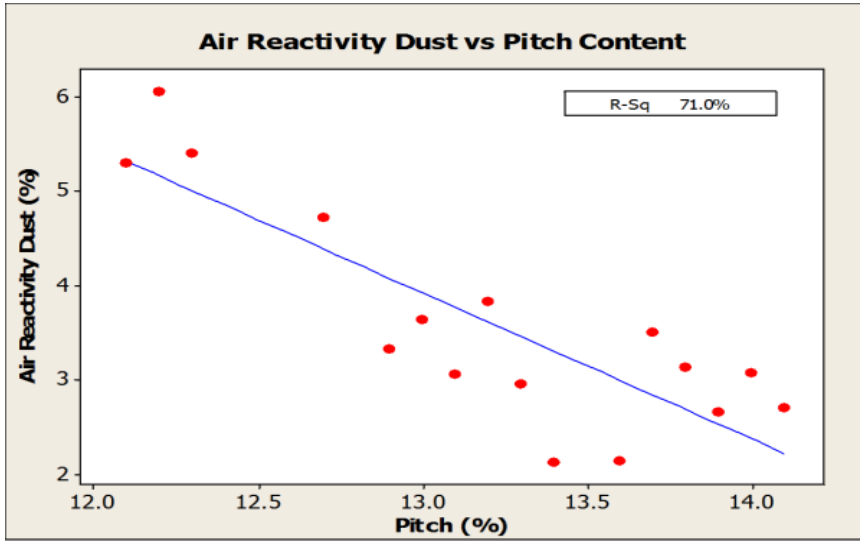
Anode Quality Optimization

Impact of Pitch Addition

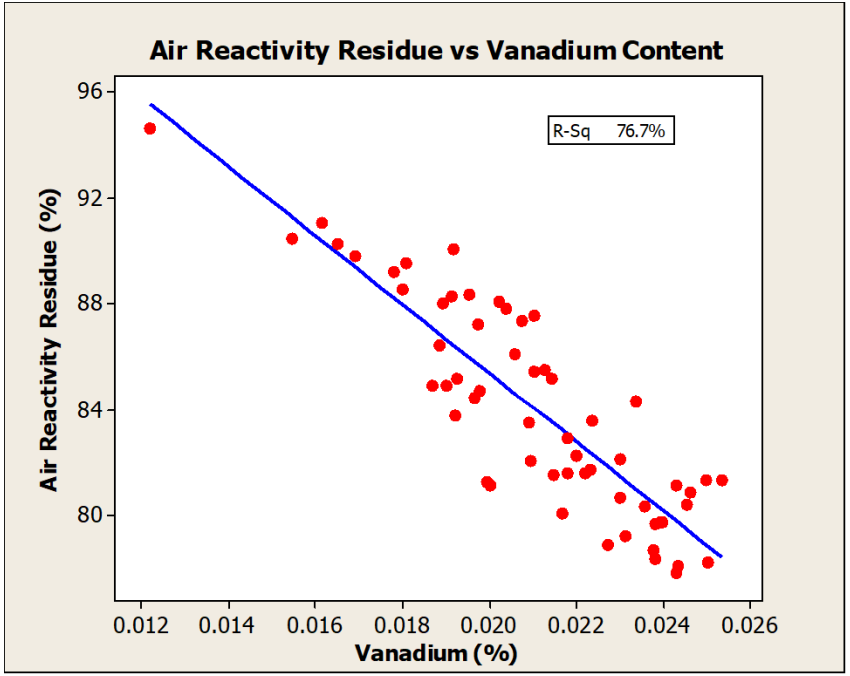


Reactivity Dust vs. Pitch Content



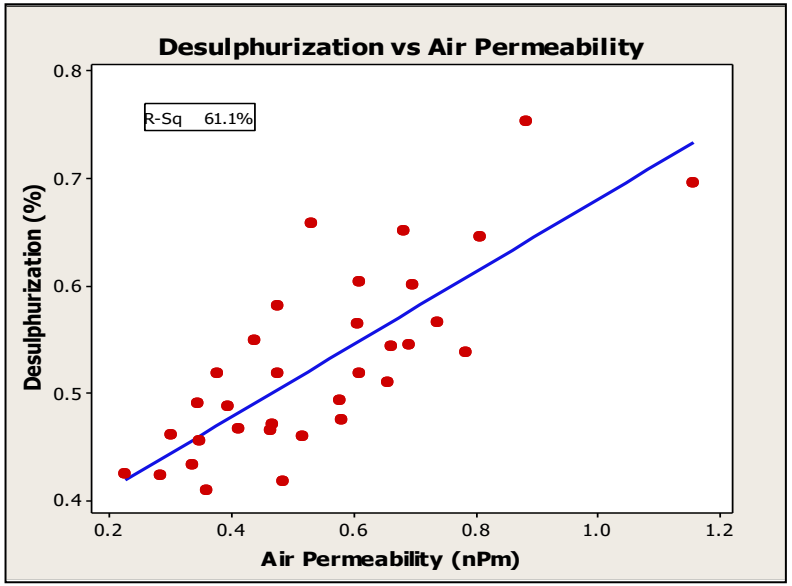


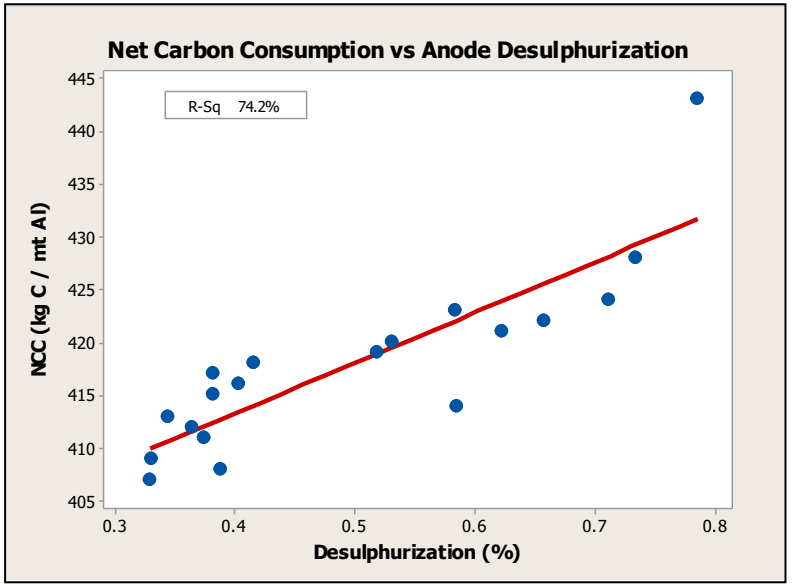
Impact of Impurities on Air Reactivity



Anode Quality Optimization

Impact of Anode Desulphurization





Factors Impacting Anode Chemical Reactivity

Process Parameters	CO_2 Reactivity		Air Reactivity	
	Residue	Dust	Residue	Dust
Pitch Addition	↑	↓	↑	↓
Desulphurization	↓	↑	↓	↑
Metallic Impurities	↓		↓	
Favourable to NCC		Adverse to NCC		

Physical Defects

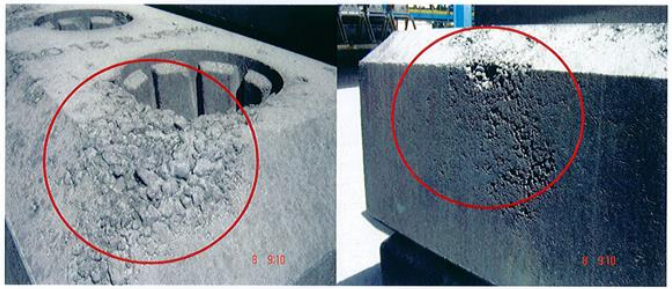
Anode Quality Optimization: Physical Defects

The anode must be free from:

- Segregation
- Horizontal and vertical cracks
- Cracks around the stub holes
- Bulging
- Peeling of surfaces
- Peeling at anode chamfer edges
- Air burn
- Deformation of dtub hole flutes and bottom

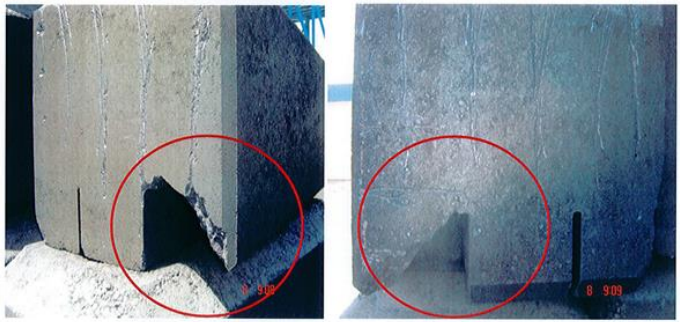
Anode Quality Optimization: Physical Defects

ANODES SEGREGATION. REJECT



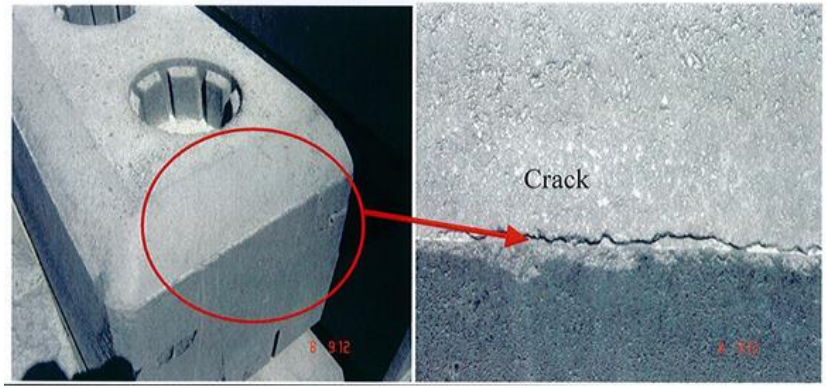
Top segregation Side segregation

DEFORMED ANODES. REJECT



Anode Quality Optimization: Physical Defects

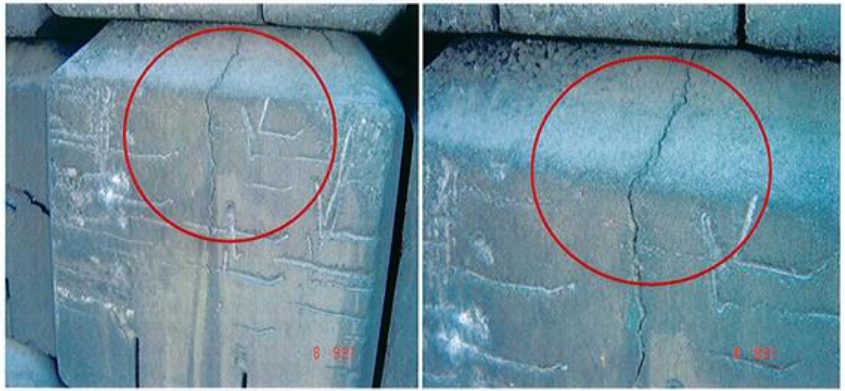
SHOULDER CRACKS. REJECT



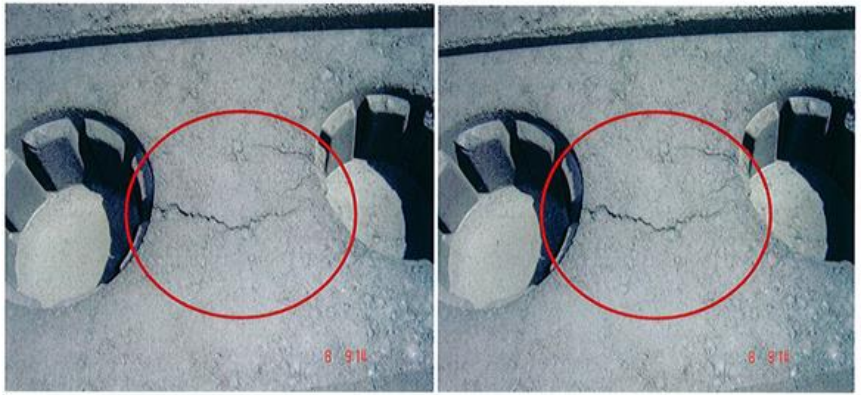
STICKING STUB HOLES. REJECT

Anode Quality Optimization: Physical Defects

HORIZONTAL & VERTICAL CRACKS. REJECT

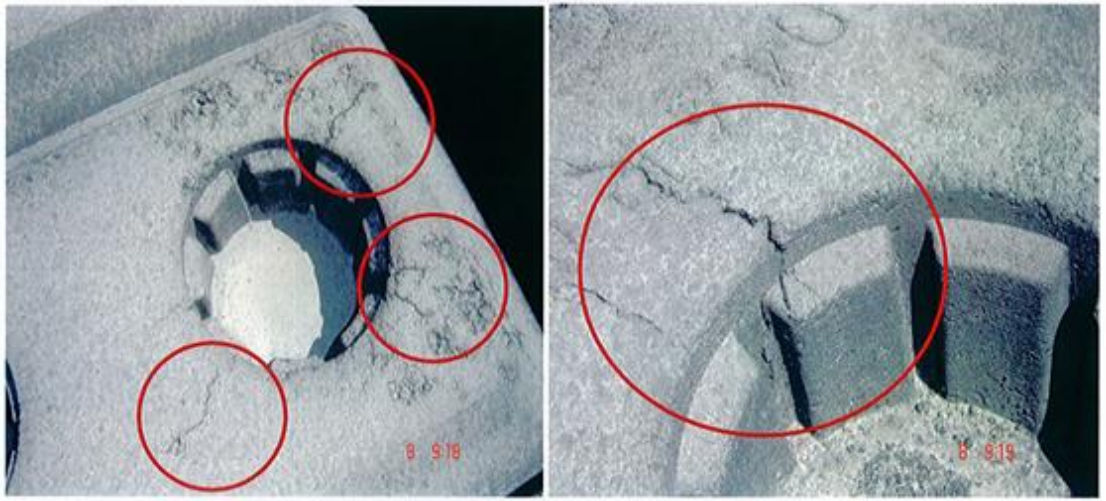


CRACKS BETWEEN STUB HOLES. REJECT

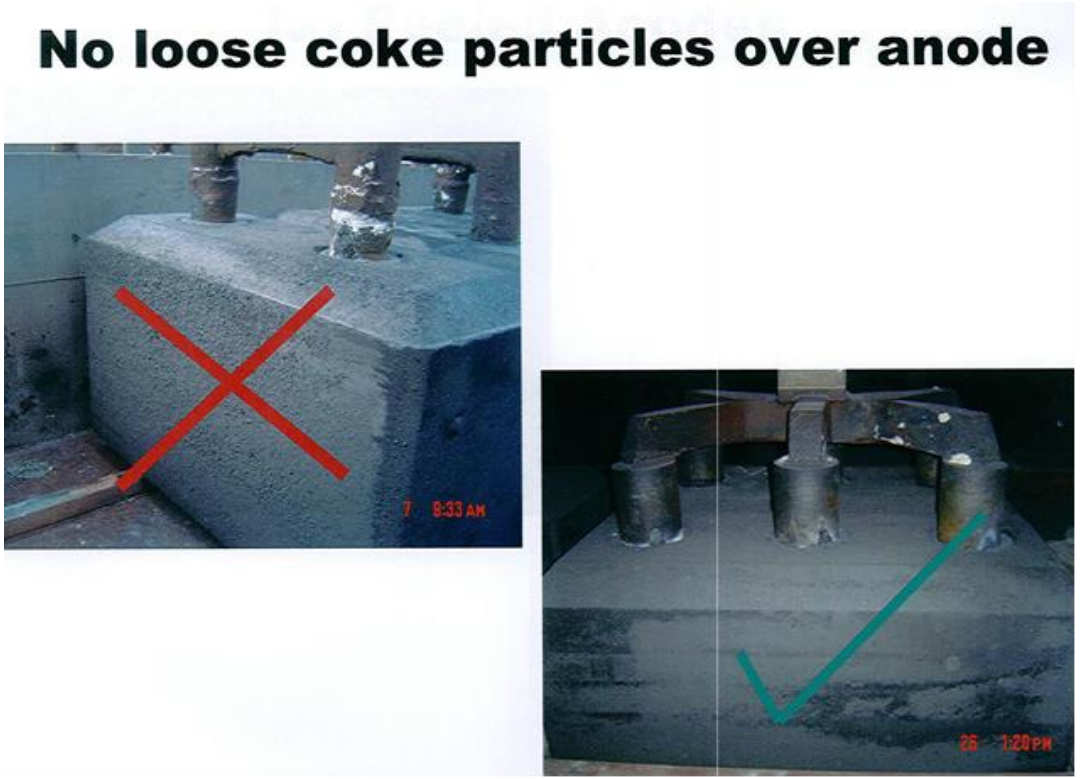


Anode Quality Optimization: Physical Defects

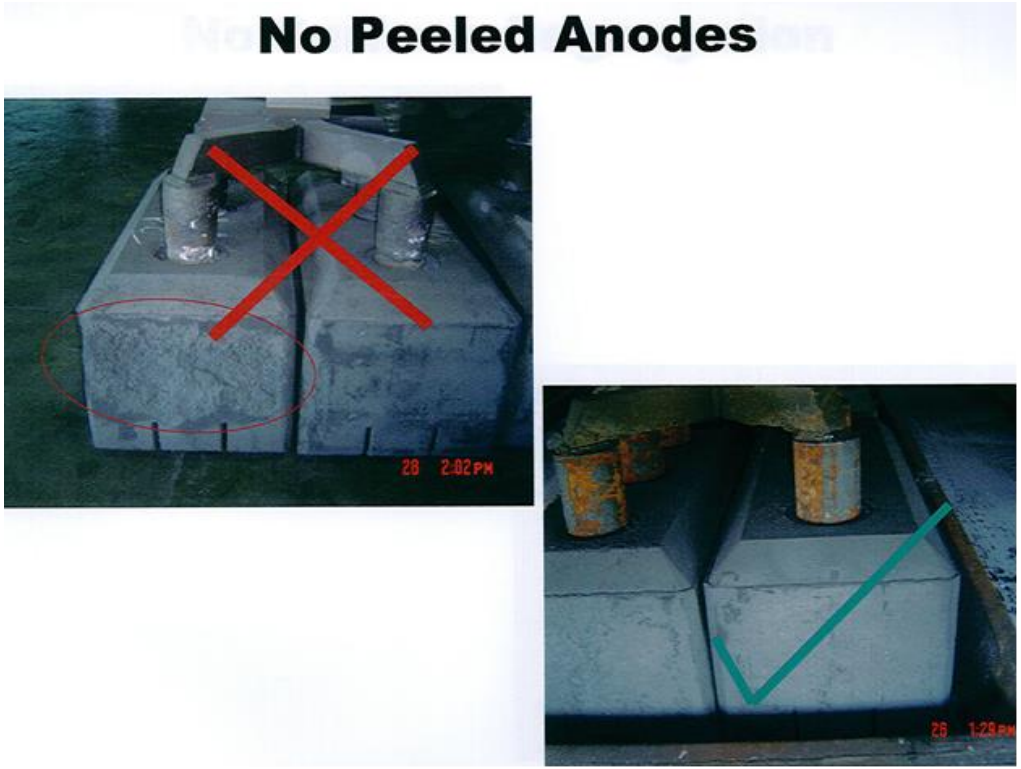
CRACKS AROUND STUB HOLES. REJECT



Anode Quality Optimization: Physical Defects

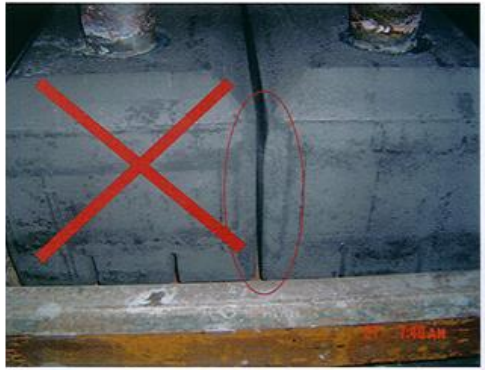


Anode Quality Optimization: Physical Defects



Anode Quality Optimization: Physical Defects

No Broken Corners



Anode Quality Optimization: Summary

Summary

Summary

- The baked anode density can be optimized blending low VBD cokes with high VBD of cokes, by minimizing variation in granulometry of cokes extracted from storage silos, by selective screening and crushing of cokes, by adjusting dry aggregate granulometry, by high temperature mixing of dry aggregate with binder, by using optimum mixing energy and by vacuum assisted paste compaction.

- The anode thermal shock resistance can be improved by increasing the GSR of dry aggregate and by providing slots in anodes

- The electrical resistivity of anodes can be reduced by reducing sulphur content in anodes, by increasing the Lc and by increasing the anode density. The sulphur content can be reduced by blending cokes, through pitch addition and by baking at higher temperatures.

- The chemical reactivity of anodes may be minimized by reducing metallic impurities, by reducing excessive desulphurization, by adequate addition of pitch, and by equalizing the reactivities of pitch coke and calcined petroleum coke.

Thank you

Open for discussions