VISION, INNOVATION AND IDENTITY:

STEP CHANGE FOR A SUSTAINABLE FUTURE

SME

2018 SME ANNUAL CONFERENCE & EXPO

MN 2018

91ST ANNUAL MEETING OF THE SME-MN SECTION

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DEM Modeling: Changing Bulk Material Handling Analysis in the Mining Industry

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JENIKE & JOHANSON

Who We Are

- A specialized engineering firm focusing on providing clients solutions to material handling applications
- Scientific approach, not trial and error
- Engineering and lab facilities in USA, Canada, Chile, Brazil, & Australia
- 52 years in business

Outline

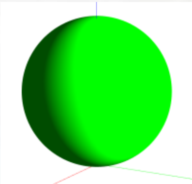
- Discrete Element Method (DEM): Then and Now
- Case Study #1: Design of bottom dump potash skip bin
- Case Study #2: Redesign of 3 magnetite concentrate transfer chutes
- Case Study #3: Solving carrying-back issues with mining trucks

Discrete Element Method (DEM): Then and Now

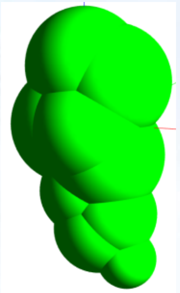
- Before DEM, used dynamics to predict stream trajectory in a chute
- DEM is a numerical technique to study behavior of particulate material
- Proposed by Cundall and Strack (1979) to address rock mechanics
- ~12 years ago, first commercial DEM programs started coming out
- Details about DEM
  - Computationally intensive
  - Limitations are number of particles → lengthens run time
  - Essential that model be calibrated to match material flow properties
  - Initially used only spherical particles, but now can do particle shape

DEM Then and Now: Particle Shape

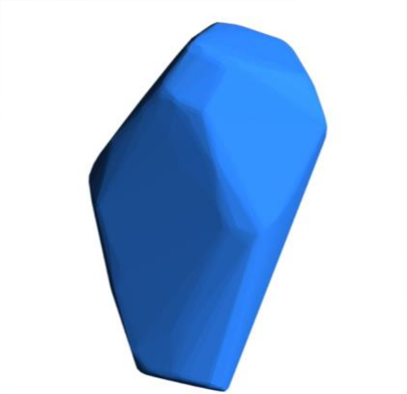
Actual particle



Sphere representation (or cluster)



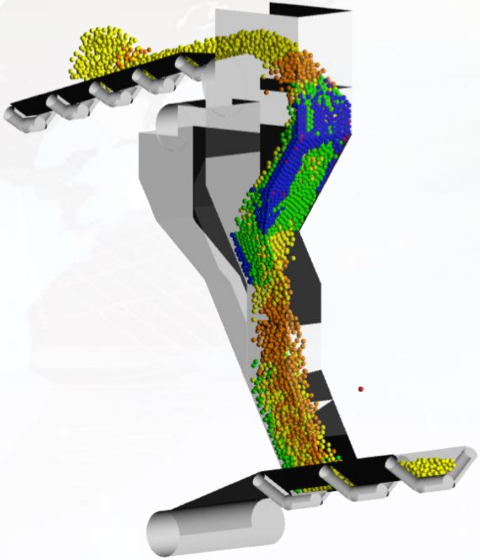
3D scan



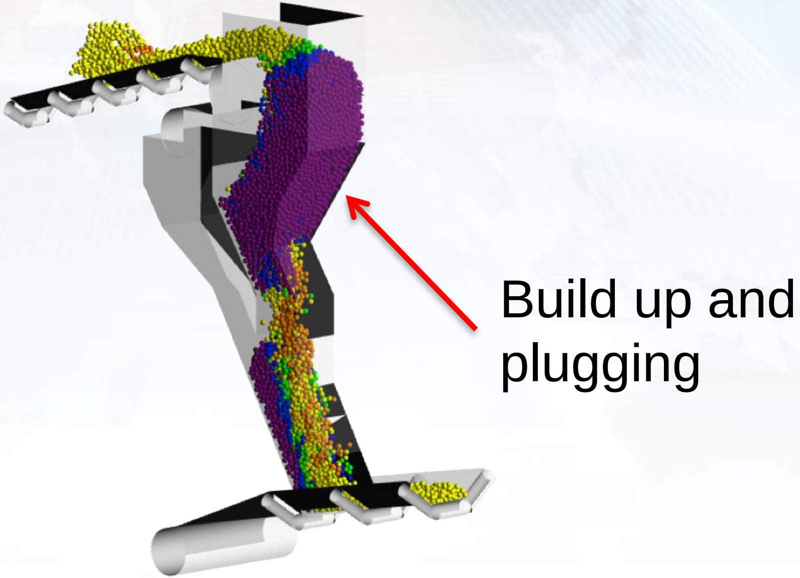
Simplified particle

DEM Then and Now: Particle Shape

DEM: Calibration is very important



Without cohesion



With cohesion (calibrated)

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Case Study #1:
Design of 50-t bottom dump potash skip

- Unique challenge!
- First ever 50-t capacity skip for hauling potash
- Concerns:
  - How to accurately predict discharge (cycle) time
  - Bridging or build-up
- Options?

Case Study #1:
Design of 50-t bottom dump potash skip

- Then: Physical modeling
  - Scale, results interpretation, $$, geometry changes, sample quantity, schedule
- Now: DEM flow simulations
  - Limitations in computing power, run time, small scale tests, precommissioning

Case Study #1:
Design of 50-t bottom dump potash skip

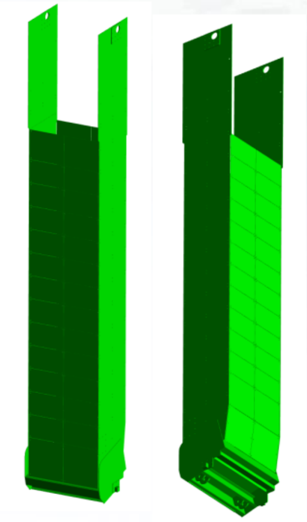
- DEM skip analysis steps:
  - Flow properties (DEM model parameters):
    - particle density, particle-to-particle friction & cohesion, particle-to-skip wall friction
  - Calibration
    - Simulate existing 30-t skip, fine tune DEM parameters to match the observed operation (especially payload, gate opening, and discharge time).
  - Simulate 50-t skip operation
    - Use calibrated DEM parameters to predict discharge for the proposed new 50-t skip design and modify geometry, if required.

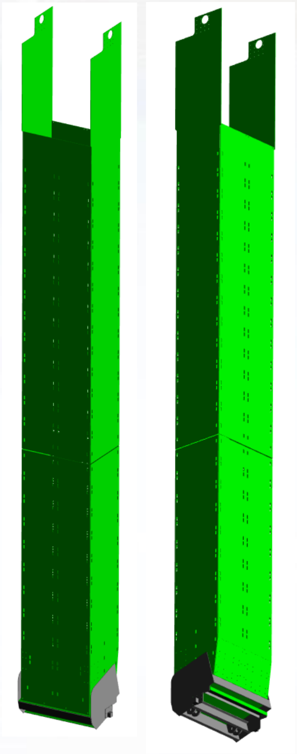
Case Study #1: Design of 50-t bottom dump potash skip

- DEM predictions:
  - Skip discharge time → Critical for load cycle time requirements
  - Flow pattern (velocity profile) → Stable uniform flow minimizes product attrition, wear, and tendency for vibration or quaking
  - Adequacy of skip discharge motion, timing and sequence

Case Study #1:

- DEM model: 30-t skip 50-t skip

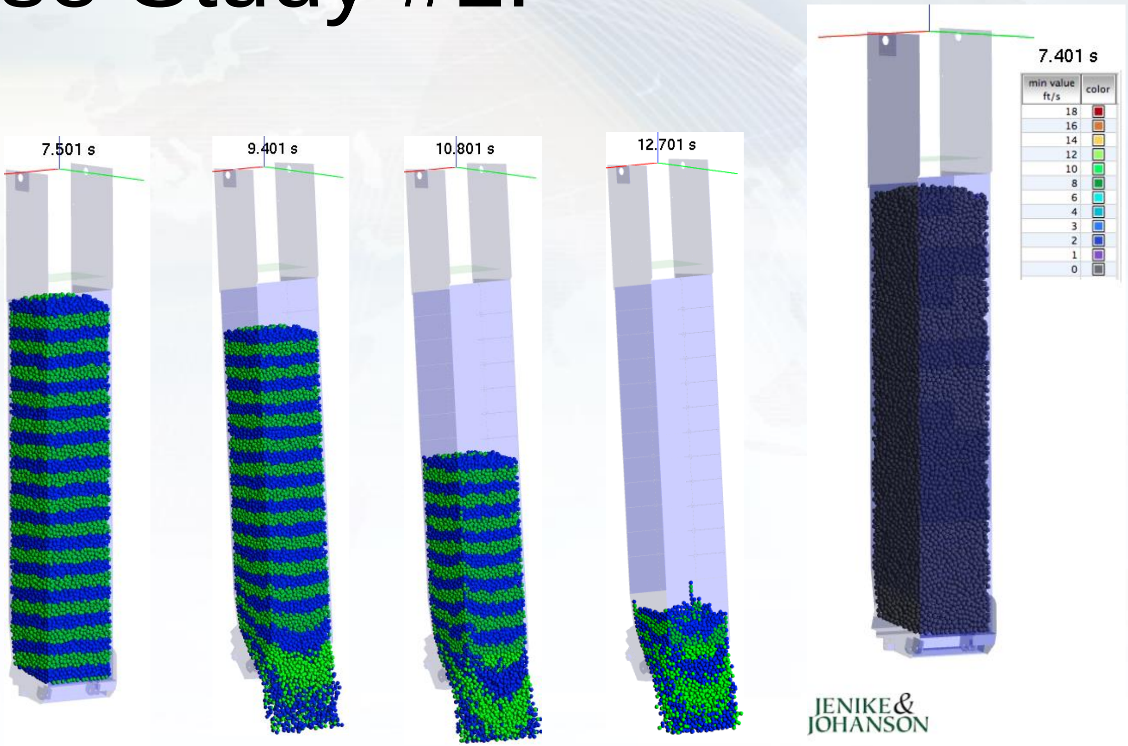




Case Study #1:

DEM simulation:

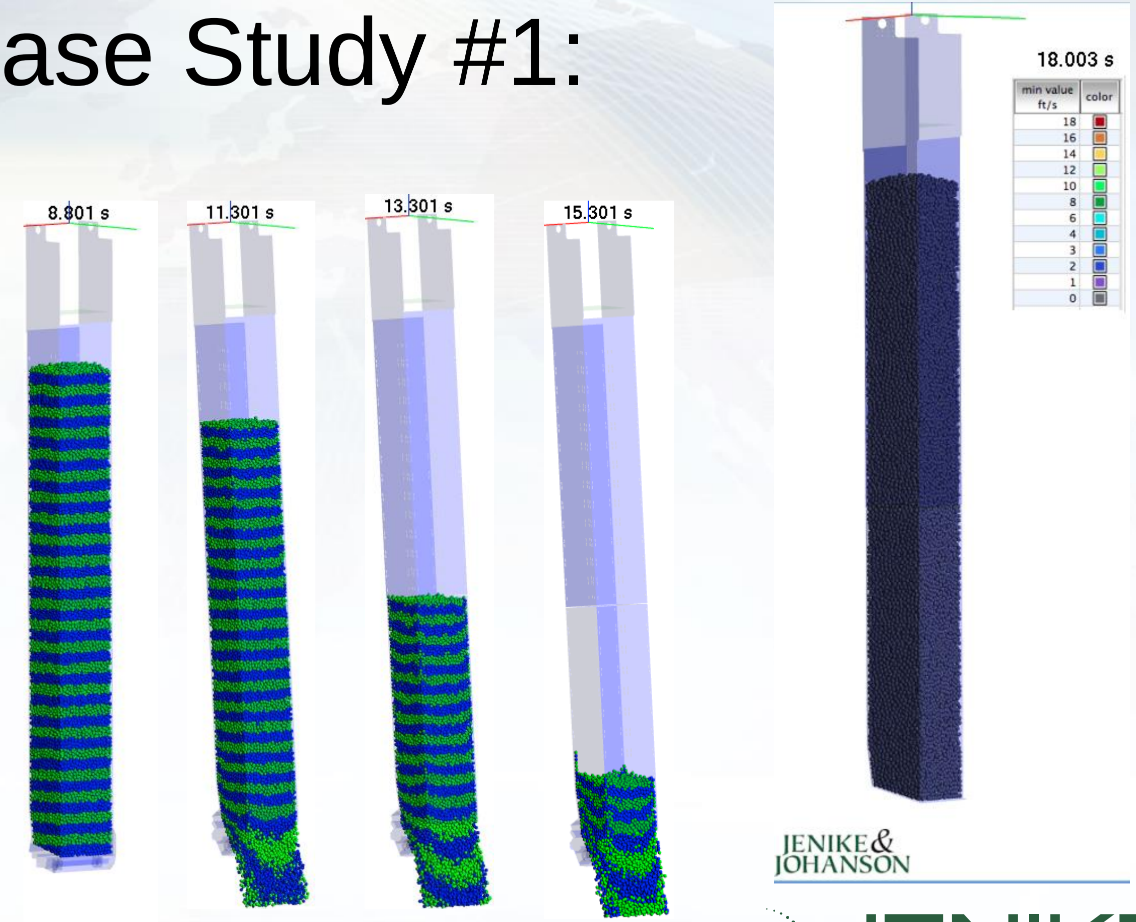
Existing 30-t skip



Case Study #1:

DEM simulation:

New 50-t skip



Plumb test at Wabi’s site

Mine site

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Case Study #1: Design of 50-t bottom dump potash skip

- DEM results gave the project team confidence that reliable handling would be achieved
  - “The storage height of the 50-t skip bin worried us greatly as we expected bridging issues. The modeling didn’t show this and we didn’t experience such incidents during operation. The skips have now been operating for approximately 5 years under a variety of material consistencies (granularity and moisture variability) with no incidents of bridging or build-up. Liner wear has also been remarkably uniform for such a slender material column”
    –Stan Gorzalczynski, President, Wabi Iron & Steel Corp.

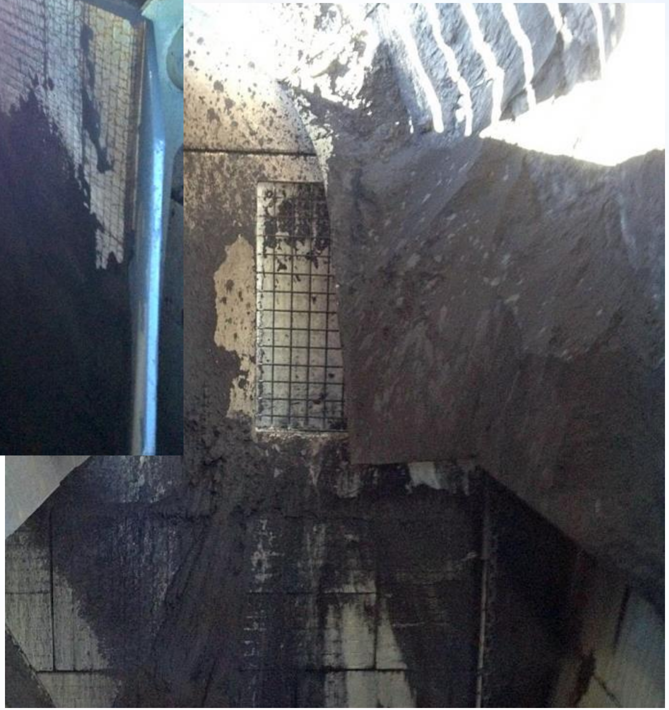
Case Study #2: Redesign of 3 magnetite concentrate transfer chutes

- Citic Pacific Mining, Cape Preston Sino Iron Terminal in Western Australia
- Handled magnetite concentrate from stockyard to barges

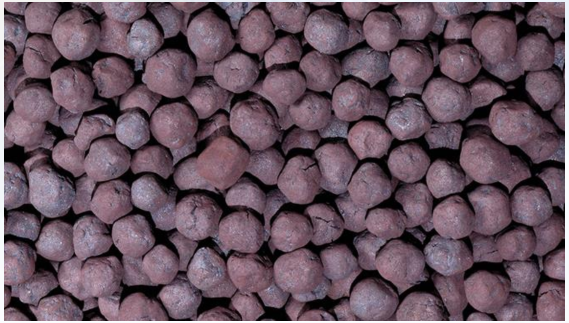


Case Study #2: Redesign of 3 magnetite concentrate transfer chutes

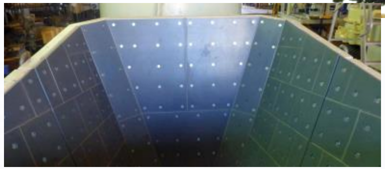
- Operated at 30% of the 8,000tph design rate due to plugging
- Chutes cleaned out every few hours due to buildup.
- Magnetite concentrate: fine, frictional, cohesive, compressible, pressure sensitive
- Original chute surface: rough weld overlay surface



Case Study #2: Redesign of 3 magnetite concentrate transfer chutes

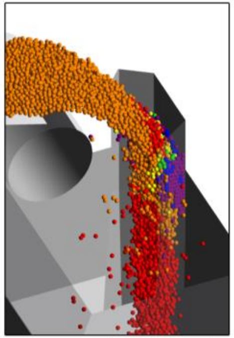


- Analysis:
  - Site visit to observe plugging
  - Learned original chute designed for coarse, free-flowing material
  - Flow properties tested (wall friction, cohesive strength, bulk density – tests required to calibrate DEM model)
  - DEM calibrated
  - Wear tests run → wear rates of liners with magnetite concentrate
  - Chutes redesigned with Matrox® UHMWPE liners → low friction and long wear life expected



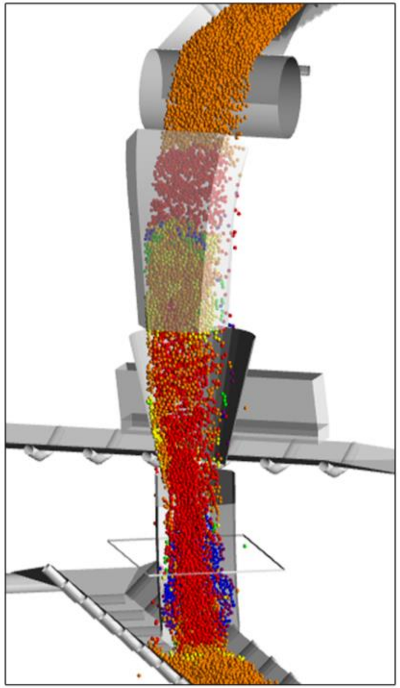
Original Design

Original Chute with build up issues



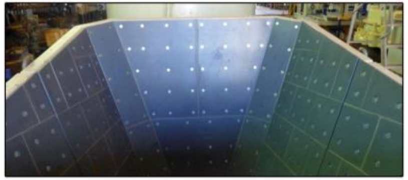
DEM calibrated to real world conditions

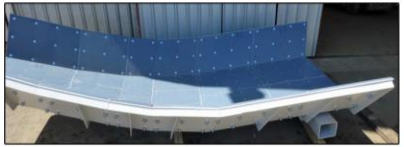
Improved Design

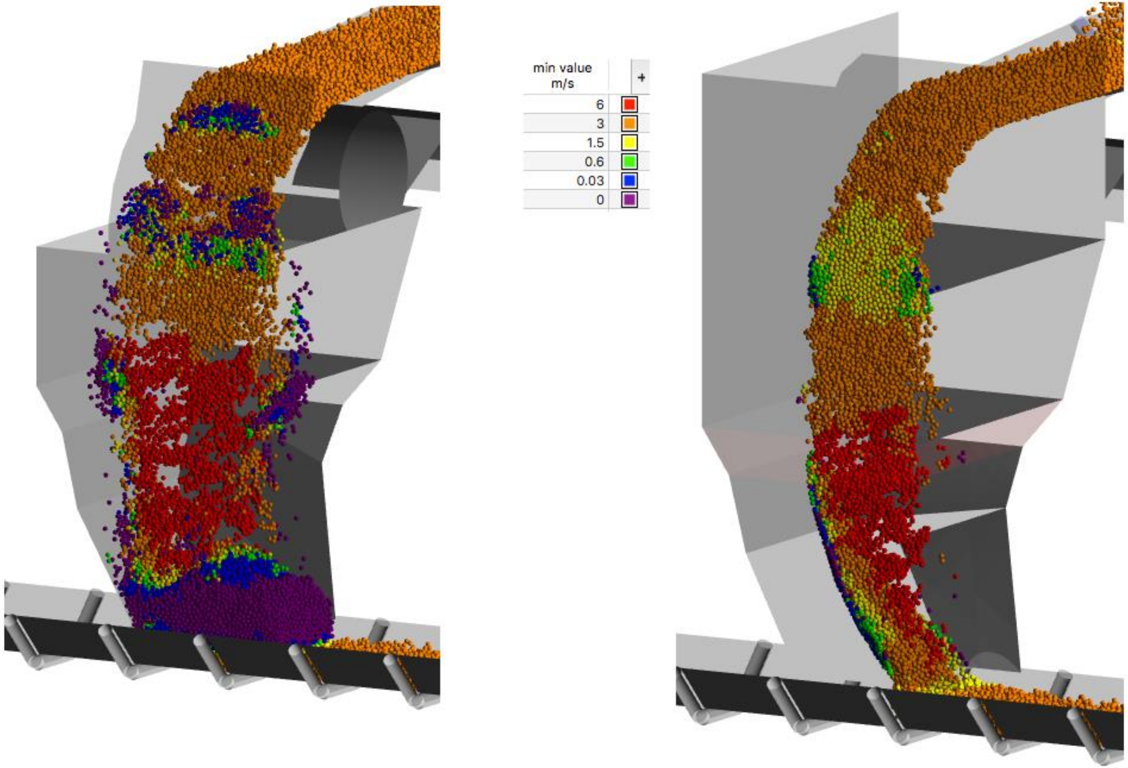


Designs created to mitigate build up and increase flow rate

Installed chute



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m/s
+
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3
1.5
0.6
0.03
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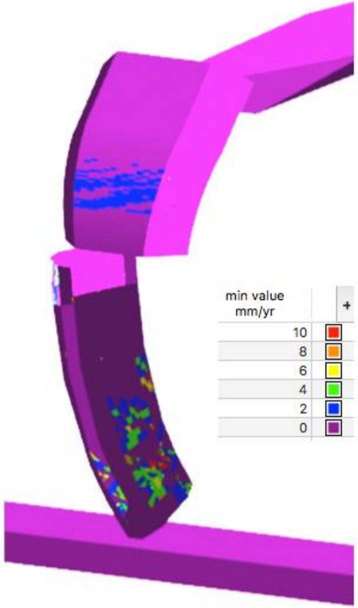
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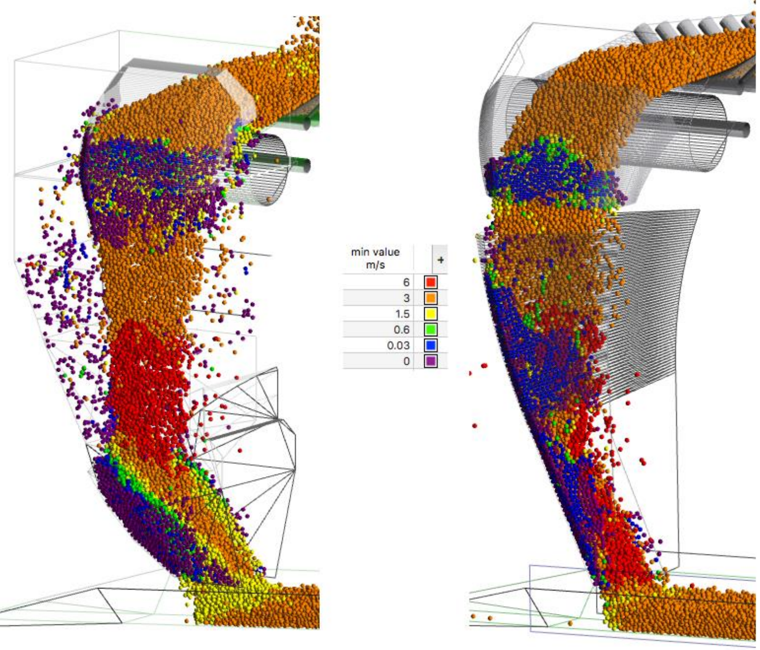
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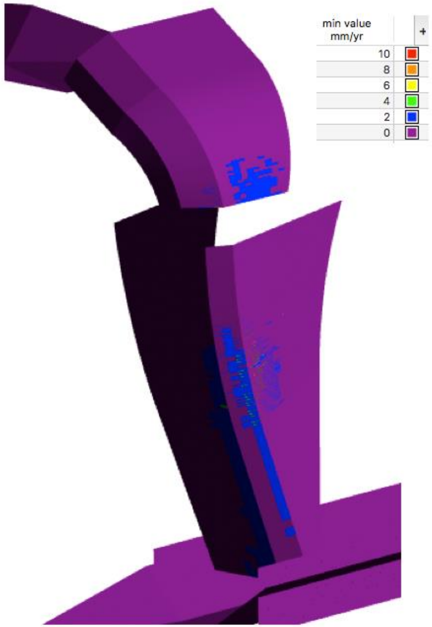
min value
mm/yr
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2
0

Case Study #2: Redesign of 3 magnetite concentrate transfer chutes

- Result: Chute worked according to plan from day one with no plugging instances having been recorded – 100% capacity achieved
  - "Jenike & Johanson engineers were receptive to client requirements. Using their bulk material testing and simulation expertise, they developed the stepping-stones for a reliable solution – from identifying the transfer chute issues to solving them. They designed and modeled a solution that has improved production and reduced maintenance requirements."
    –Nathan Fuller, Manager Port Projects, Sino Iron Pty Ltd

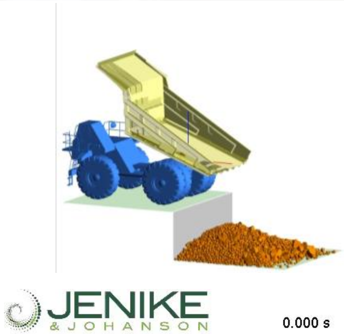
Case Study #3: Solving carrying-back issues with mining trucks

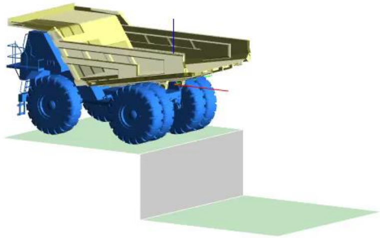
- Problem
  - Mining trucks – carry-back reduced live capacity (total mine production) of the trucks – wanted to reduce carry-back

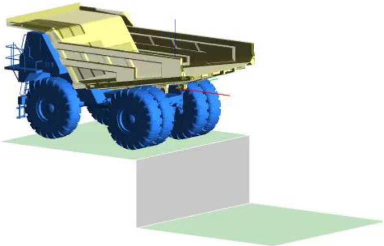
Case Study #3: Solving carrying-back issues with mining trucks

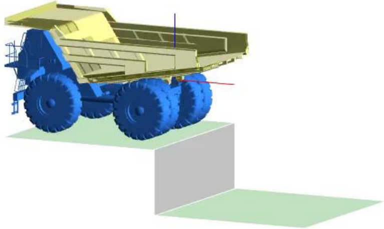
- Analysis
  - Bench scale wall friction tests on different liners to find a low friction liner
  - Vibration chute tests to simulate consolidation during transport
  - Considered impact pressure, moisture content, particle size distribution (fines), truck bed tilt speed

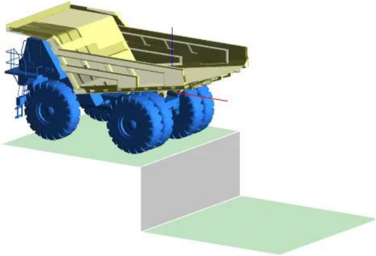
Case Study #3: Solving carrying-back issues with mining trucks

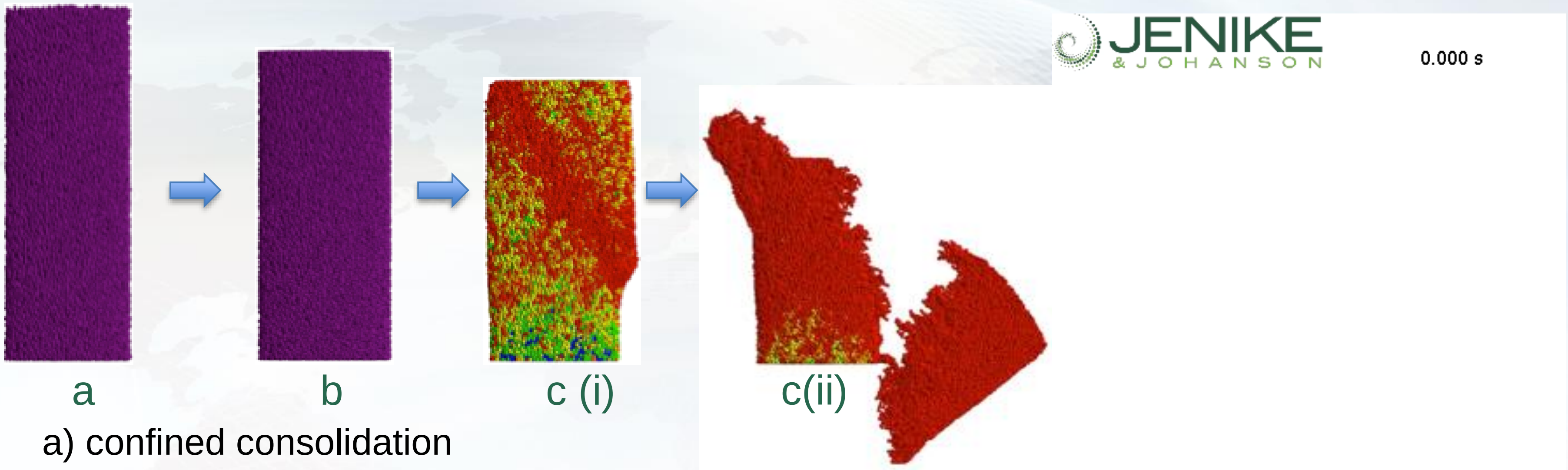












a) confined consolidation

b) removal of load and confinement

c) unconfined shearing

Contact model must allow for realistic representation of failure mode -- particularly for cohesive materials

Without an accurate contact model, DEM becomes a “pretty picture generator”

Additional DEM Advancements

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