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2020 Vision of Engineering Analysis and Simulation
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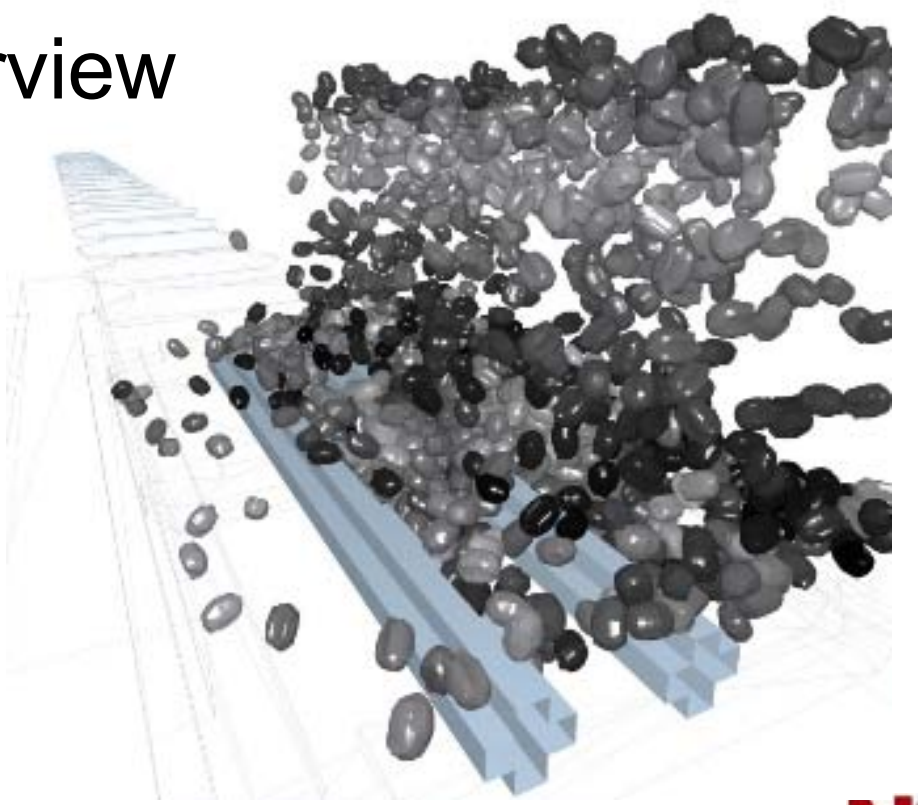
DEMSolutions

Simulation of Particulate Solids Handling and Processing Operations Using the Discrete Element Method

Dan Scharpf, Ph.D.
DEM Solutions

Outline

- Company Profile
- What is the Discrete Element Method?
- EDEM Software Overview
- Applications
- Summary



DEMSolutions

Company Profile

- Founded in 2003.
- Offices in Edinburgh, UK (HQ); Lebanon, NH, USA; Frankfurt, Germany and Singapore.
- Provide software and support services for application of DEM (Discrete Element Method).
- Developers of EDEM™ software for DEM simulation and analysis.
- Partnership with leading CAE software vendors to provide multi-disciplinary solutions with DEM.

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Offices and Channel Partners

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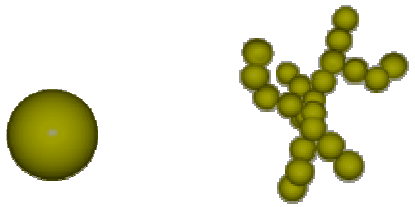
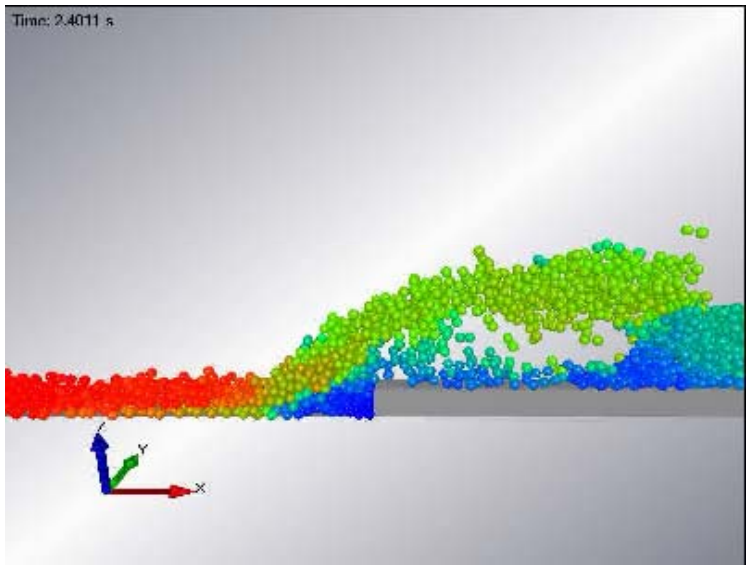
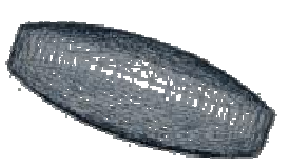
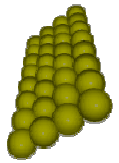
Discrete Element Method (DEM)

- Models the interaction of each discrete object/element or “particle” with:
  - Other particles,
  - Objects under kinematic control,
  - Surrounding media and force fields (fluid, electromagnetic).
- Accounts for particle size, shape and mechanical properties
- Solves at the particle scale
- Computes the dynamics of each object









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DEM Calculation Cycle

Initialise particles and surface geometry elements

Detect contact between elements

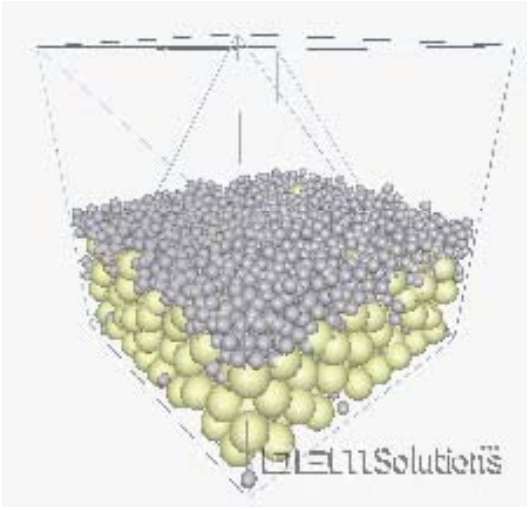
Calculate contact forces on each particle

Calculate body forces acting on each particle: gravity, fluid drag, electrostatic, …

Update particle acceleration and velocity

Update particle and boundary element positions

Track each particle and surface geometry element



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Bulk-Scale Information from Particle-Scale Data

Particle

Particle kinematics

Particle size/mass/temperature

Particle-particle contact forces

Particle-boundary contact forces

Particle body forces: gravitational, fluid, electro-magnetic

New particle formation

EDEM results

Bulk

Mixing dynamics

Uniformity of flow

Bridging

Granulation

Agglomeration

Mechanical energy consumption

Loads on machinery

Mixing profile

Segregation

Residence time/ hold-up

Damage/attrition

Breakage

Surface coating

Erosion

Heat transfer

and more….

Why Industry is Using DEM

Over 70% of industrial processes involve particles BUT

Problem
• The majority of particle handling and processing operations are empirically designed, • Measurement and control of particulate systems is difficult and costly.
Causing: ○ High prototyping and test costs, ○ Dependence on rule-of-thumb and operator experience, ○ Low rate of design and process innovation.

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Why Industry is Using DEM

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Solution

- DEM is the most accurate and computationally efficient method for modelling particle processes.
- The price-performance of computer hardware now enables cost effective application of DEM by industry.

Providing:

- Simulation of real-world processes,
- A tool for use in design and optimisation of particle handling and processing operations,
- A means of modelling interactions between particles and other media (fluids, structures, electromagnetic fields).

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Why Industry is Using DEM

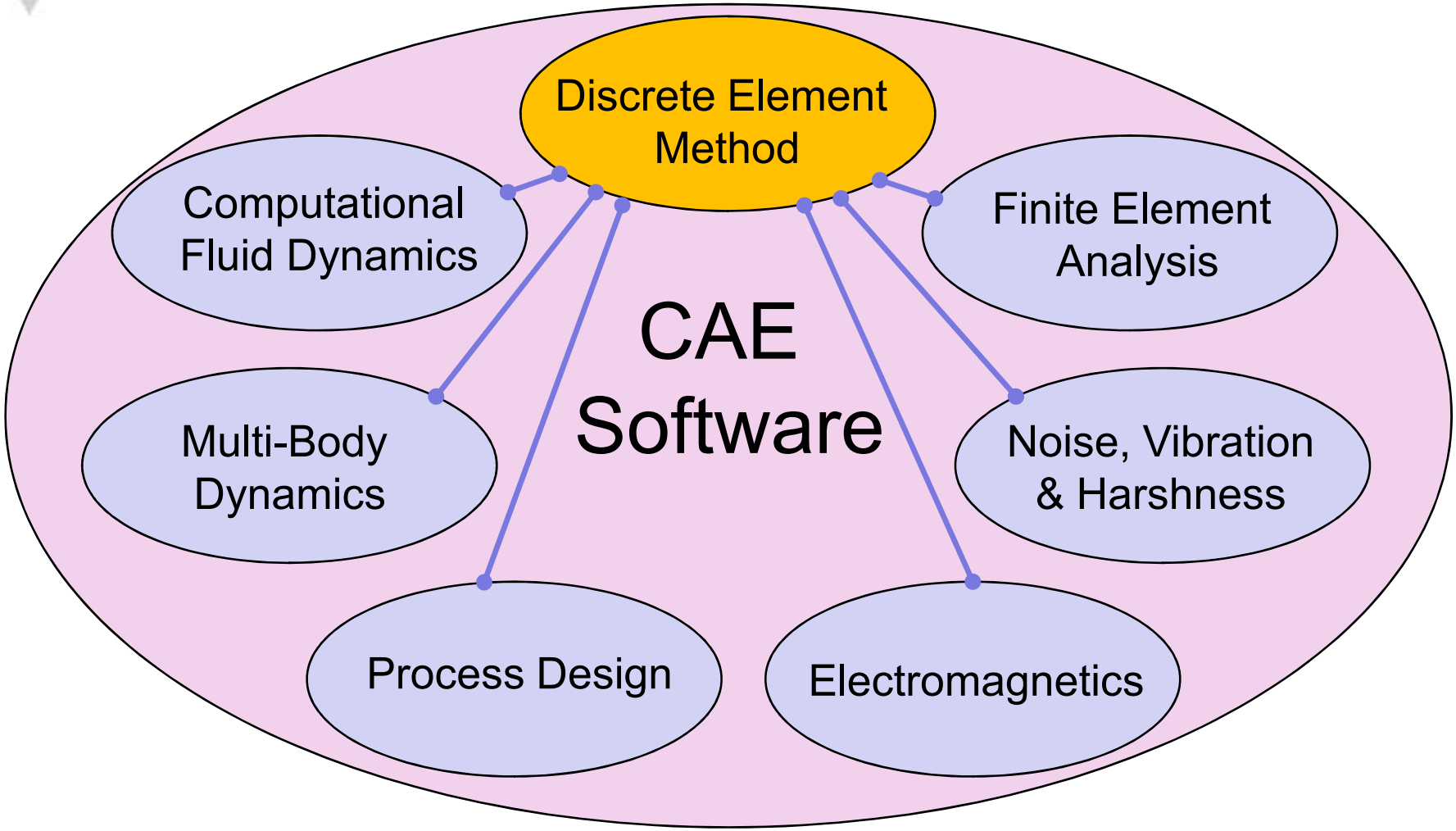
Problem

Solution

Benefits

- Lower prototyping costs,
- Shorter design-cycle time,
- Reduction in rework,
- Better product quality,
- Lower risk of system malfunction,
- Greater return on engineering resources,
- Improved understanding of product design and process fundamentals.

Expansion of the CAE Market



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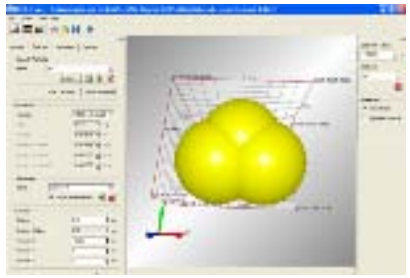
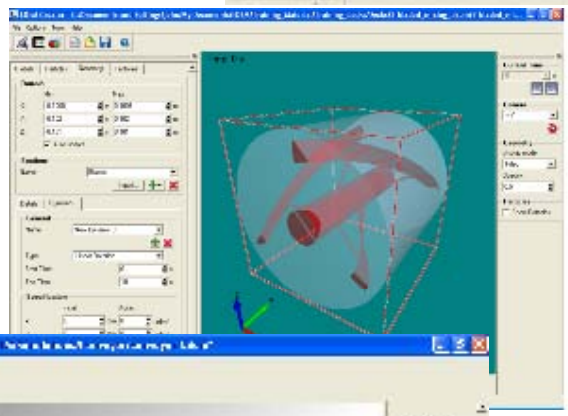
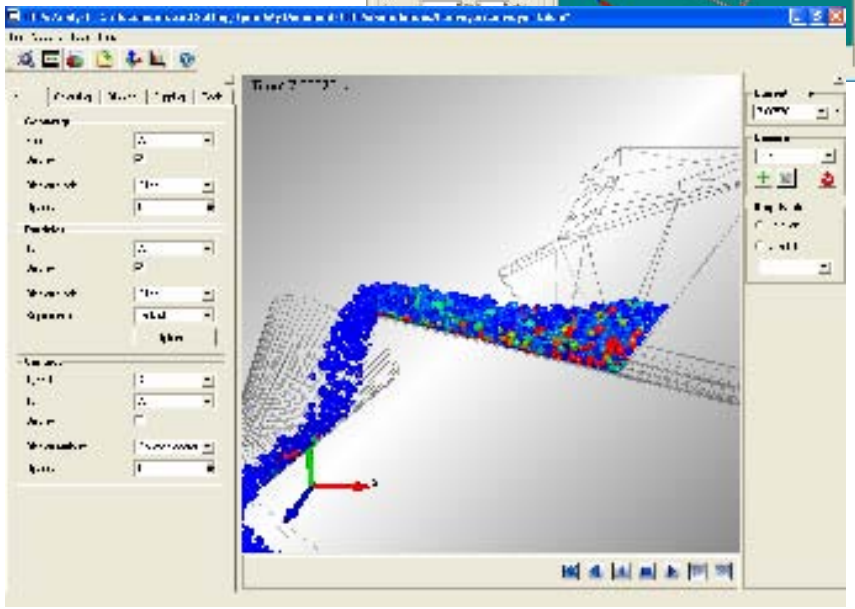
Software Overview

EDEM

- Multi-purpose DEM software
- GUI-driven workflow
- Programmable Applications Interface
- Generic and native CAD import
- Multi-core parallel solver
- Couples with CFD, FEA and MBD
  - Common mesh
  - Momentum exchange
  - Heat exchange
  - Control of kinematics
- Run-time visualisation
- Data extraction tools







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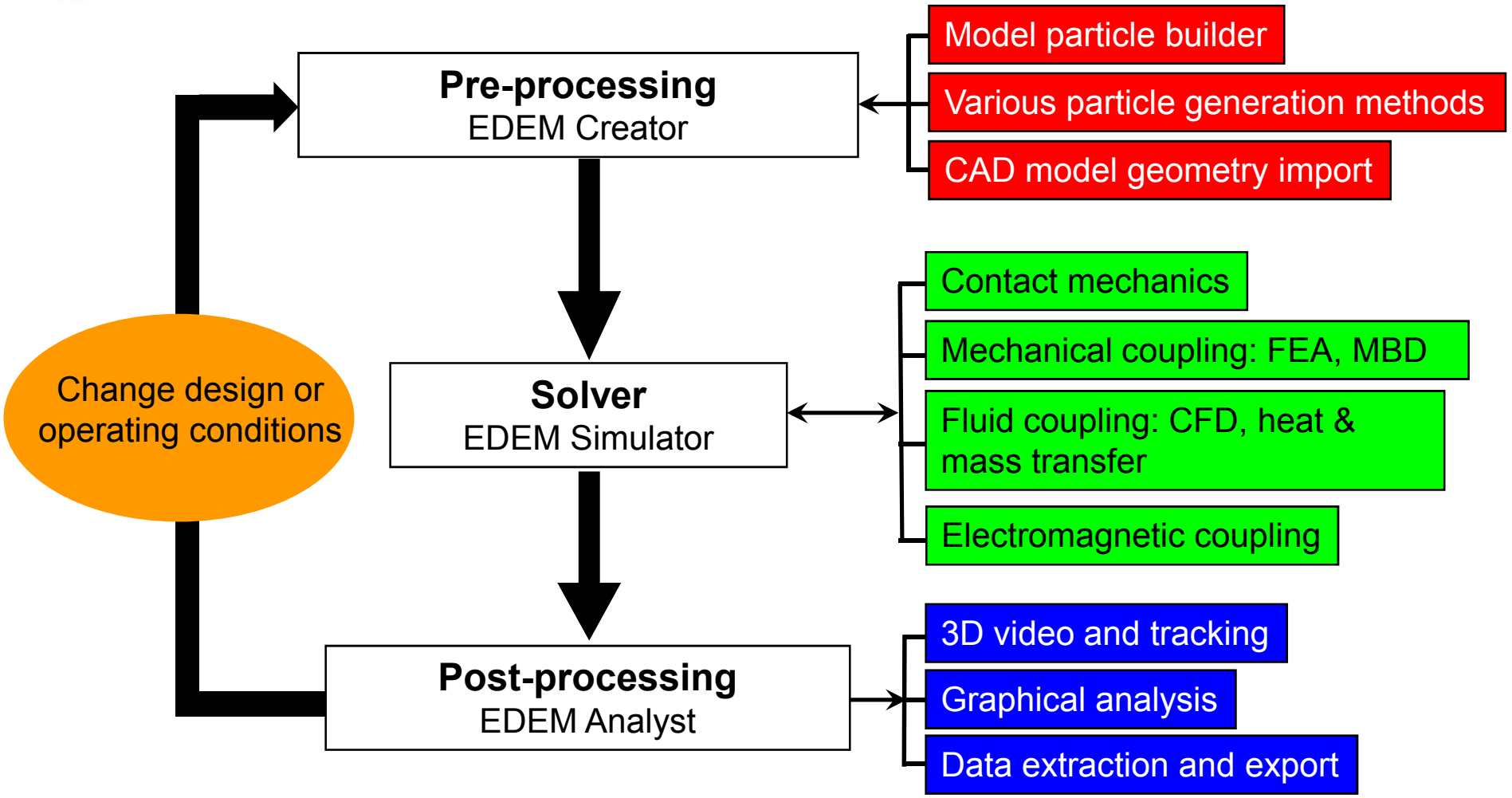
EDEM Workflow



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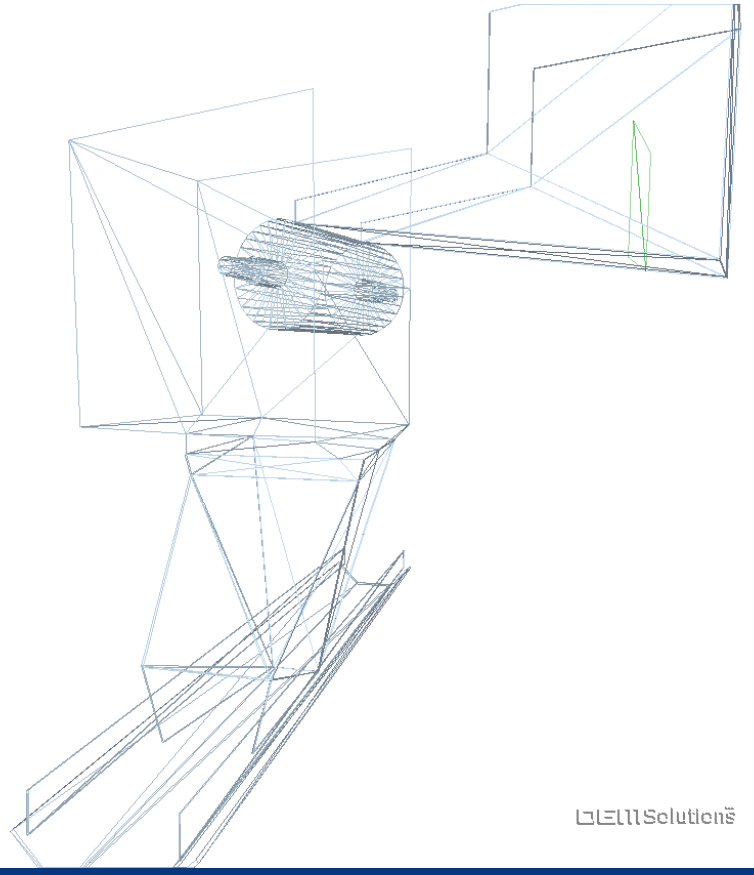
Bulk Handling

Simulation Objectives

- Predict likely material hold-up and blockage relative to material properties and system design.
- Identify regions of high impact loads and surface abrasion.
- Minimize spillage.
- Determine conditions causing particle segregation.



Bulk transport of cohesive particles through a conveyor transfer point

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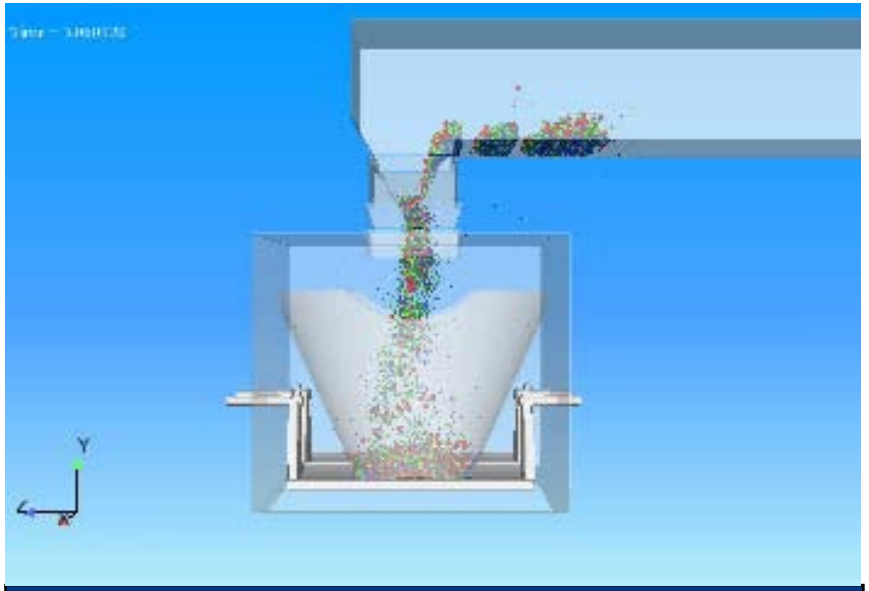
Bulk Handling

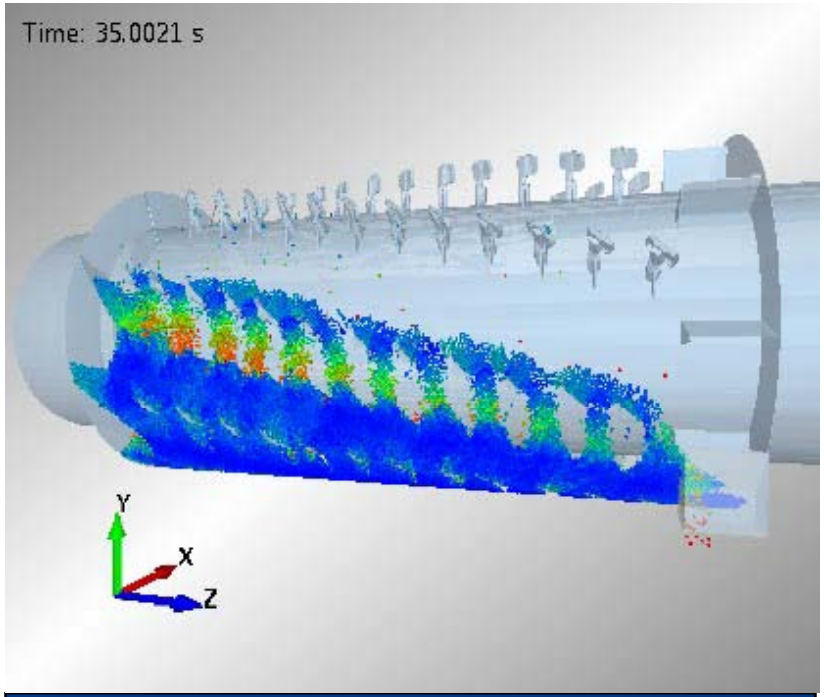


Hopper filling & discharge

Simulation Objectives

- Estimate the effect of filling on particle segregation.
- Determine dynamic load distribution on hopper walls.
- Test the effect of material properties on rate and time to discharge.
- Identify regions of high rate of wear.

Construction and Mining



Mixing of aggregate rock in a Hot Mix Asphalt Drum Mixer

(Courtesy: Astec, Inc)

Simulation Objectives

- Visualize material behavior
- Identify modes of poor mixing
- Identify potential size segregation
- Develop design improvements

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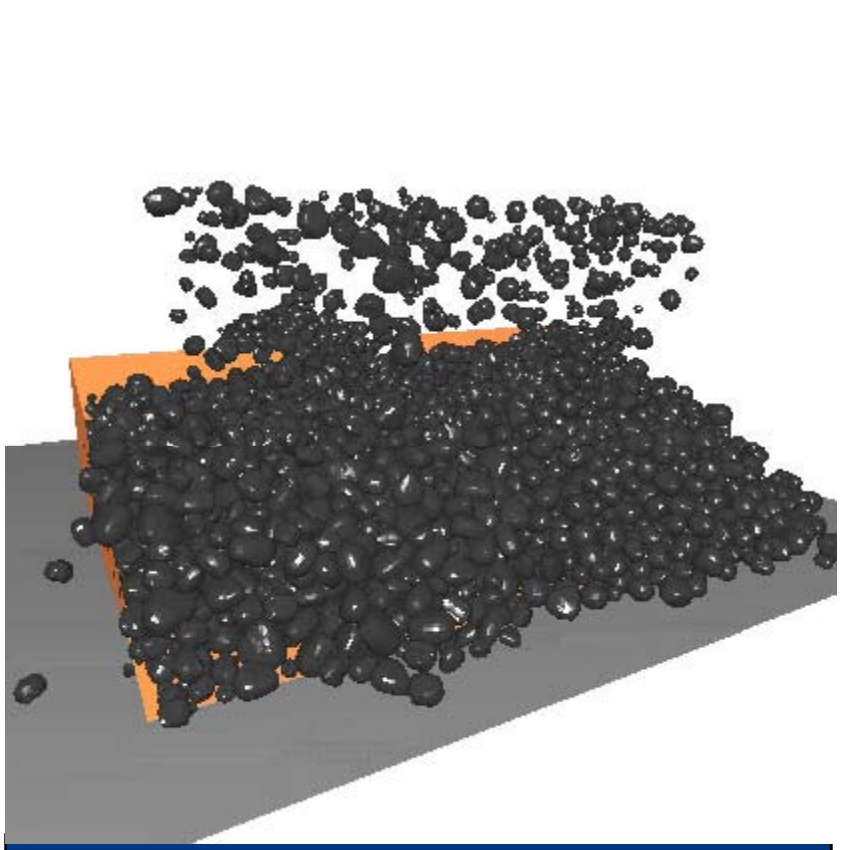
Construction and Mining



Pickup of coal from a long-wall miner

Simulation Objectives

- Explore the effect of paddle geometry on delivery of coal to the conveyor
- Determine optimum operating envelope to avoid blockage and maximise throughput
- Estimate level of breakage and dust generation

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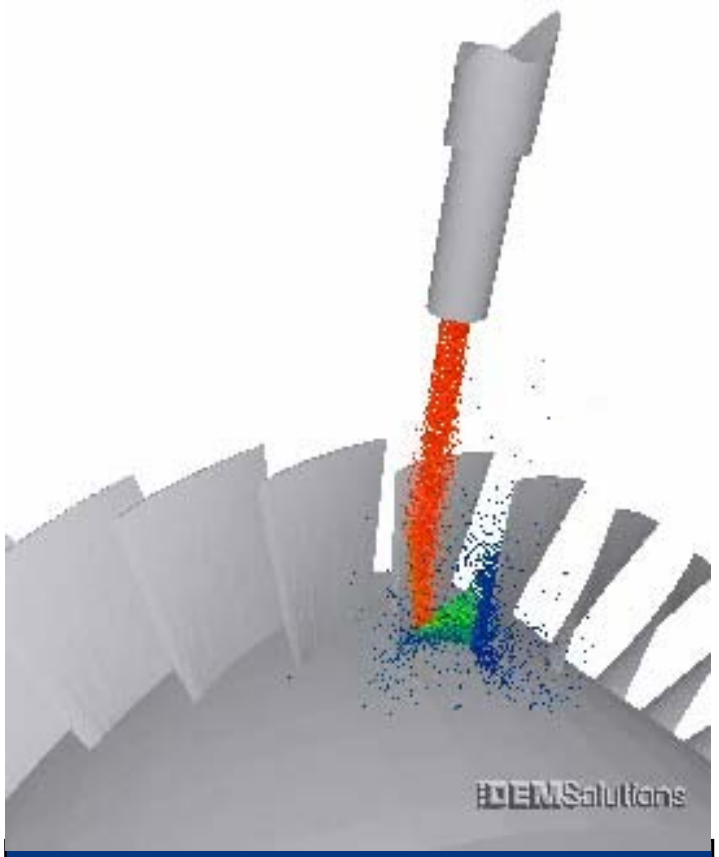
Aerospace and Automotive

Shot peening increases the surface yield strength of machine components

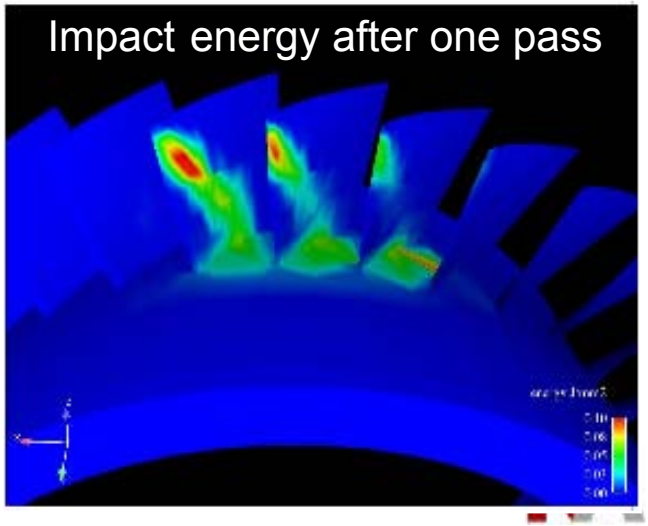


Shot peening of turbine blades

Simulation Objectives

- Identify the optimal combination of peening process parameters to maximize peening coverage and surface residual stress at critical locations on the work-piece
- Use the simulation data to optimize the peening process

Prediction of the impact energy imparted to turbine blades during nozzle peening



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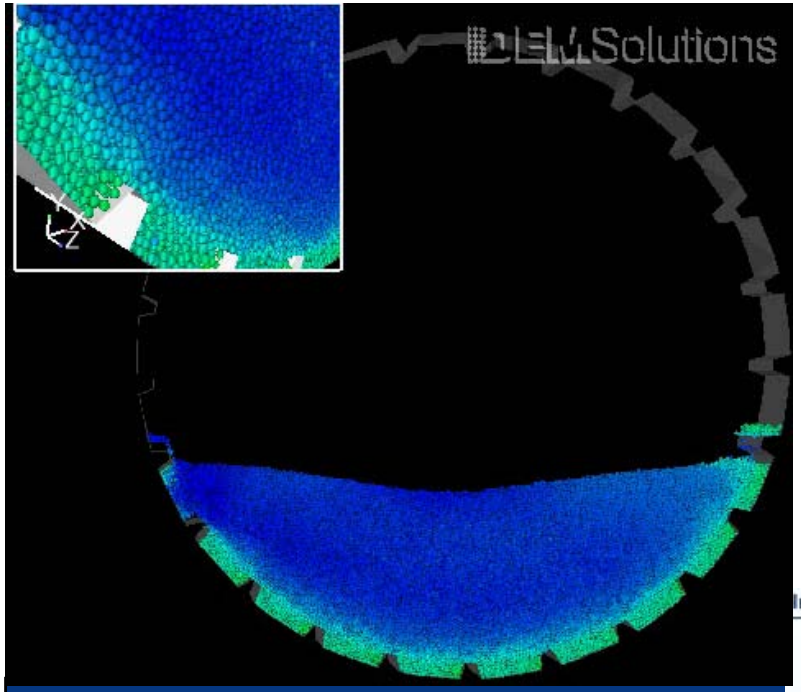
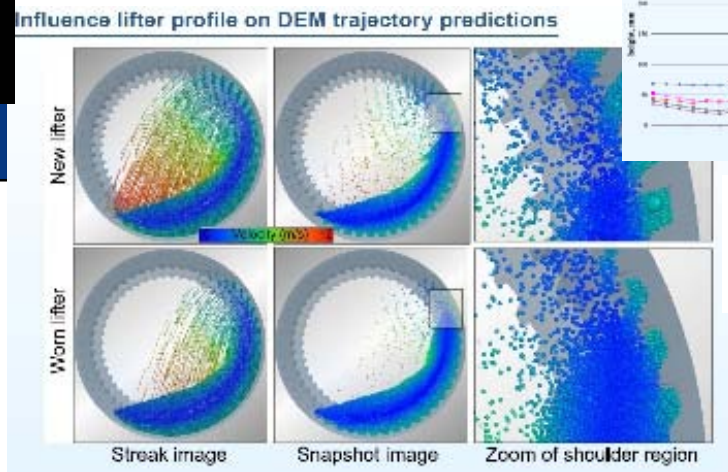
Construction and Mining

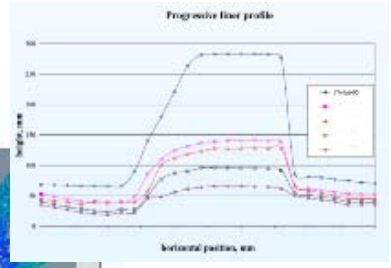


Rock grinding in a tumbling mill

Simulation Objectives

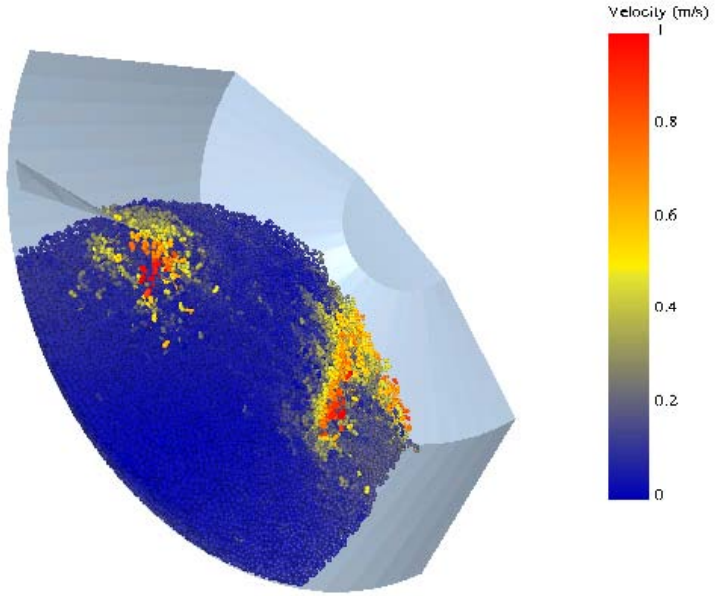
- Predict rock breakage
- Visualise separate components by size and type
- Model charge size reduction
- Predict mill power draw
- Estimate rate of liner wear





Lifter wear over time

Pharmaceutical Manufacturing

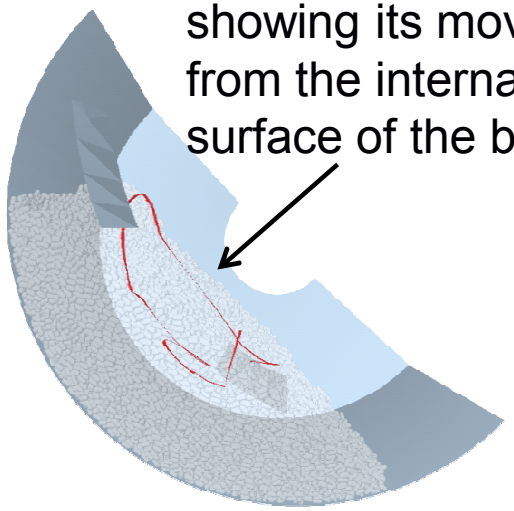


Spray coating of tablets in a pan coater

Simulation Objectives

- Determine the location and frequency of impact forces on tablets
- Estimate the residence time of tablets in the region of the spray

Track of a single tablet showing its movement from the internal to the surface of the bulk



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Multi-Disciplinary Simulation

EDEM coupled with:

CFD, FEM, MBD, Emag

provides a solution for:

Particle-Fluid Interaction

Particle-Structure Interaction

Particle-EMAG Interaction

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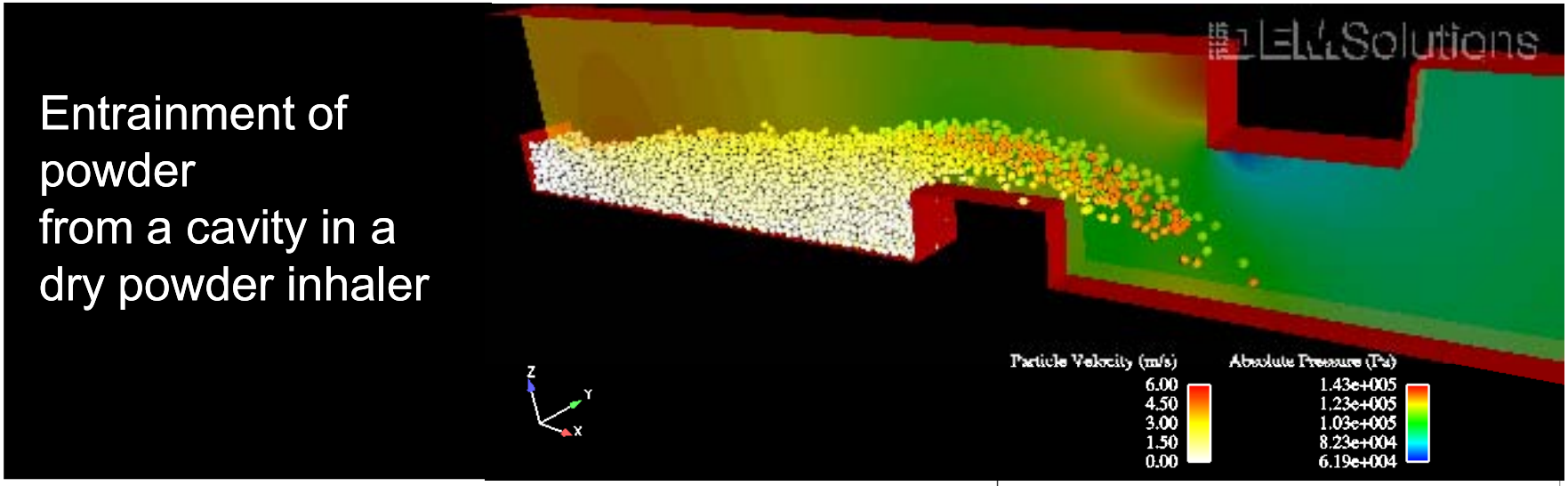
Drug Delivery

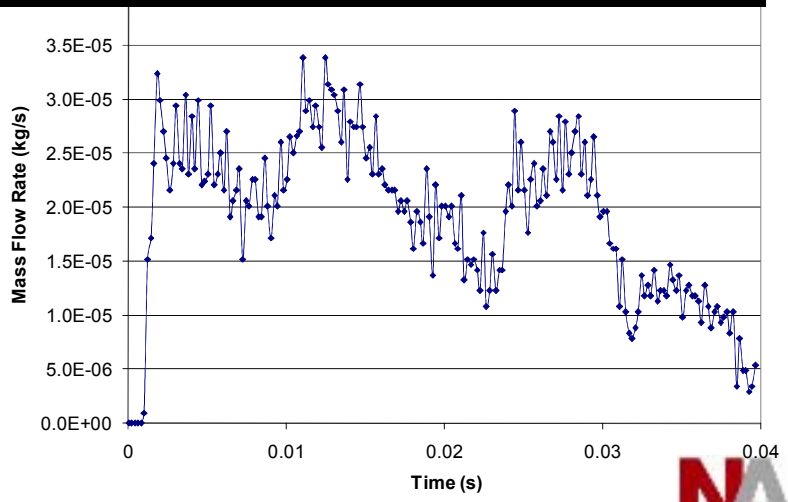
Coupled DEM-CFD simulation

Entrainment of powder from a cavity in a dry powder inhaler



Simulation Objectives

- Investigate the effect of cavity and internal inhaler design on the powder flow transient
- Correlate particle impacts with distribution of drug components



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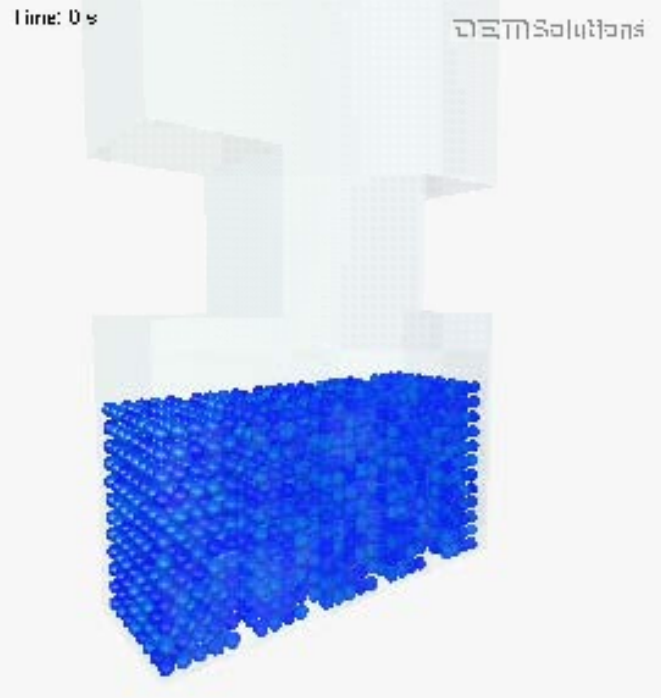
Flow of Deformable Particles

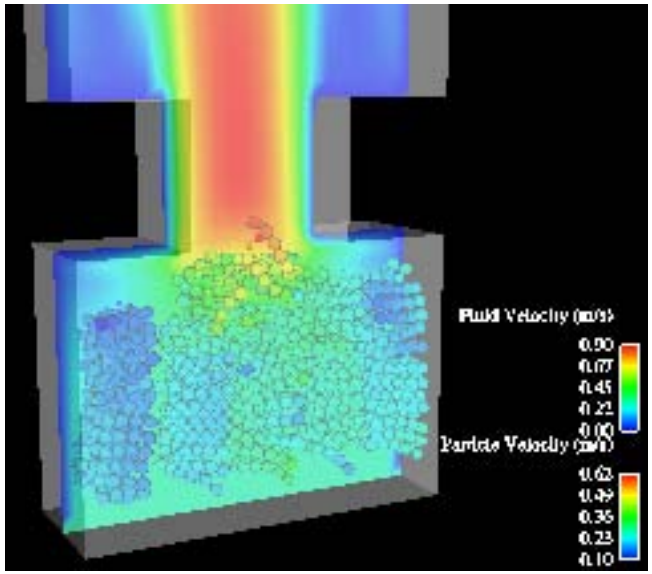
Coupled DEM-CFD simulation



Blockage of an opening by a deformable clump

Simulation Objectives

- Study the break-up of clumps relative to clump shear strength and fluid flow rate
- Predict blockages relative to size of opening, fluid pressure and material properties



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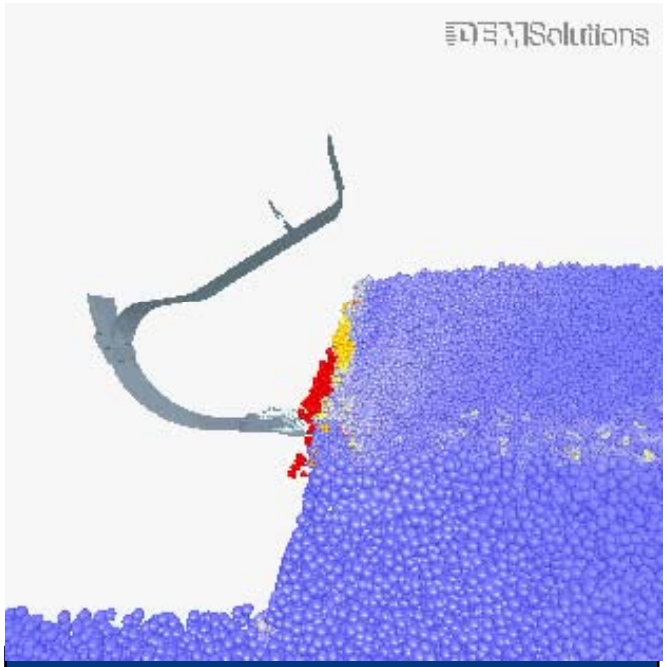
Excavation Bucket Design

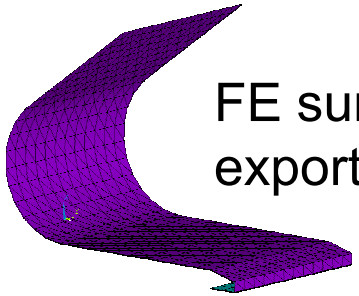
Coupled DEM-FEM simulation



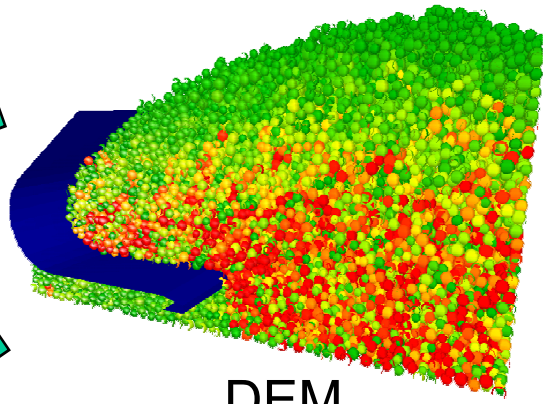
Digging cycle of an excavation bucket

Simulation Objectives

- Prediction of bucket structural response for different geometries and materials.

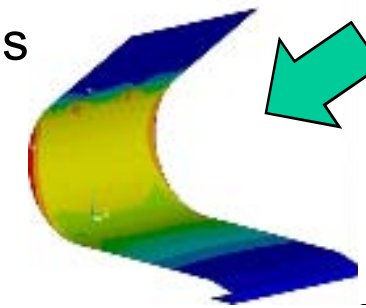


FE surface mesh exported to EDEM



DEM model

FE model: von Mises stress



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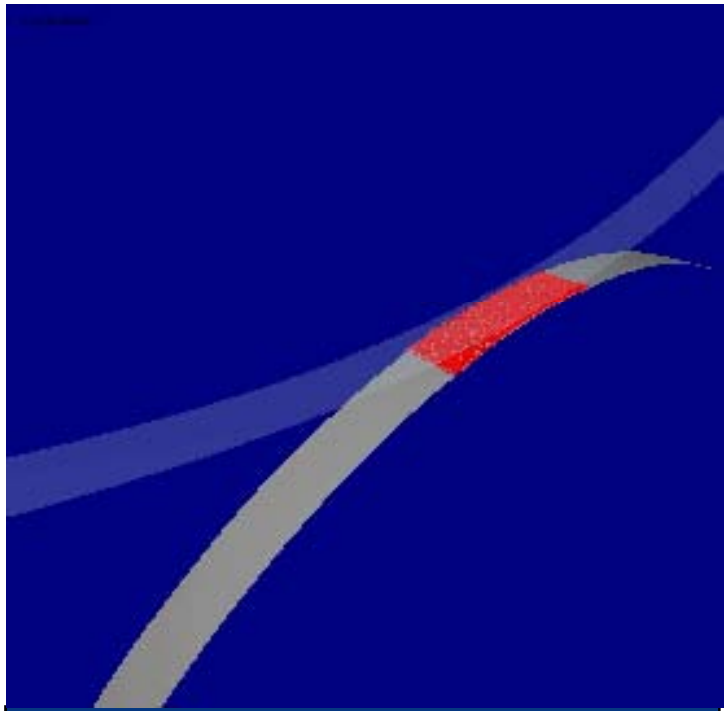
Electrographic Printing

Coupled DEM-EMAG simulation



Formation of toner image on drum

Simulation Objectives

- Investigate the effect of carrier and toner particle interaction
- Determine the influence the electric and magnetic fields on pickup and deposition of toner particle
- Greater understanding of complex system dynamics
- Explore of the performance of new design prototypes

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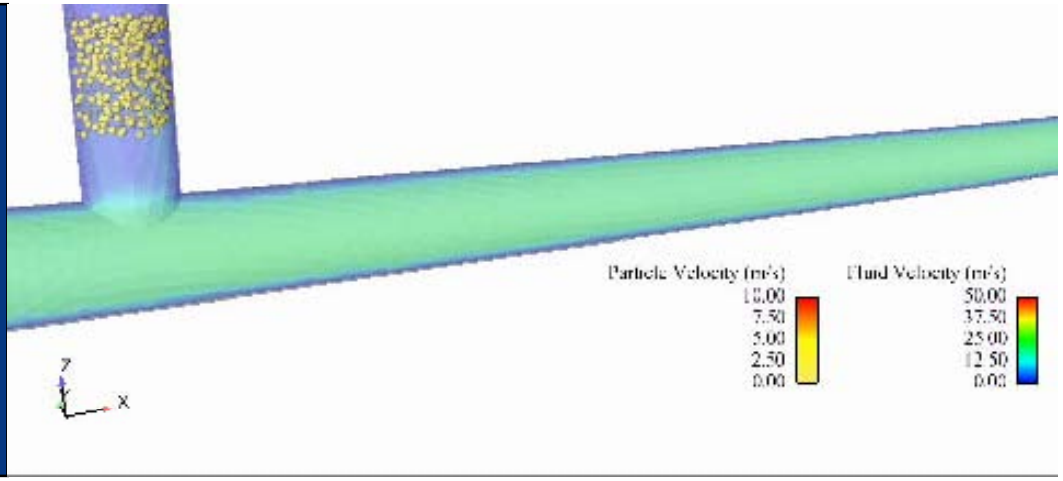
Pneumatic Conveying

Conveyance of cohesive material in air



Coupled DEM-CFD simulation

Simulation Objectives

- Investigate the effect of clumping particles on the material flow rate
- Predict pressure drop due to blockage
- Examine particle cohesion limits based on performance

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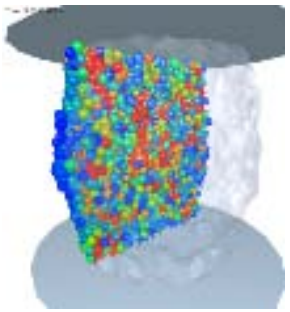
Summary

- Improvements in the traditional empirically-based design of handling and processing operations are now possible.
- DEM provides a solution for simulating particle systems.
- Now being used as a CAE tool by industry.
- Application areas expanding due to better software and lower-cost computer hardware.



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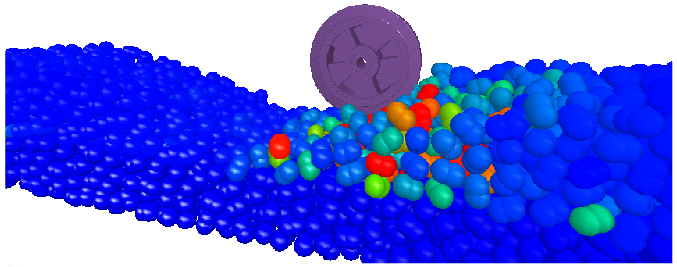

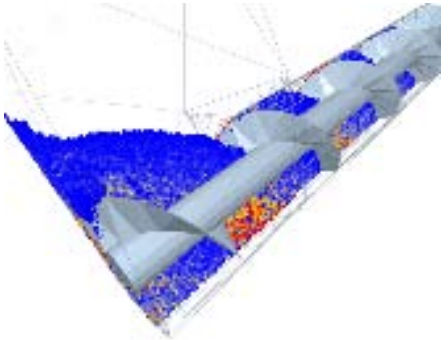

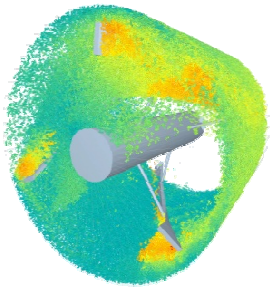

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