Entrainment Reduction: Modeling & Plant Data

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Process Schematic

Chlorinator → TiCl₄ Condensation Purification → AlCl₃ Generator → Oxidizer → Pigment

Ore → Coke

TiCl₄

Al + Cl₂

TiCl₄ + Cl₂ + AlCl₃

Oxygen

Chlorine
Problem Description - Generator

- “Fluidized bed” with bed media & aluminum pellets
- Bottom inlet with discrete entry points
- Excessive media entrainment
  - Pluggages & downtime in oxidizer
  - Bed sintering when sat down
- Superficial velocity < terminal velocity
- Sufficient disengagement height

Inlet (TiCl₄ + Cl₂)

Outlets (TiCl₄ + Cl₂ + AlCl₃)
Proposal #1: Change Media

- Alternative media
- Dense media
- Larger media
- Issues
- Cost
- Media chlorination
Proposal #1: Change Media

**Normalized Mass in Bed**

- **Densest**
- **Standard**

**Normalized Mass in Bed**

- **Larger**
- **Standard**
Proposal #2: Look at Design

Gas only flow with Fluent: Large central plume, velocity above terminal velocity
Proposal #2: Look at Design

Areas above superficial velocity

Task: Reduce the height and intensity of central plume, while retaining bottom design
Alternate Designs

- Increased hole diameter
- Increased hole diameter + added rows
Alternate Designs

Existing

Larger Holes (LH)

Larger Holes + Additional Row (LH+NR)

Areas above superficial velocity
Alternate Designs – Volume Fractions

Existing

Larger Holes

Larger Holes + Additional Row
Alternate Designs – Entrainment Comparison

**Key:**
- LH: larger holes
- NR: new row

**Diagram:**
- **Uniform**
- **LH + NR**
- **LH**
- **Existing**

**Graph:**
- **Normalized Bed Mass vs Time**
- X-axis: Time (s)
- Y-axis: Normalized Bed Mass (m)
- Lines indicate the trend over time for different designs.
Additional Designs

**Key:**
- LH: larger holes
- NR: new row
- LD: larger diameter
- IH: increased height
Additional Designs

Key:
LH: larger holes
NR: new row
LD: larger diameter
IH: increased height

LH
LH + NR
LH + NR + LD
LH + NR + LD + IH
LH + NR + IH
Increased diameter has less effect than increased height.
Recommendations & Outcome

- Distributor design contributes to increased entrainment
- Denser/larger media is better than standard media
- Larger holes + extra row reduces entrainment by reducing height of central plume
- Increasing hearth diameter has same effect as increasing hole size
- Increasing the height provides lowest entrainment rate
- Implemented in plant: larger holes + additional row + increased height
- Reduction of entrainment > 80%
- Substantial reduction in oxidizer downtime
Recommendations & Outcome

Low Rate

High Rate
Observations

- Project took ~ 2 months
- GPU capability of CPFD allowed for rapid iteration of designs
- Injection BC capability provides for more realistic boundary conditions
- Request:
  - Ability to see injection points after grid is generated & .csv file read in
  - No need to run a single time-step first
Chlorinator Entrainment

- Changes:
  - Geometry
  - Ore & coke feed
  - Distributor design
  - Start-up procedures
  - Effect of PSD
- Resulted > 1% reduction in losses