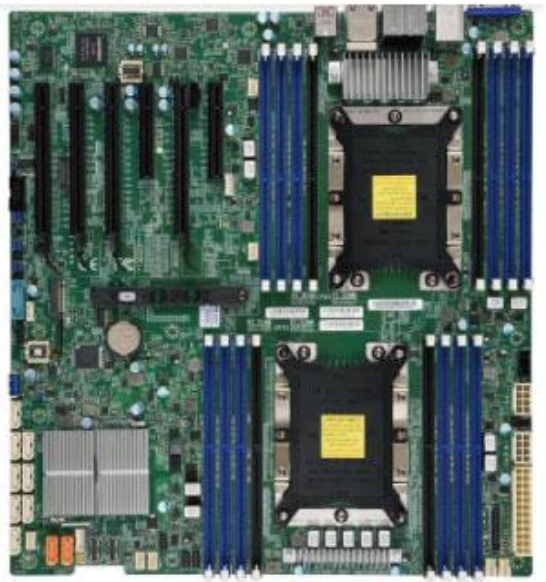
CADMEN 虎門科技 | Ansys精英合作夥伴

Ansys 2022/R1 Engineering What's Ahead.

# 新技術線上研討會

| | | |
|---|---|---|
| 4/7 (四) 14:00-14:40 | Ansys CFD 進階應用_TurboWorkflow 新技術線上研討會 | 李奕璋 |
| 4/7 (四) 15:00-15:40 | Ansys Rocky 新技術線上研討會 (Ansys Fluent、Motion & OptiSLang 耦合應用技術) | 林健文 |
| 4/7 (四) 16:00-16:40 | Ansys GRANTA 碳足跡應用與產業成功案例分享- 新技術線上研討會 | 李易軒 |

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Ansys / ROCKY

# *Using Rocky-DEM to Model Non-Spherical Particle Coupling with ANSYS Solutions*

虎門科技 CAE 事業部
技術副理 林健文

2022/04/07

Ansys

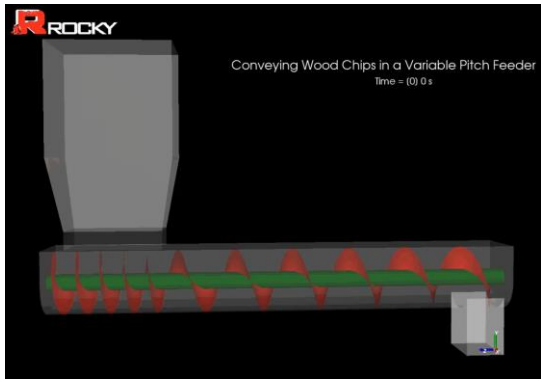
# Overview

1. Rocky-DEM introduction(Discrete element modeling)
2. Physical Models
3. How does Rocky fit into Ansys Portfolio?
4. Success Story

# What is Ansys Rocky?

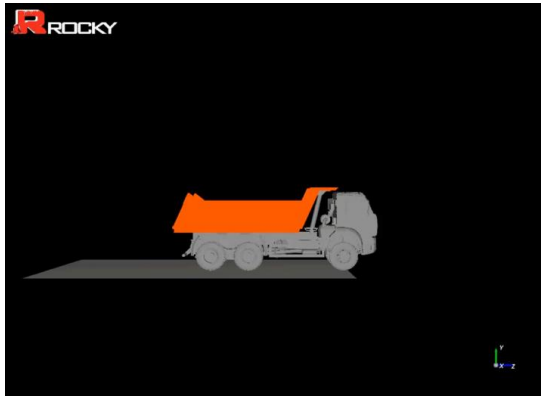
- Ansys Rocky is a high-fidelity particle simulation software, that quickly and accurately simulates the particle flow behavior

Wood chips (biomass handling)

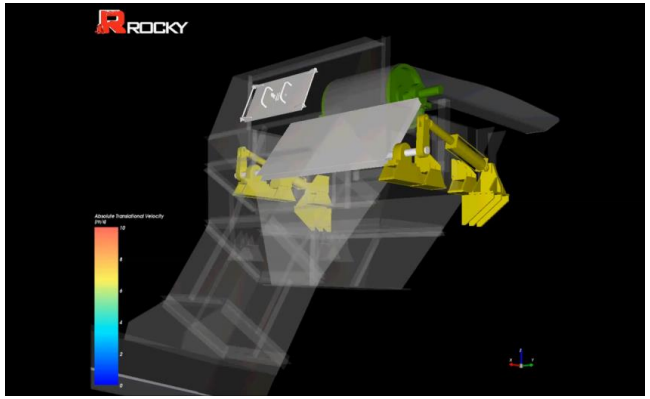



Tablets (pharmaceutical tablet coating)


Rocks (truck dump)




Wet and sticky ore (chute transfer in mining)



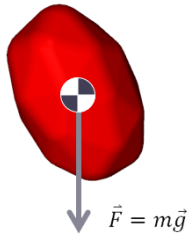
# What is DEM (Discrete Element Method)?

## Simulating Particle Dynamics in Time

### Typical forces

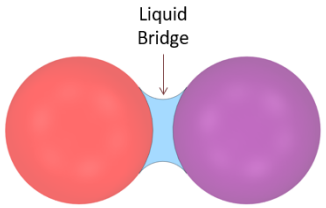
Body forces:

- Gravity
- Fluid forces
- Electrostatic/Magnetic fields




Surface forces:

- Contact force
- Adhesion/Cohesion force (ex: liquid bridging)




### DEM Fundamentals

Newton's second law of motion:

$$\sum \boldsymbol{F}_{net} = \sum \boldsymbol{F}_{body} + \sum \boldsymbol{F}_{surface} = m\frac{d\mathbf{v}}{dt}$$

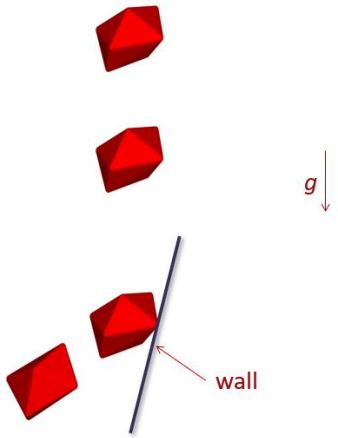
Particle falling under gravity:

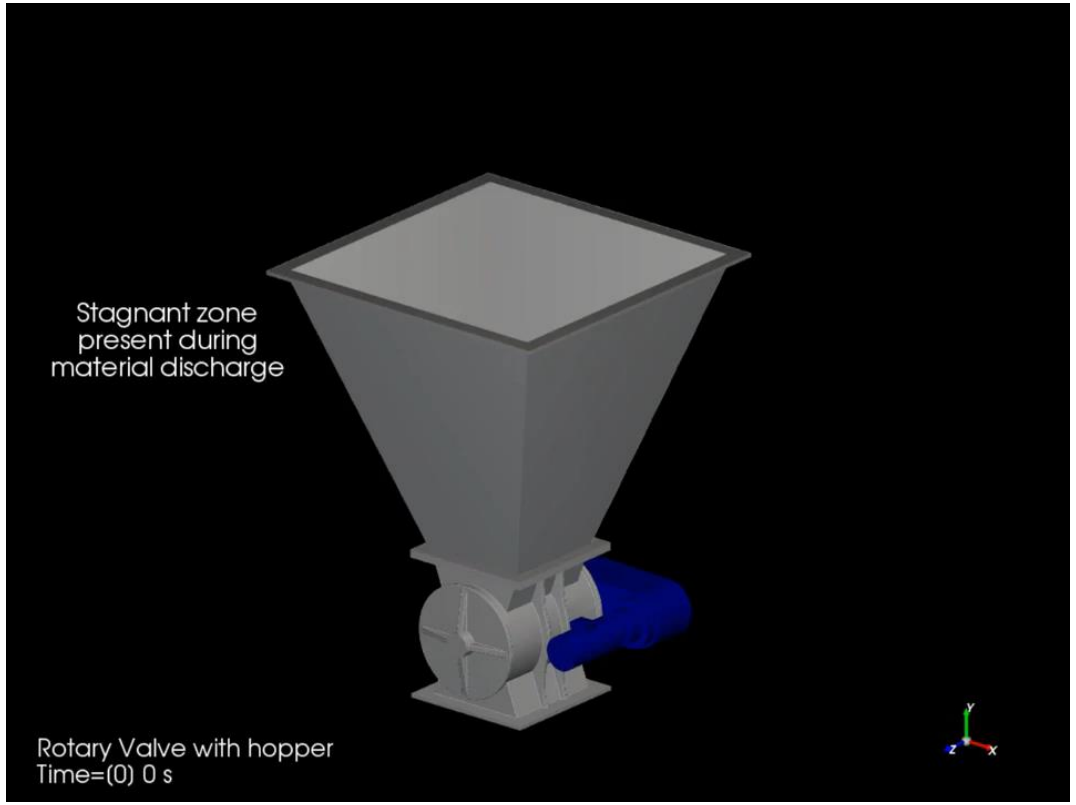
Time: $t = t$ $\quad \sum \boldsymbol{F}_{net} = \sum \boldsymbol{F}_{body} = m\mathbf{g}$

Time: $t = t + \Delta t$ $\quad \sum \boldsymbol{F}_{net} = \sum \boldsymbol{F}_{body} = m\mathbf{g}$

Time: $t = t + 2\Delta t$ $\quad \sum \boldsymbol{F}_{net} = \sum \boldsymbol{F}_{body} + \sum \boldsymbol{F}_{surface} = m\mathbf{g} + \boldsymbol{F}_{contact}(t)$

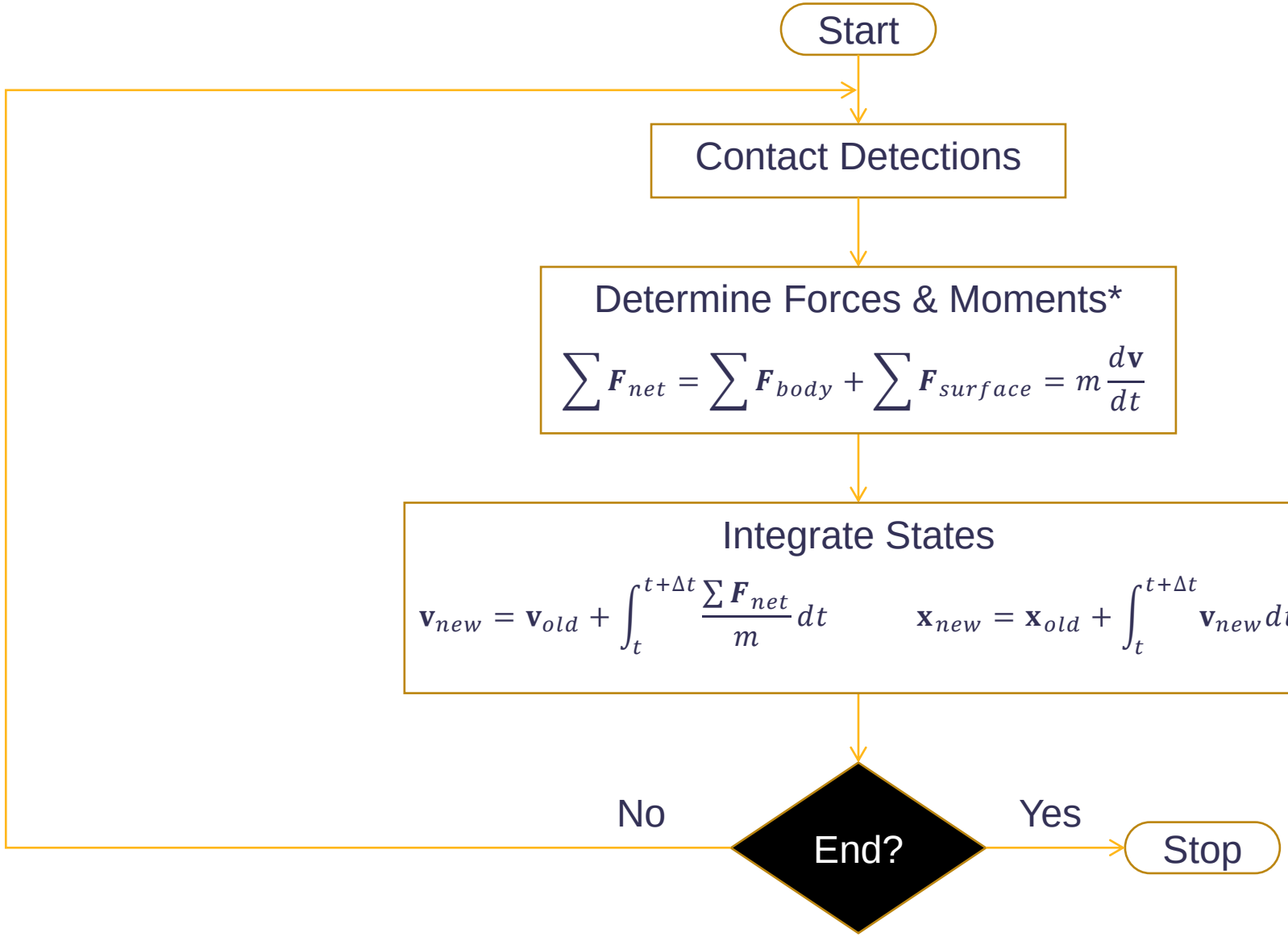
Time: $t = t + 3\Delta t$ $\quad \sum \boldsymbol{F}_{net} = \sum \boldsymbol{F}_{body} = m\mathbf{g}$




**Example: Solid Particle loading and discharge – Rotary Valve**

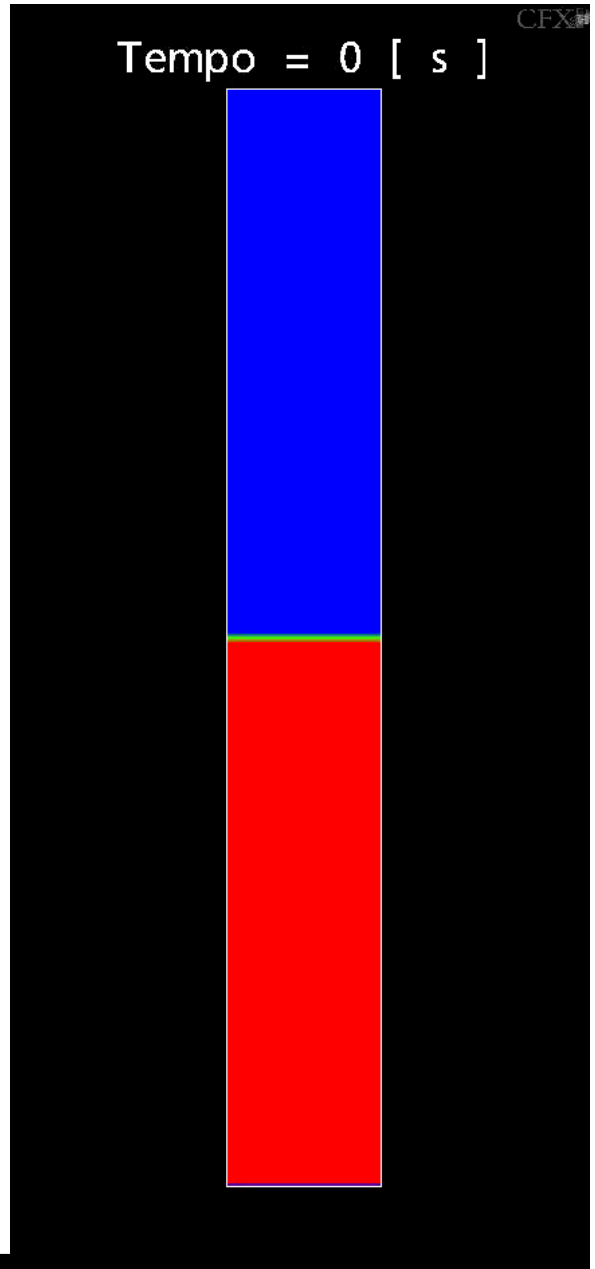
# DEM Calculation Loop




* The Euler equations of motion are not shown in the diagram for simplicity.

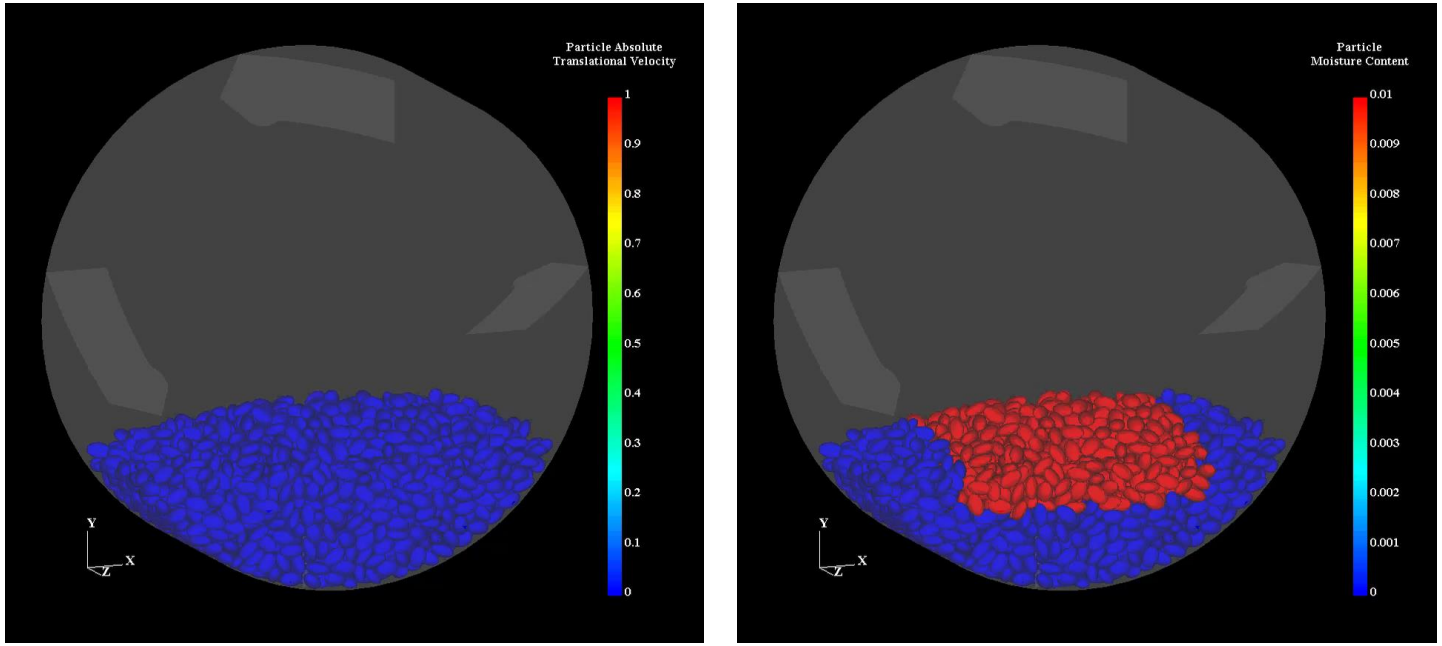
# Continuum vs. Discrete methods

- Continuum methods – Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA)
  - Granular material is treated as a continuous substance, individual particles are ignored
    - Knudsen number $Kn \ll 1$ (length scale $\gg$ particle diameter)
  - Constitutive law needed (relationship between applied stress to strain and history dependence)
  - Meshing of the flow domain is required and conservation laws (mass, momentum, energy) are applied at each cell
  - Resulting equations are solved either using a finite difference, finite volume or finite element method



# Rocky Enables Capturing Particle Physics

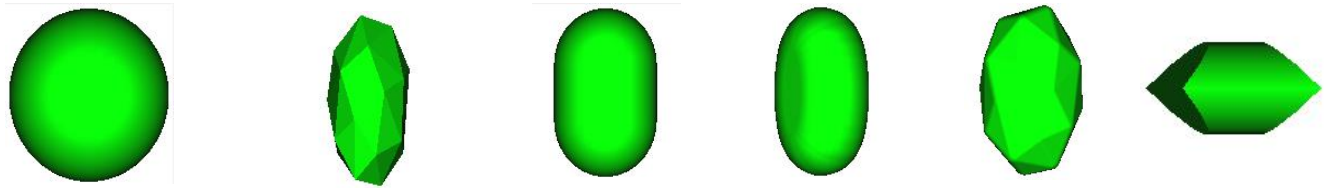
- Contact
- Collision
- Friction
- Adhesion
- Electric charge
- Wear
- Breakup
- Contact heat transfer
- ….



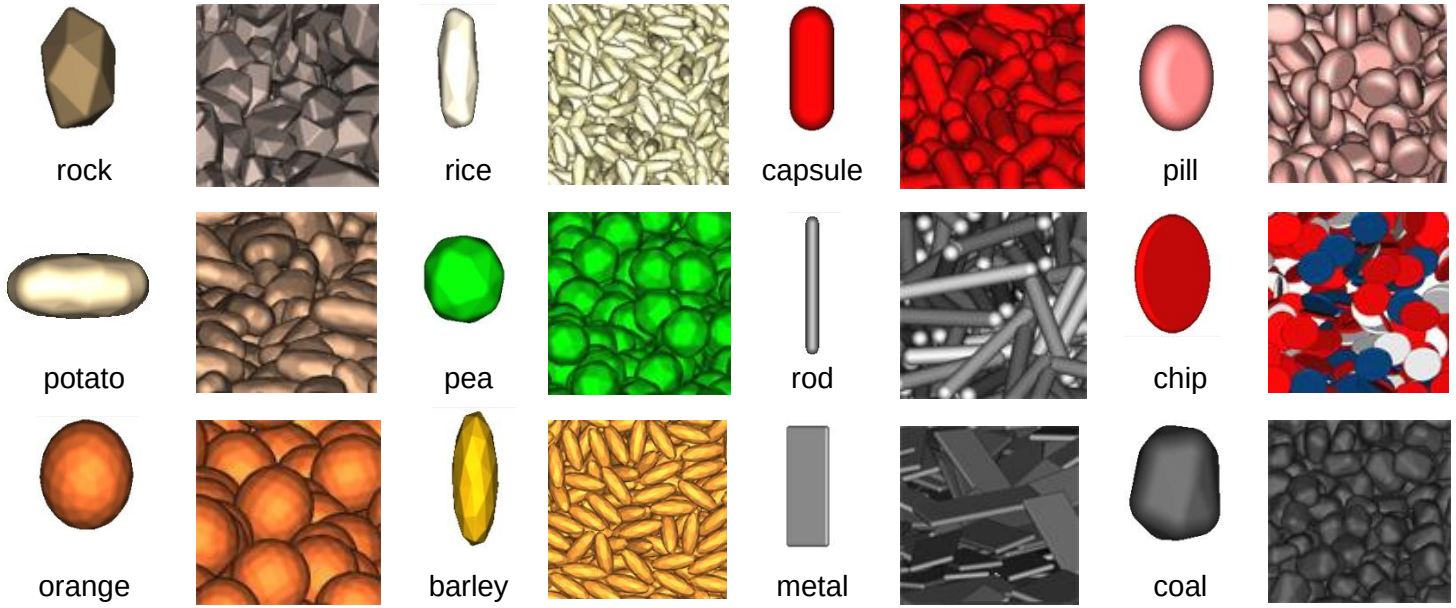

**Example: Tumbling of dry(left) and cohesive particles (right)**

# ACCURATE, with realistic physical representation

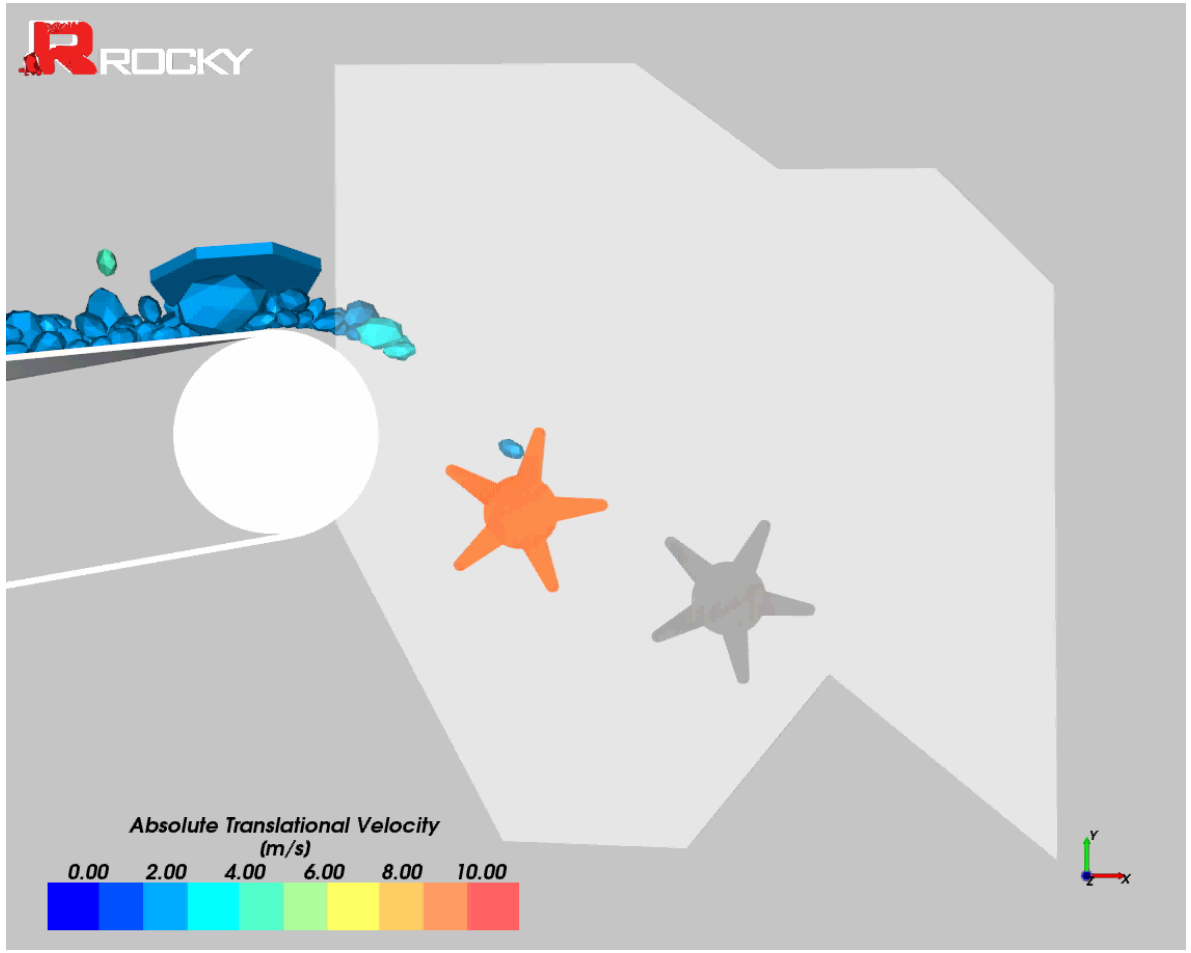
## Default particle shapes in Rocky:

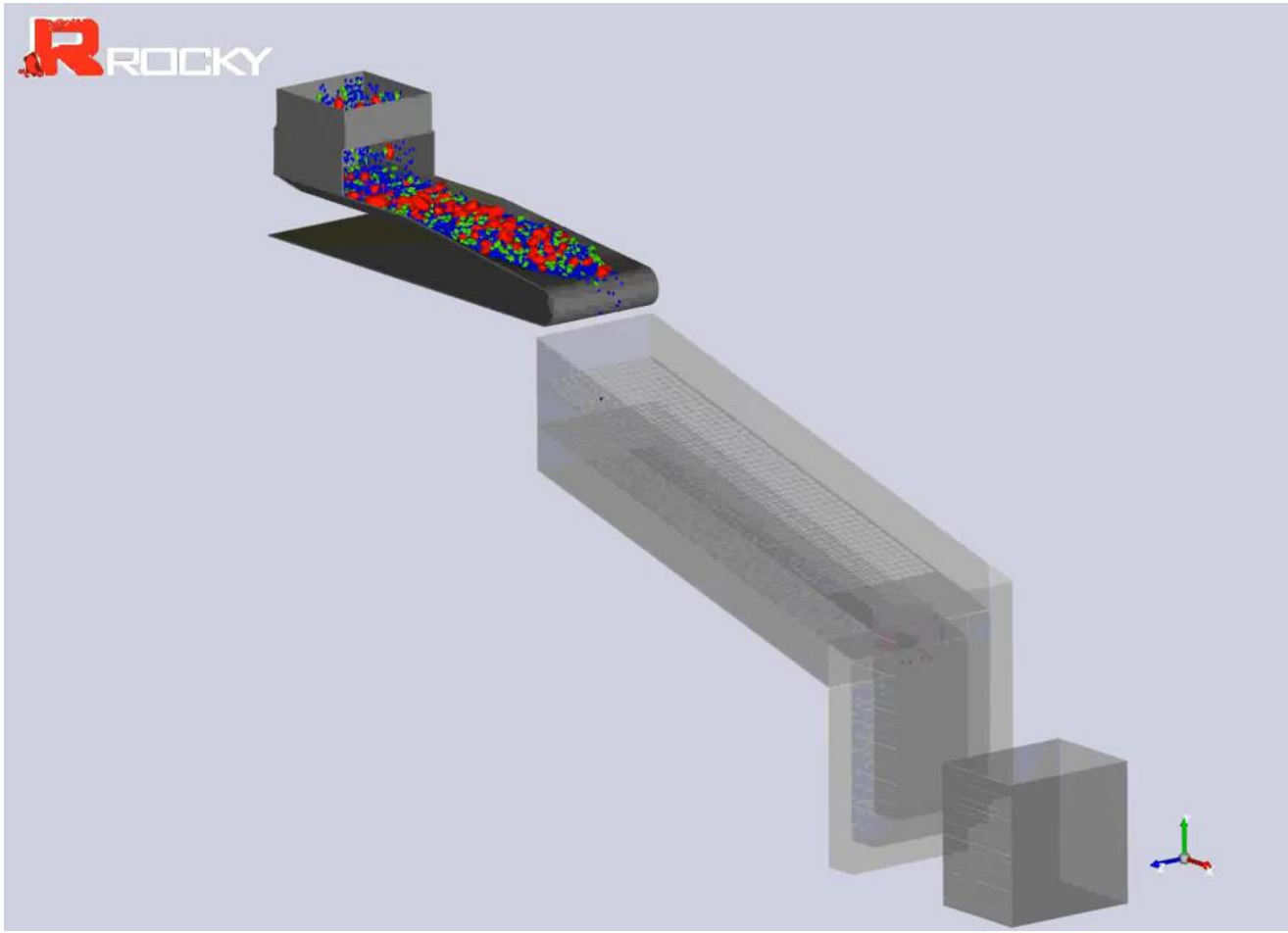



## Rocky shape examples:



# ACCURATE, with realistic physical representation



# ACCURATE, with realistic physical representation

- Scan any shape and import it into Rocky:

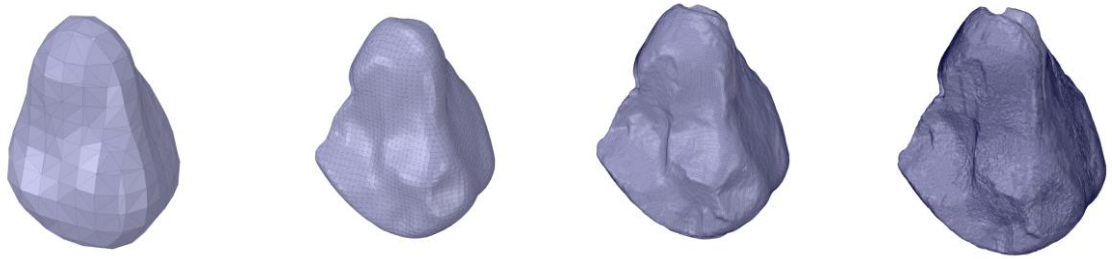
1. A real-world particle is scanned on a 3D scanner

2. The scanned particle is saved as a 3D model (.stl file)

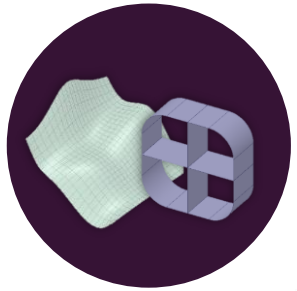
3. The .stl file is imported into Rocky as a custom particle shape

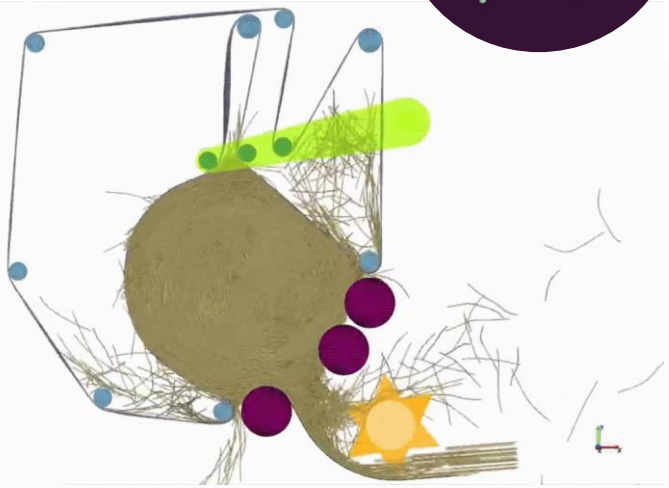
4. A Rocky simulation is conducted using the new custom particle shape

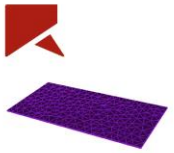
Low Resolution — High Resolution

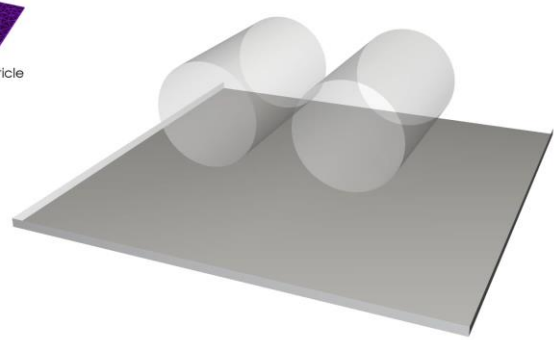


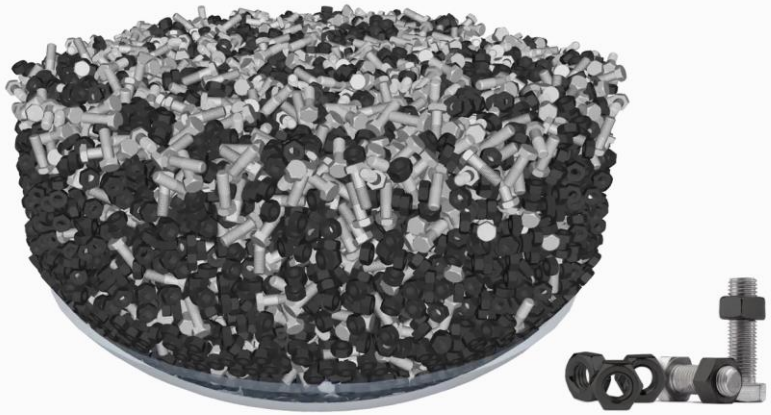
# Real Physical Representation

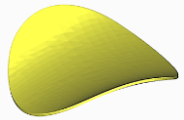










**Fiber**

✓ **Flexible**

**Breakage**

**Shell**

✓ **Flexible**

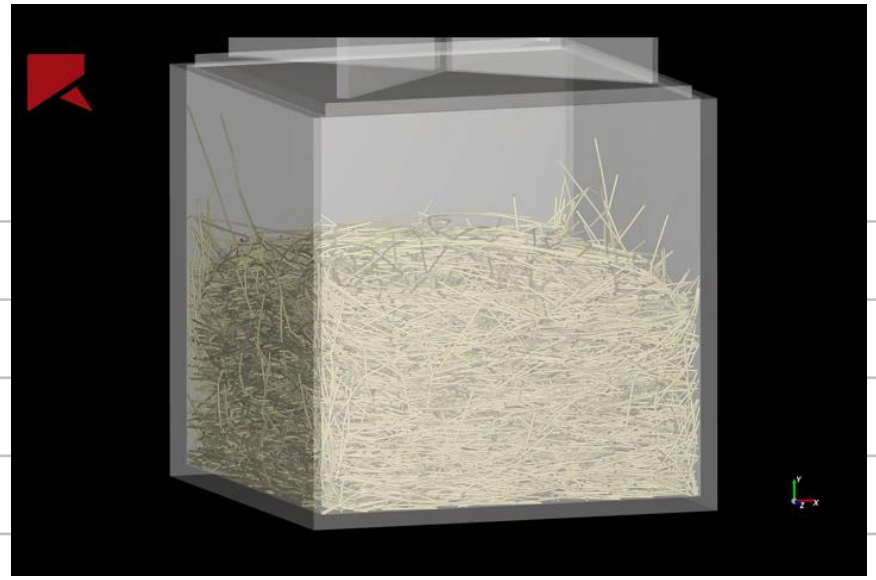
**Breakage**

**Concave and Convex Solid**

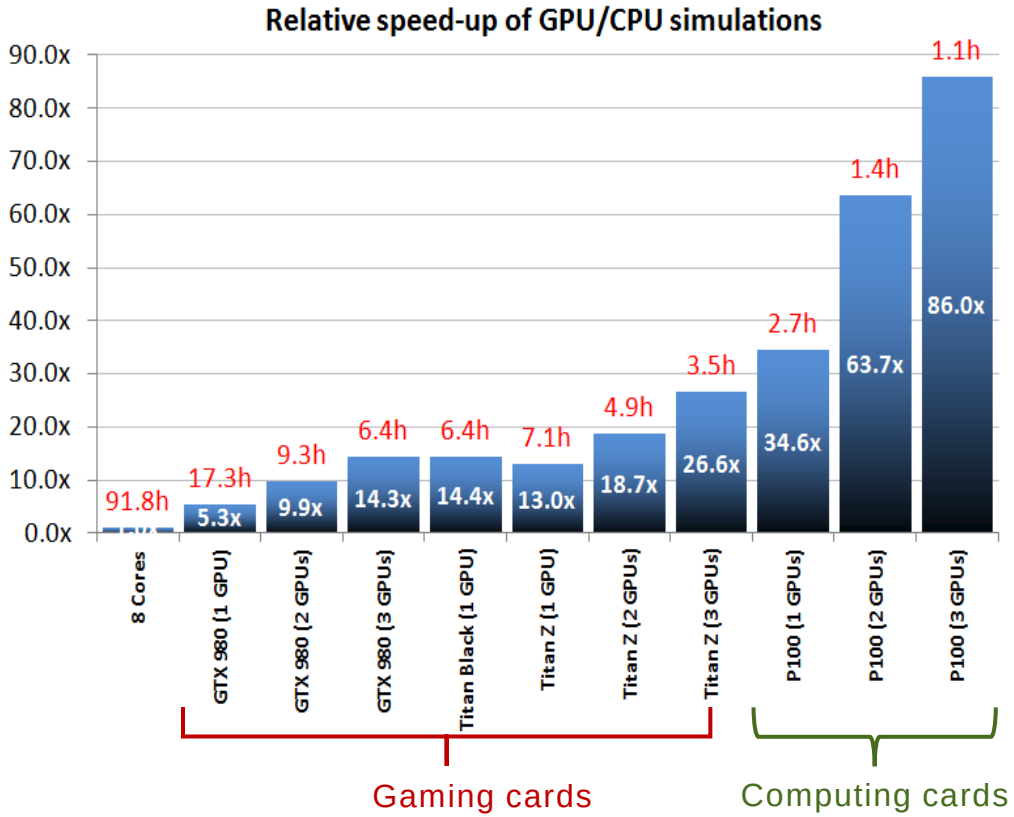
✓ **Flexible**

✓ **Breakage**

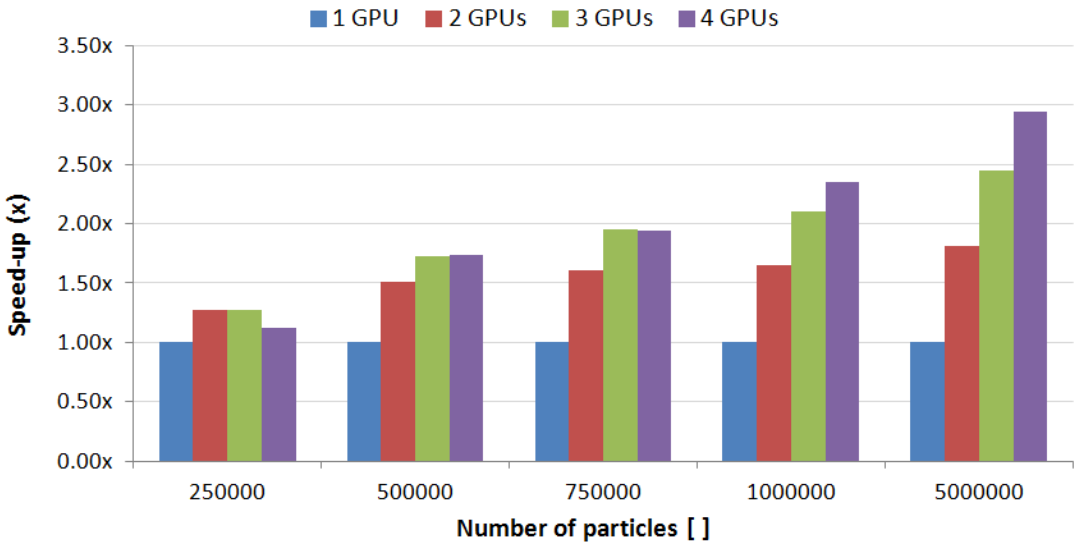
# Flexible fiber: accurate stress-strain response



# GPU x Multi-GPU




Scalability (and memory) for
large particle numbers on multi-GPU




**< 1 M Particles** → GPU

**> 1 M Particles** → Multi-GPU

## 1. Which GPU cards are recommended for use with Rocky?

Rocky has been tested and verified with all of the following NVIDIA GPU cards:

**Gaming:** RTX 2080, RTX 2080 Ti, Titan RTX, RTX 3080, and RTX 3090 **PROS:** Fast when using only spherical particles, inexpensive, can be installed on individual workstations, has video output

**CONS:** Slow when using shaped particles

**Workstation:** Titan V, Quadro GP100, and Quadro GV100

**PROS:** Fast when using spherical and/or shaped particles, can be installed on individual workstations, has video output

**CONS:** More expensive

**Server:** Tesla P100, Tesla V100, Tesla A100, and Tesla A30

**PROS:** Fast when using spherical and/or shaped particles

**CONS:** More expensive, must be installed in a server enclosure, no video output

For best results, use only one of the above recommended GPU cards during Rocky processing.

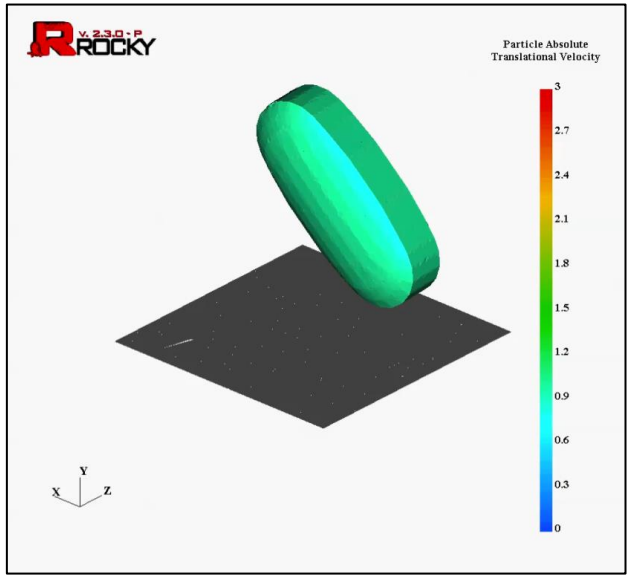
# Physical Models

# Particle Breakage

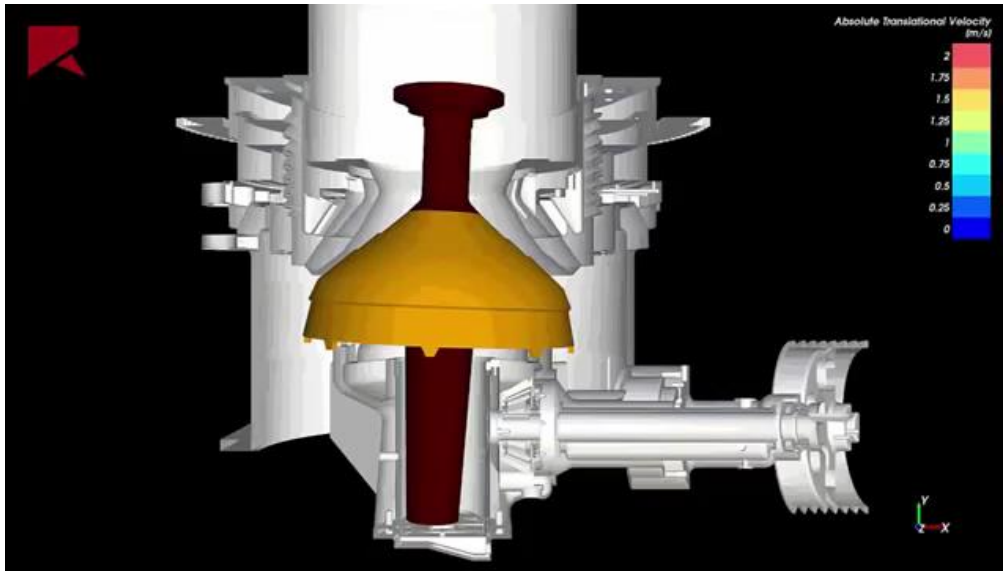
## Instant Fragmentation


Shape independent

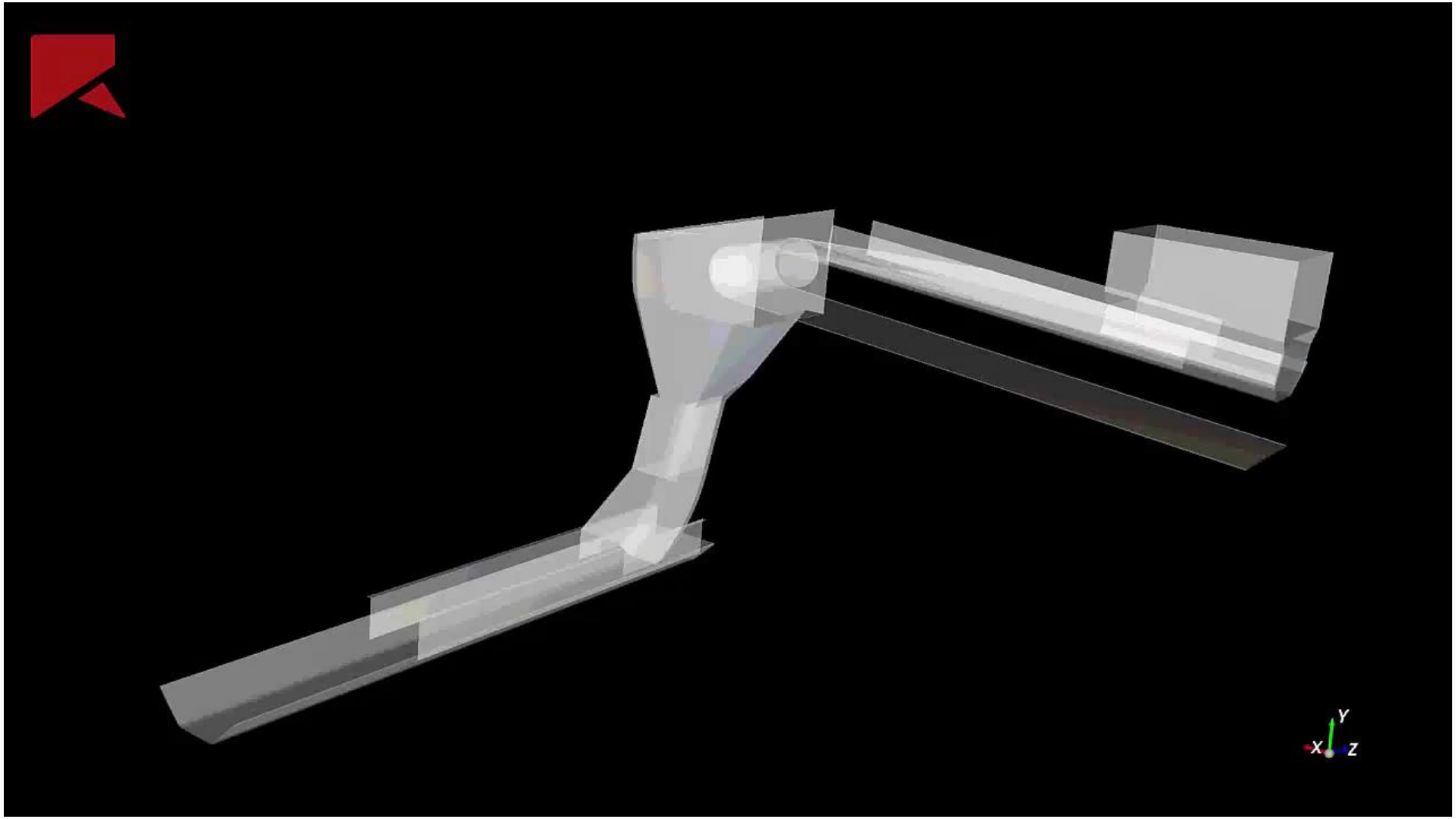
## Discrete Grain Breakage



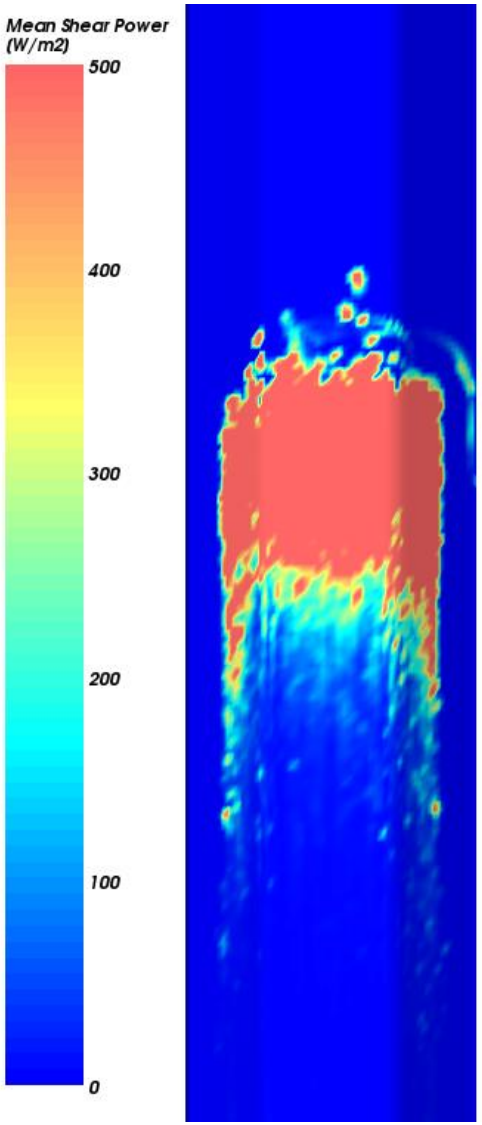

”Meshed” particle model



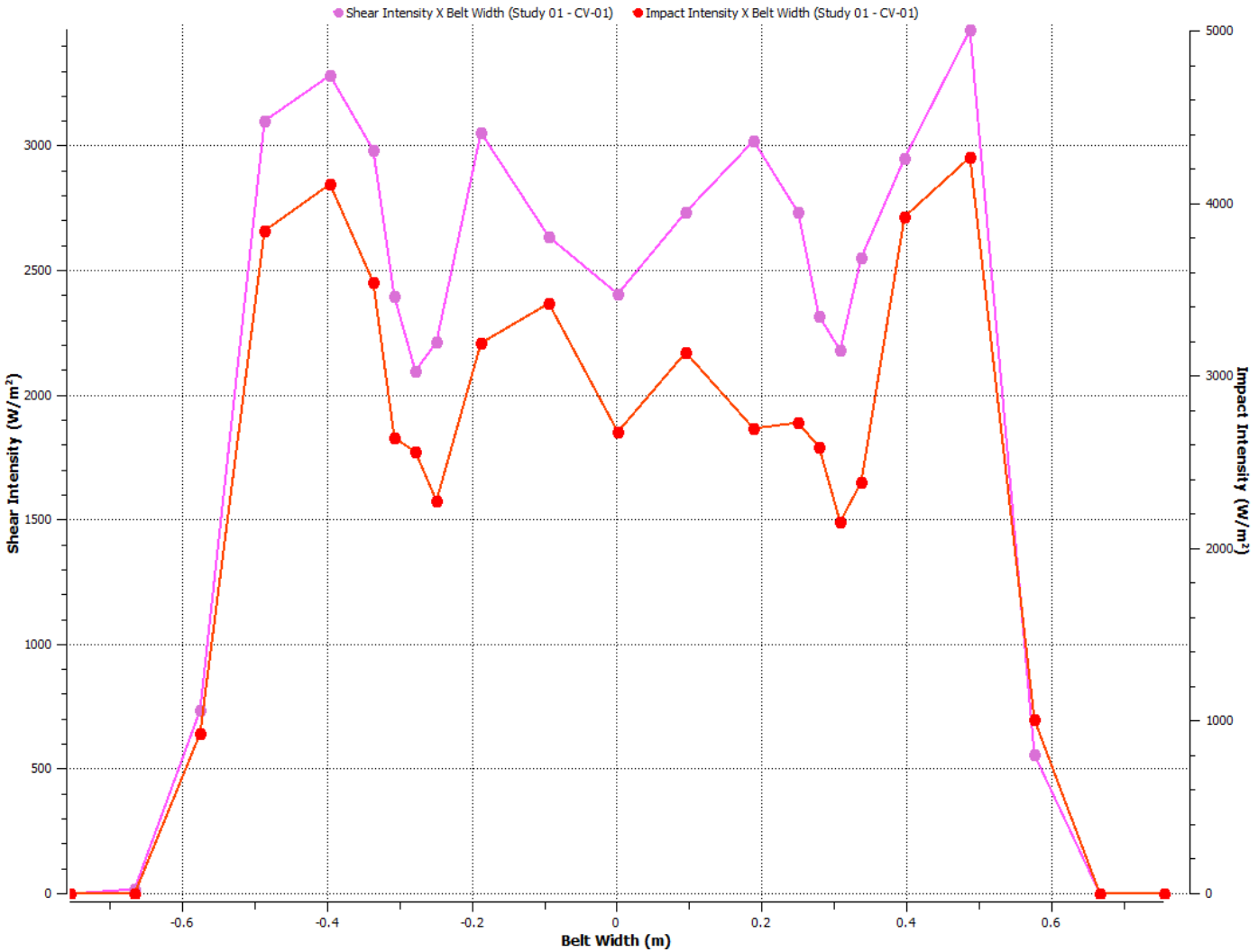
# Boundary Surface Wear



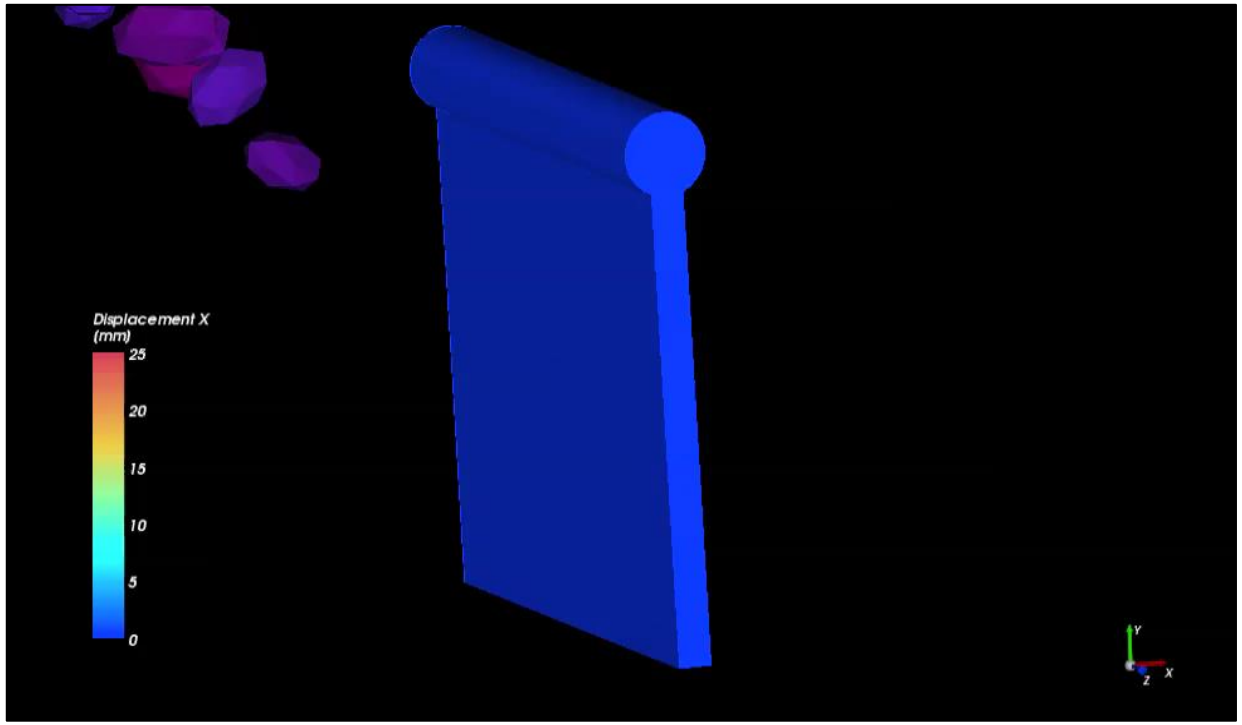
# Boundary Surface Wear



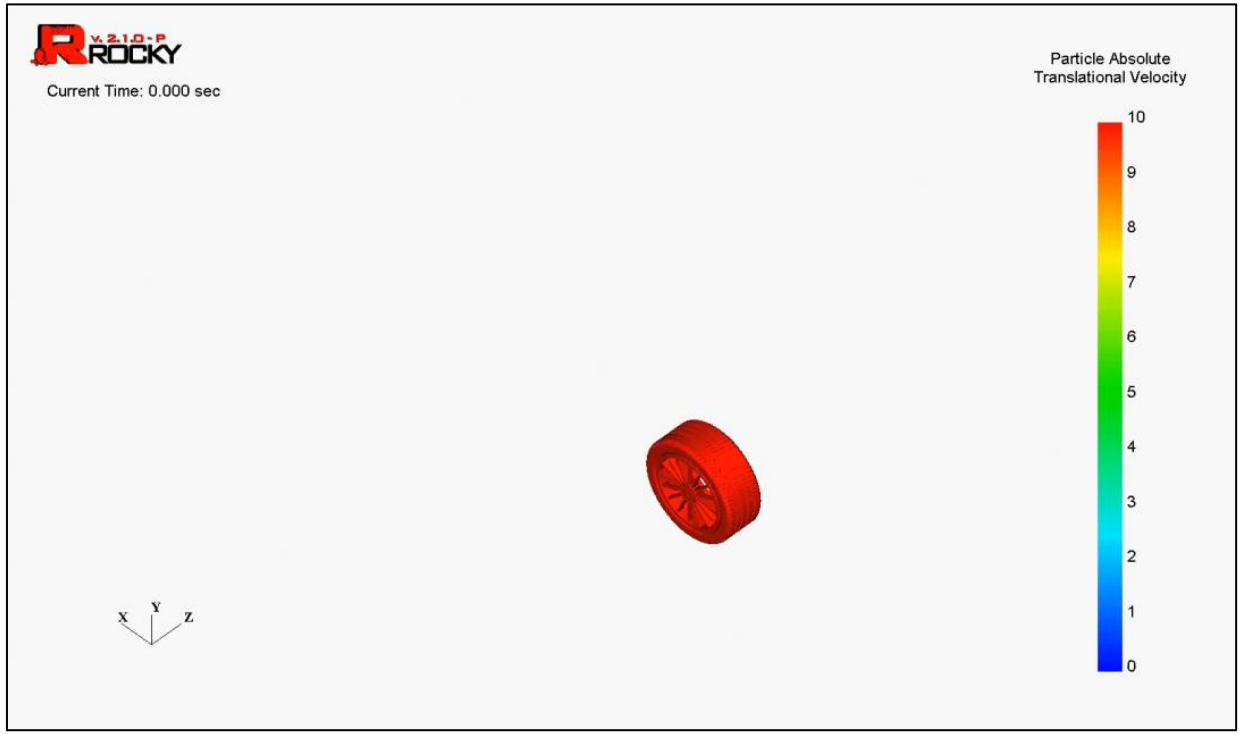

Useful statistics: shear intensity and impact intensity vs. belt width



# Complex Motions: 6 Degrees of Freedom (DOF)




Hinged flop gate free to rotate about the Z axis.
Displacement and wear rate also captured.




Wheel with six degrees of freedom motion.
Wheel mass is m=10 kg, moments of inertia are Ixx=1.0,
Iyy=0.1, Izz=0.1 kg*$m^2$

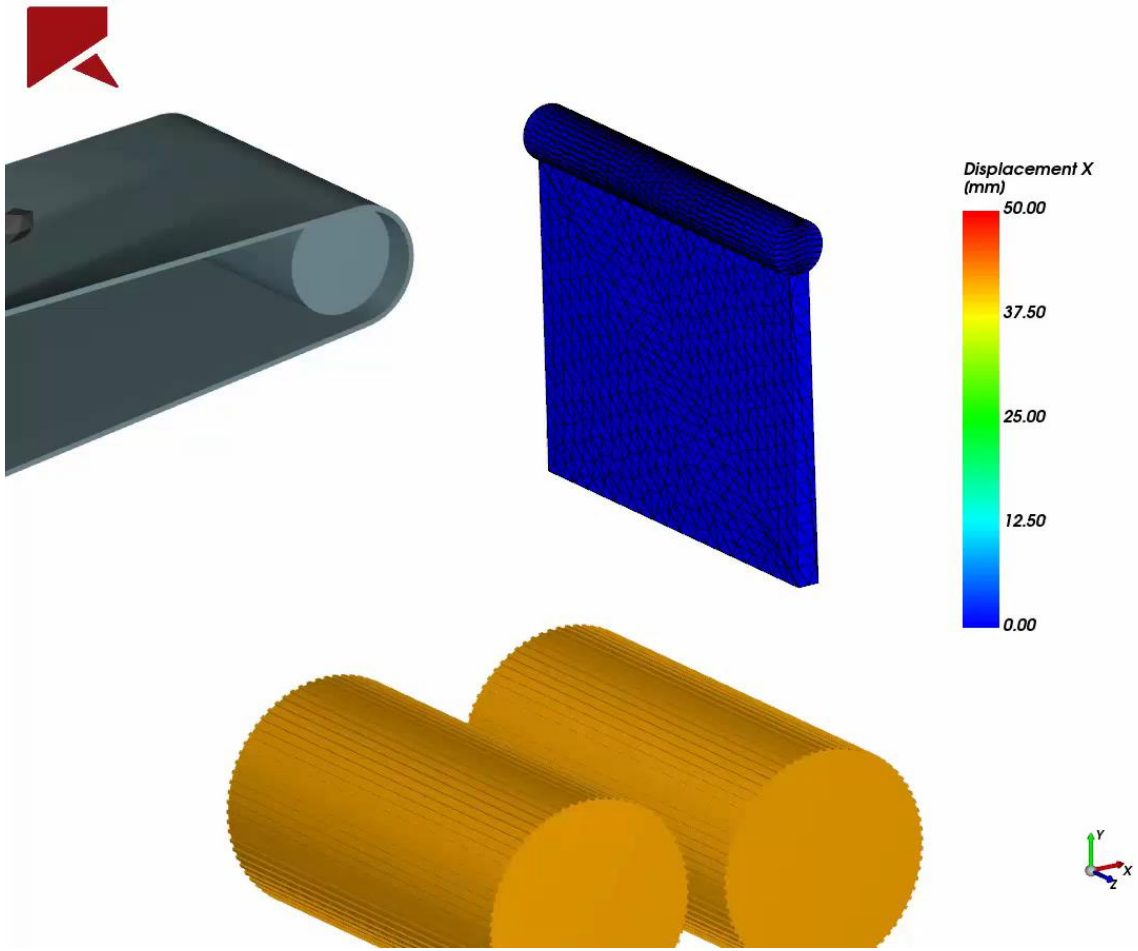
# Wear Prediction - High Pressure Grinding Roll

**Simulation Goal:**

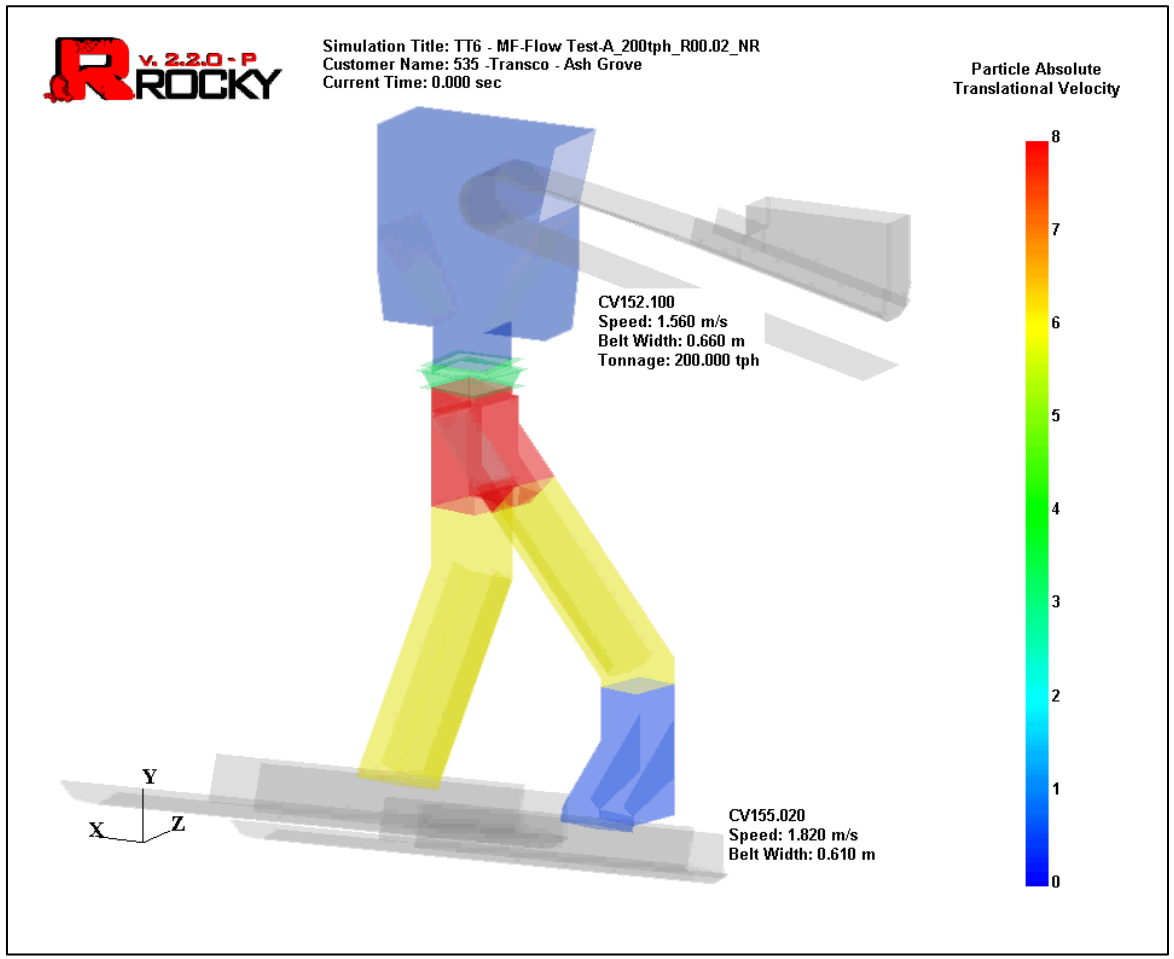
Predict wear on the deflector and find the particle size distribution of material after grinding process

**Rocky DEM highlights:**

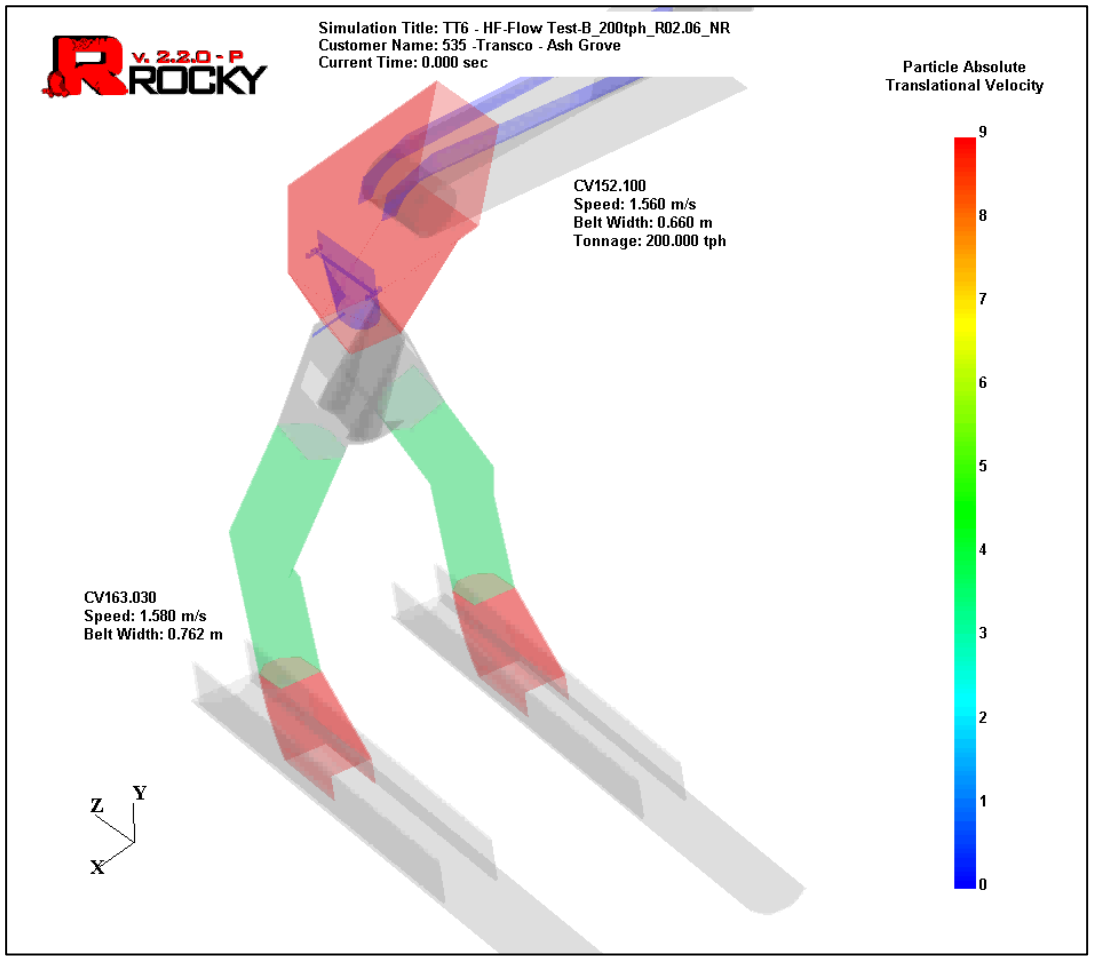
- **Wear model that enables geometry deformation**
- **Breakage models that preserve mass and volume**



# Simulation of wet and sticky material flow

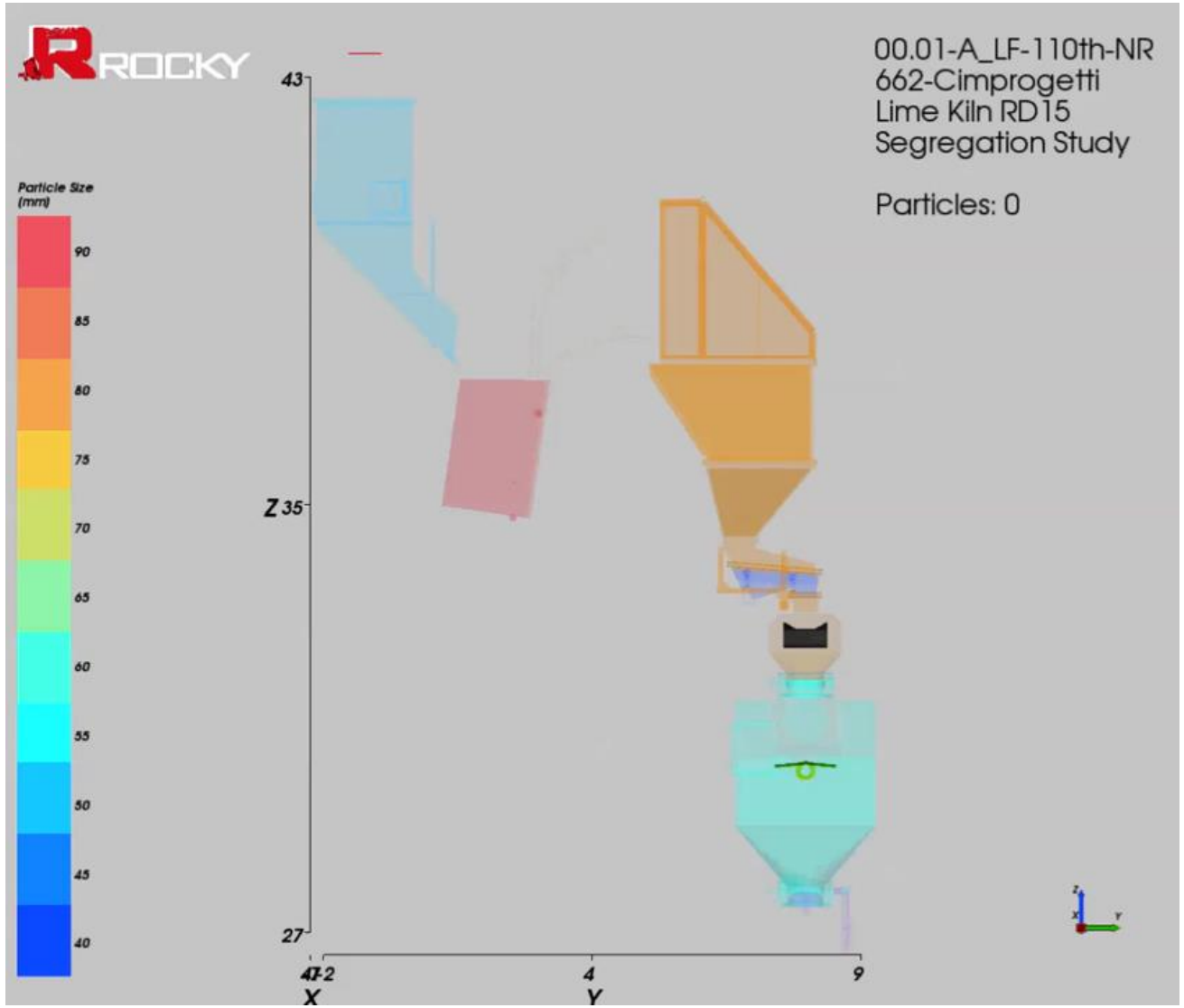



Existing Design

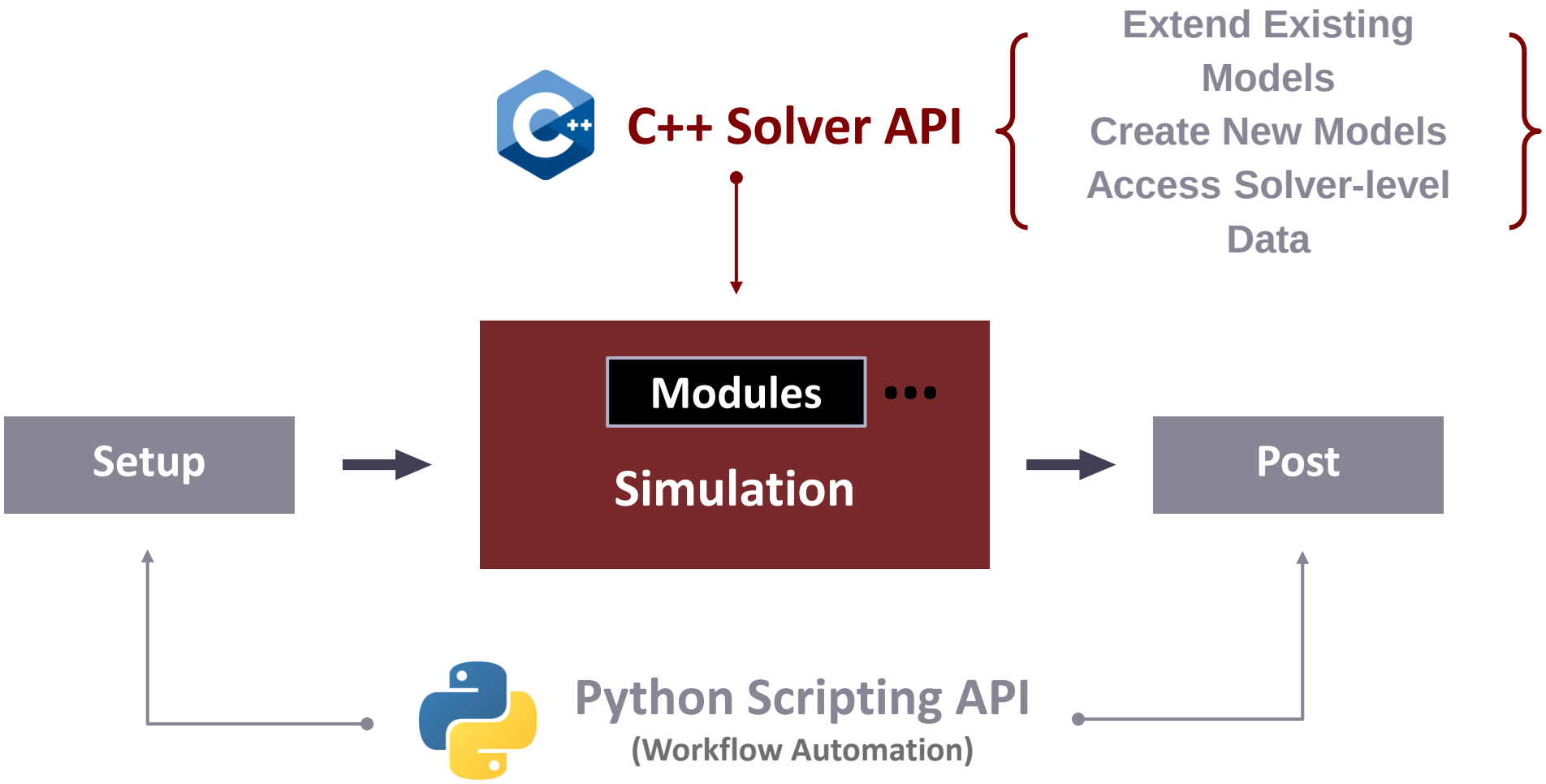



New Design

# Complex Motions



# Complete Customization and Extension

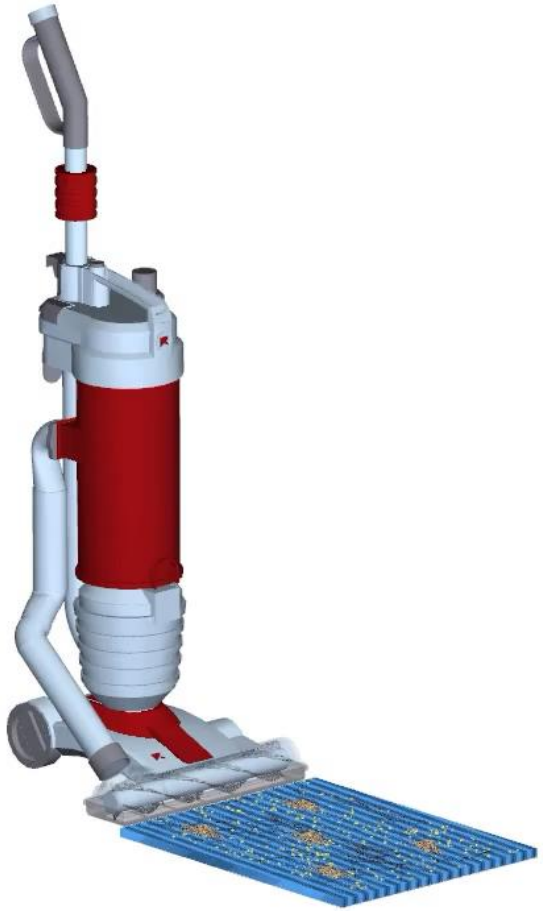


# Complete Customization and Extension

| Type | Name | Description | Version | Links |
|---|---|---|---|---|
| Adhesion Model | **[NEW]** Velocity-Dependent Adhesive Force | Enables you to use a parametric adhesive force model that takes into account the particle's impact velocity. This model is best suited for spherical particles. Application examples include snow accretion. The Source code is not provided for this item. | 1.0.0 | Windows, Linux |
| Boundary Condition | Region Outlet | Enables you to define a custom cube region as an outlet for particles; any particles entering this region will be removed from the simulation, similarly to what happens when a particle crosses the limits of the simulation domain. Application examples include blast furnaces. | 1.0.2 | Windows, Linux, Source |
| | Boundary Outlet | Enables you to define an imported geometry component and/or default conveyor as an outlet for particles. This module then removes from the simulation any particle that becomes in contact with that geometry. Application examples include blast furnaces. | 1.0.0 | Windows, Linux, Source |
| Breakage Model | **[NEW]** Overlap-Based Breakage Model | This module enables you to use a custom, instantaneous breakage model and a custom fragments size distribution model to account for the physical effects of compression upon particle breakage, where the contact overlap is used as a measurement of particle deformation. Application examples include jaw, gyratory, or roll crushers. | 1.0.1 | Windows, Linux, Source |
| CFD Coupling | Parametric Ranz & Marshall Law | Enables you to use a parametric version of the Ranz & Marshall Convective Heat Transfer Law included by default in Rocky for interactions between spherical particles and fluids when CFD Coupling is enabled. This model is made parametric by adding two free parameters to the calculation of the Nusselt number. | 1.0.1 | Windows, Linux, Source |
| | **[NEW]** Dhole, Chhabra & Eswaran Drag Law | Enables you to use a power-law drag correlation for your CFD Coupling simulations that is specifically designed to model non-Newtonian fluids that obey the Ostwald–de Waele (power-law) relationship. This module is designed to work with Rocky's 1-Way Constant, 1-Way Fluent Steady State, or 2-Way Fluent (unresolved) coupling methods. This module is a drag factor correction that accounts for the fluid non-newtonian properties in the drag correlation, it does not account for the particle shape nor the local volume fraction. Therefore it is suited for espherical particles in dilute flows. | 1.0.0 | Windows, Linux, Source |
| Contact Model | Leeds Contact Model | Enables you to use the Leeds Contact Model for both the Normal Force and Adhesive Force used in the project. Application examples include cohesive frictional powders. | 1.0.1 | Windows, Linux, Source |
| | Stress-Based Multi-Contact Normal Force | Enables you to use the Stress-Based Multi-Contact Model proposed by K. Giannis et al. for the Normal Forces used in the project. | 1.0.0 | Windows, Linux, Source |
| | Nonlinear Hysteretic Normal Force | Enables you to use the Non-Linear Hysteresis Model for the Normal Forces used in the project. Application examples include elasto-plastic materials. | 1.0.1 | Windows, Linux, Source |
| Data Gathering | **[NEW]** Normal and Tangential Energy Dissipation | This module re-implements and then splits into its normal and tangential components the same Particle Curve calculations you get in Rocky when the Energy Dissipation option is enabled on the Inter-group Collision Statistics module; and similar Particle Property calculations you get in Rocky when the Power option is enabled on the Inter-particle Collision Statistics module, only instead of power, it calculates energy. | 1.0.1 | Windows, Linux, Source |
| External Force | Magnetic Force | Enables you to use an imported magnetic field to define an additional body force acting on particles. Application example includes magnetic separators. | 1.0.0 | Windows, Linux, Source |
| | Spring-Dashpot Body Force | Applies a spring-dashpot force to particles. The force is proportional to the distance from a given point and to the particle's translational velocity. Application examples include measuring forces in single-particle validation experiments. | 1.0.0 | Windows, Linux, Source |
| | **[NEW]** 1-Way CFD Field Coupling | This module enables you to couple 1-way with Rocky a fluid velocity field that has been imported into Rocky as a Point Cloud. It can be used as an alternative to the 1-Way Fluent Steady State coupling method included with Rocky, as it enables you make use of the fluid results from various external CFD solvers. This module also re-implements the Schiller & Naumann Drag Law that comes by default with Rocky, and is therefore best suited for spherical particles. It can be used as an example of API: Solver usage. | 1.0.0 | Windows, Linux, Source |
| | Electrostatic Force | Enables you to add attractive or repulsive electrostatic forces between each particle-particle and particle-boundary interaction that occurs during the simulation. Application examples include powder handling units, electrostatic separators, and additive manufacturing processes. | 1.0.1 | Windows, Linux, Source |
| | Magnetic Force on Ferrous Material | This module adds a magnetic force resulting from the interaction of a ferromagnetic particle and a magnetic induction vector field, the latter of which is imported as a point cloud. Application example includes a cross-belt magnetic separator. | 1.0.2 | Windows, Linux, Source |

# … and the Result is a Custom, Accurate Multiphysics Engineering Tool

- Custom Fibers
- Fixed Elements
- Shaped Particles
- Ansys CFD Coupling
- Motion Parts
- GPU Solver

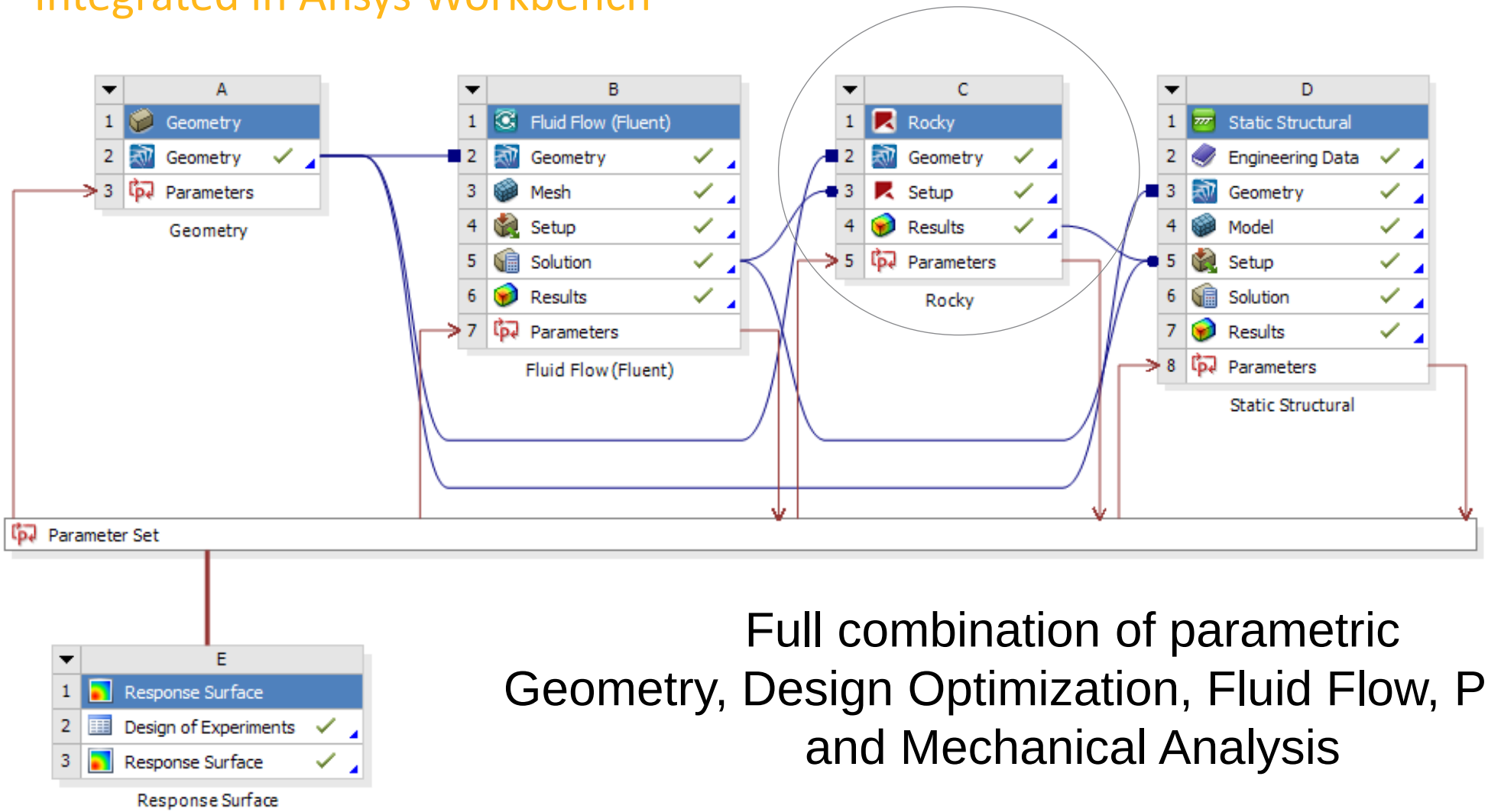


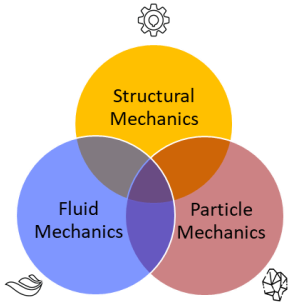
Accurate Vacuum Cleaner Model

# How does Rocky fit into Ansys Portfolio?

# How does Rocky fit into Ansys Portfolio?

## Integrated in Ansys Workbench



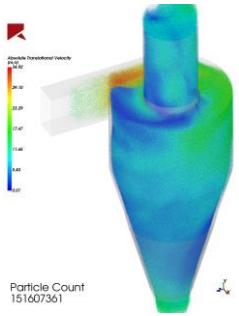




Full combination of parametric Geometry, Design Optimization, Fluid Flow, Particles and Mechanical Analysis

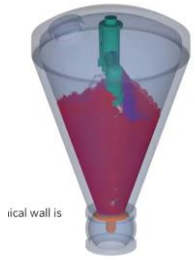
# Example - Ansys CFD Coupling (Fluent)

## Powerful CFD-DEM simulation software for granular-fluid systems (not exhaustive)

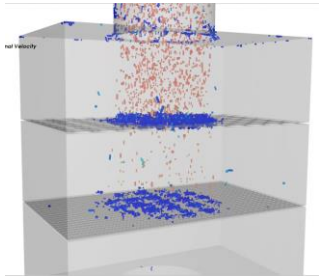
**Cyclone Separators**



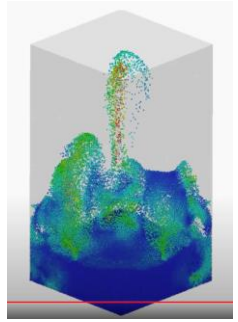

**Dryers**



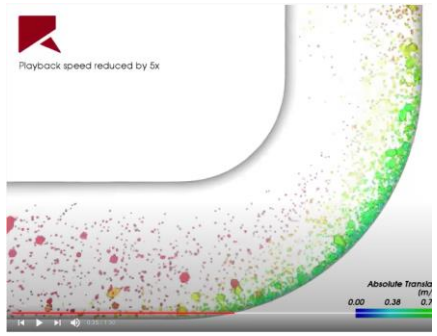
**Filtration**



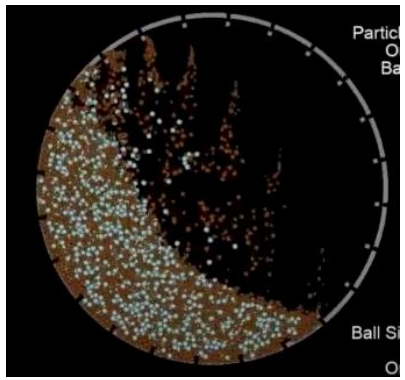
**Fluidized bed**



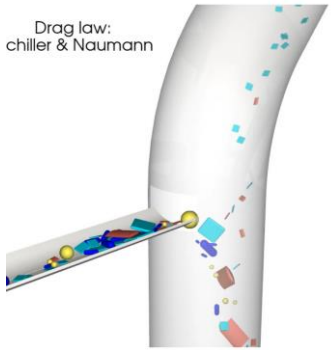
**Particle transport**



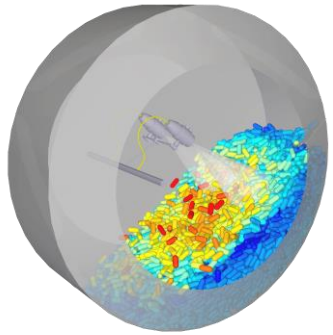

**Slurry mills**



**Solid suspension**



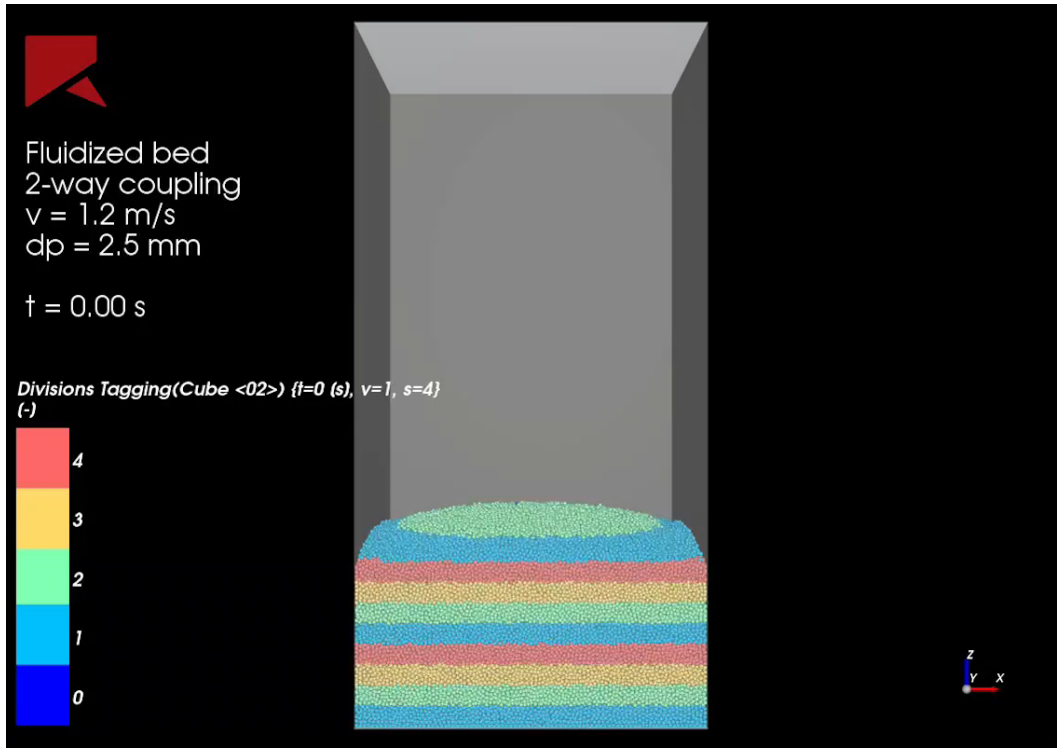

**Spray coating**



# Ansys CFD Coupling (Fluent)

Both one-way and two-way analyses are possible.


One-way coupling example: waste separator

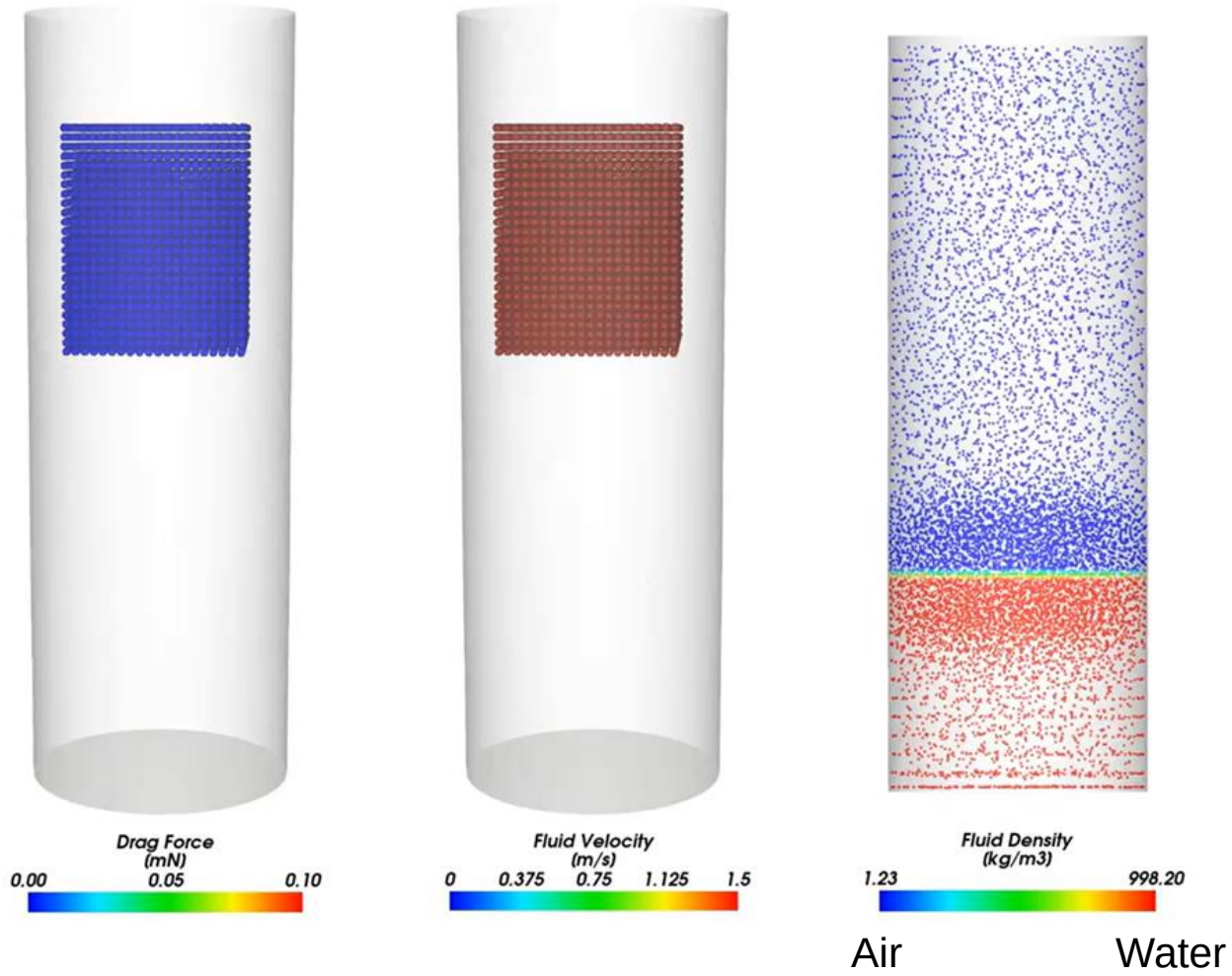



Two-way coupling example: fluidized bed

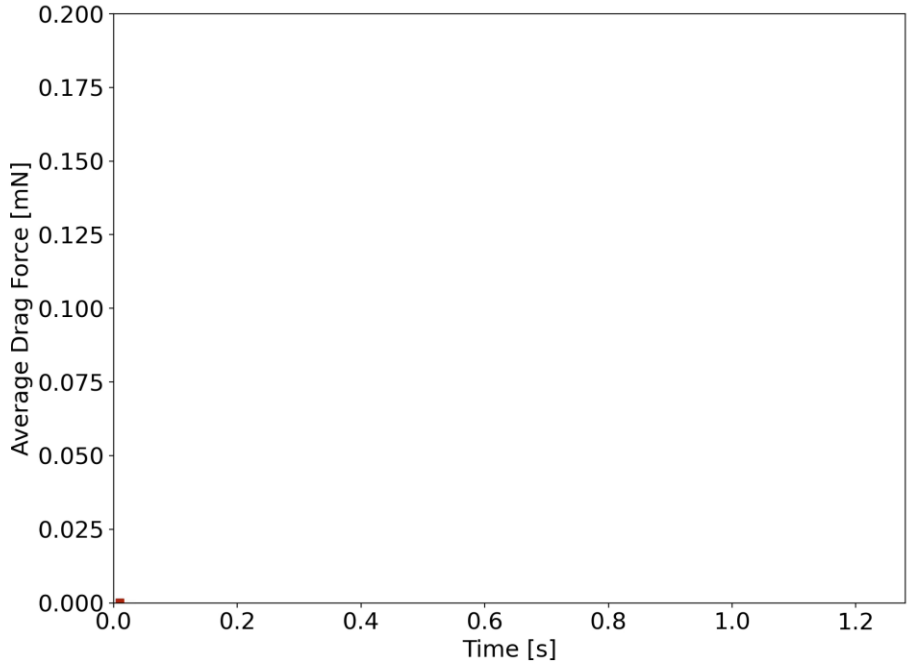
# Expanded Fluent Coupling

## Particle + Fluid Integrated Post-Processing

**Integrated Visualization**




**Particle-Fluid Interaction Statistics**

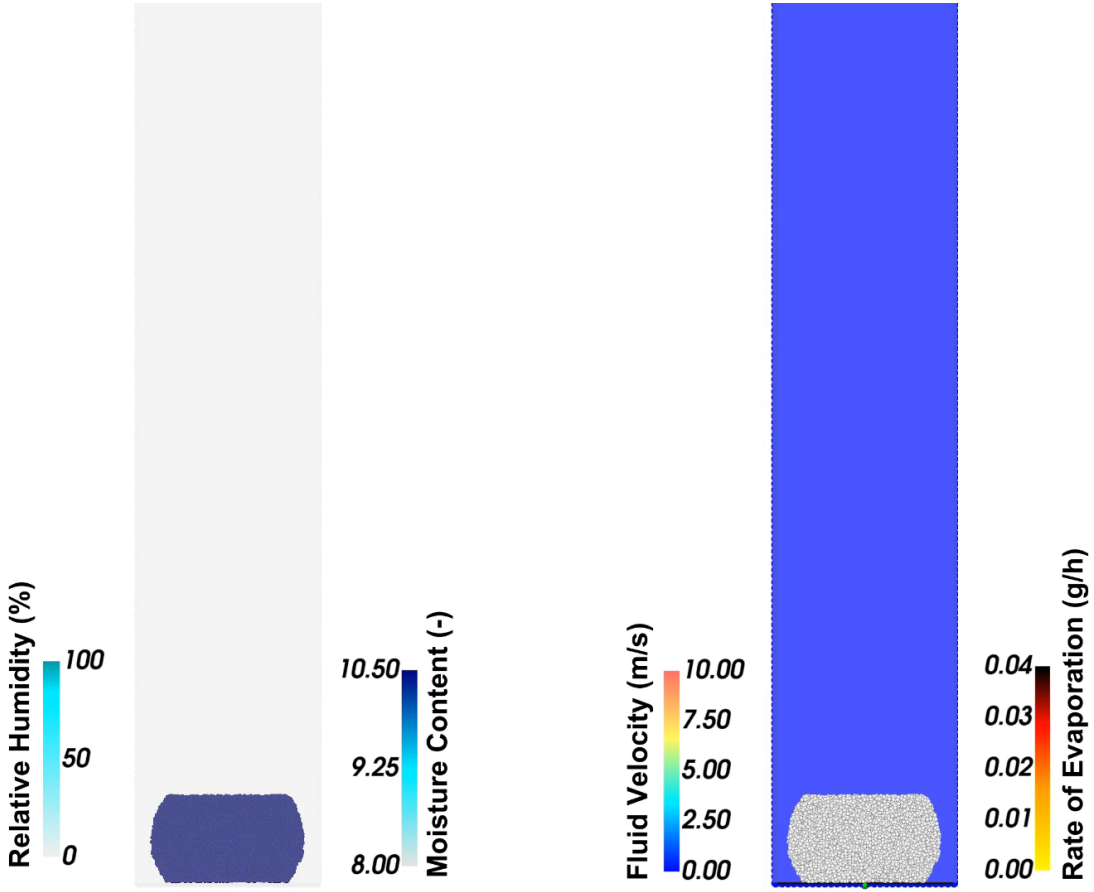



**Drag Force, Torque, Lift, Virtual Mass, Buoyance & Heat Transfer**

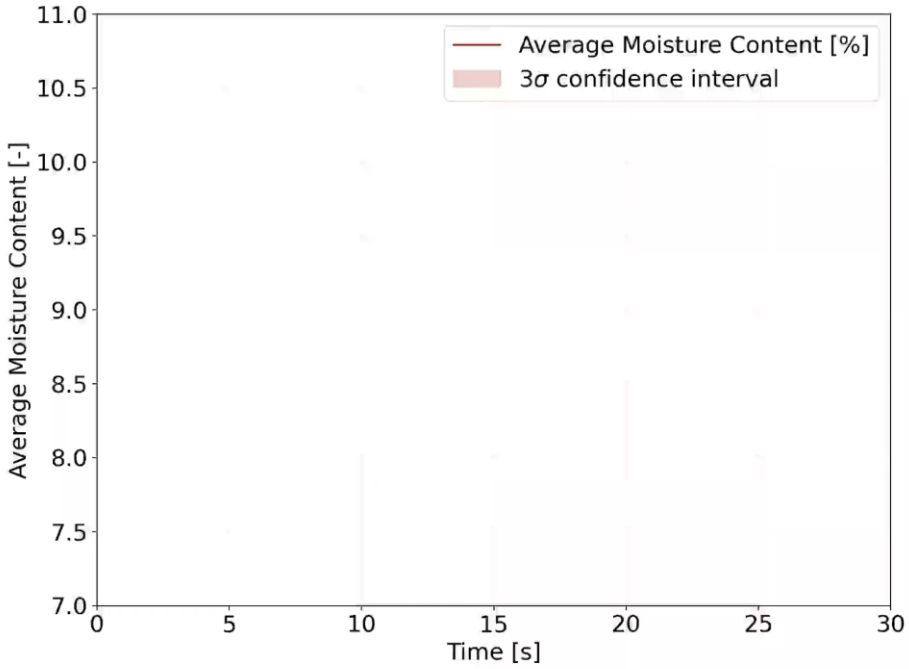
Ansys

# Expanded Fluent Coupling

## Drying Model




**Fluidized Bed Drying**

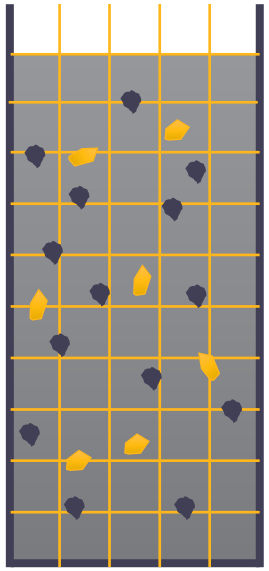



**Particle Moisture Content**

# 2-way CFD Coupling (Fluent)

## Strategy 1: Single phase + porous media

- **Special implementation for single-fluid flows**
- **3x times faster than multiphase implementation**



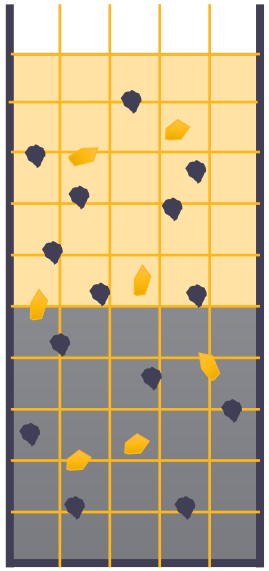


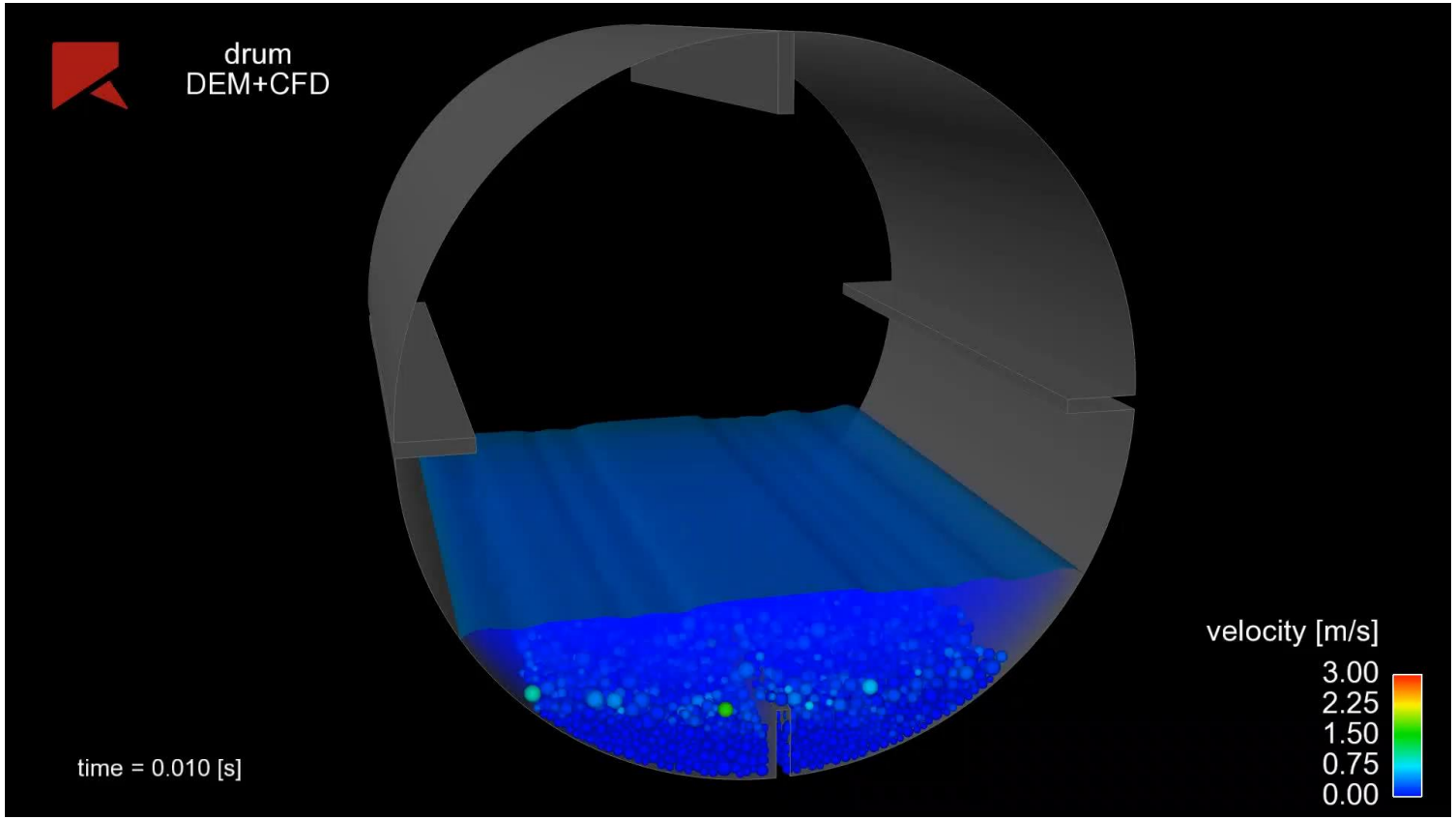
**Example: Hydraulic transport**

# 2-way CFD Coupling (Fluent)

## Strategy 2: Full Eulerian multiphase

- General case scenario
- Solids + several “fluids”



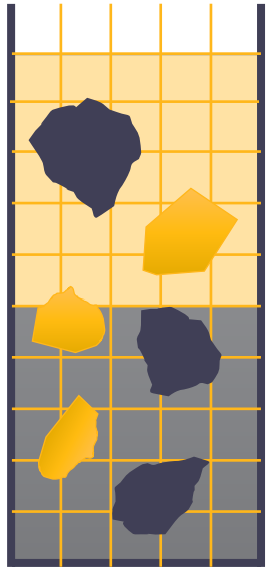



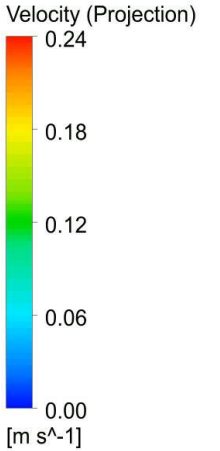

**Example: Rotating drum**

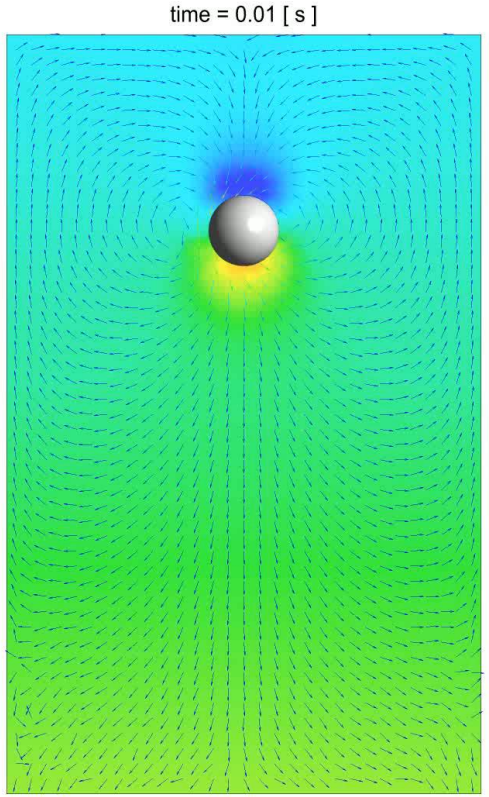
# 2-way CFD Coupling (Fluent)

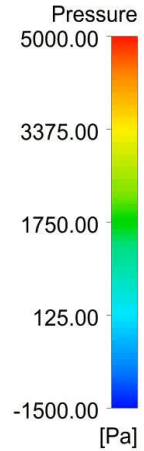
## Strategy 3: Semi-resolved coupling

- **Particle-grid size ratio >> 1**
- **Multi-phase flow**
- **Solid volume fraction correction**

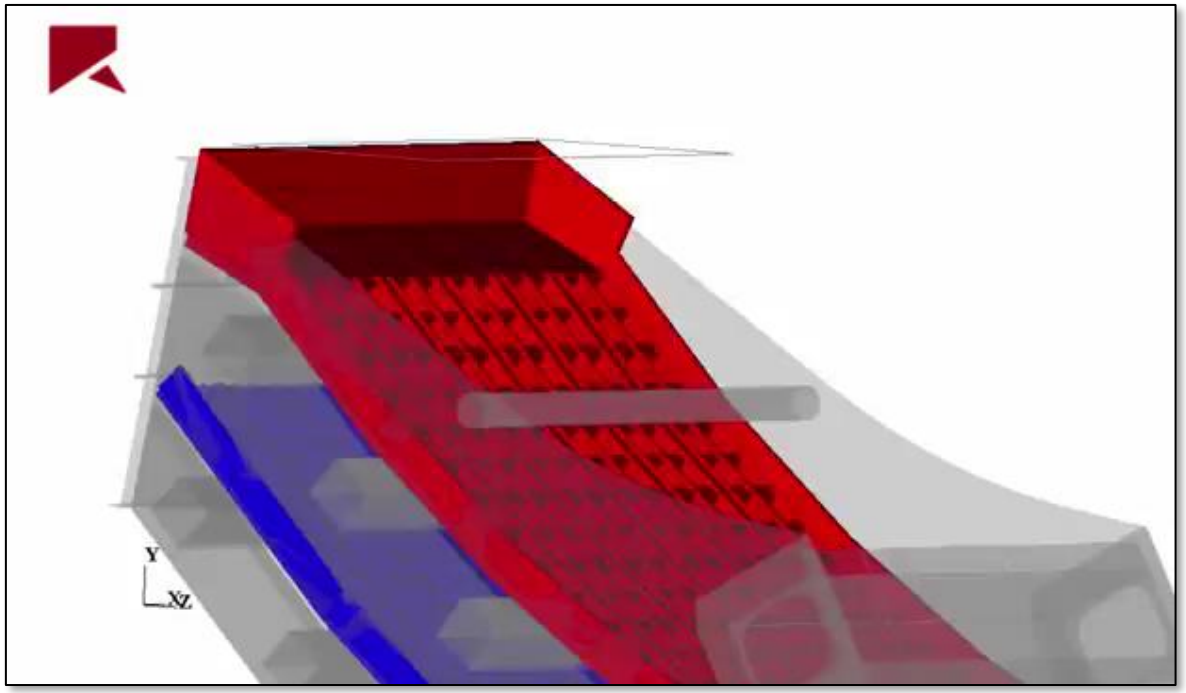


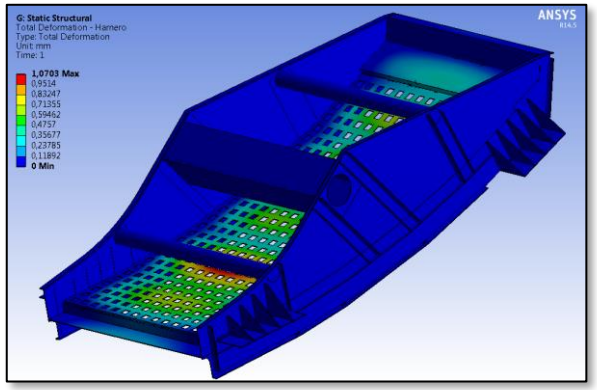



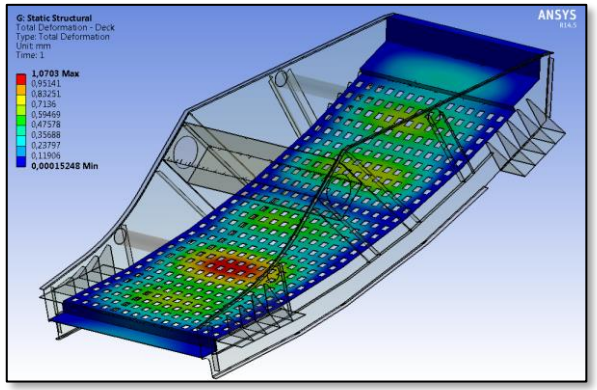



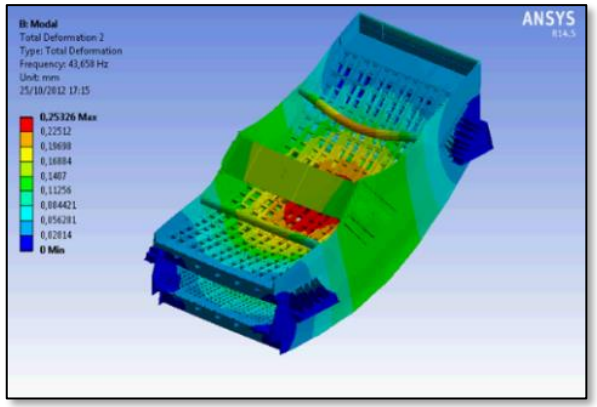



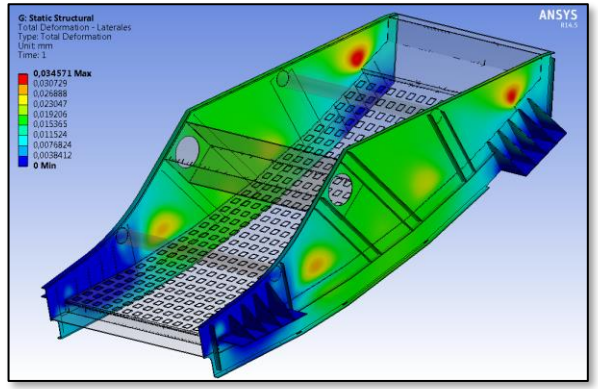

# Ansys Mechanical Coupling

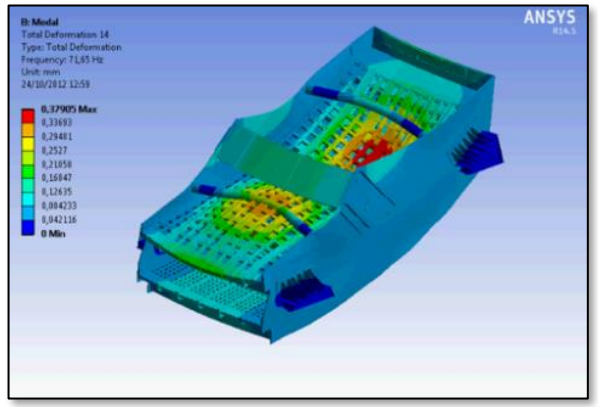


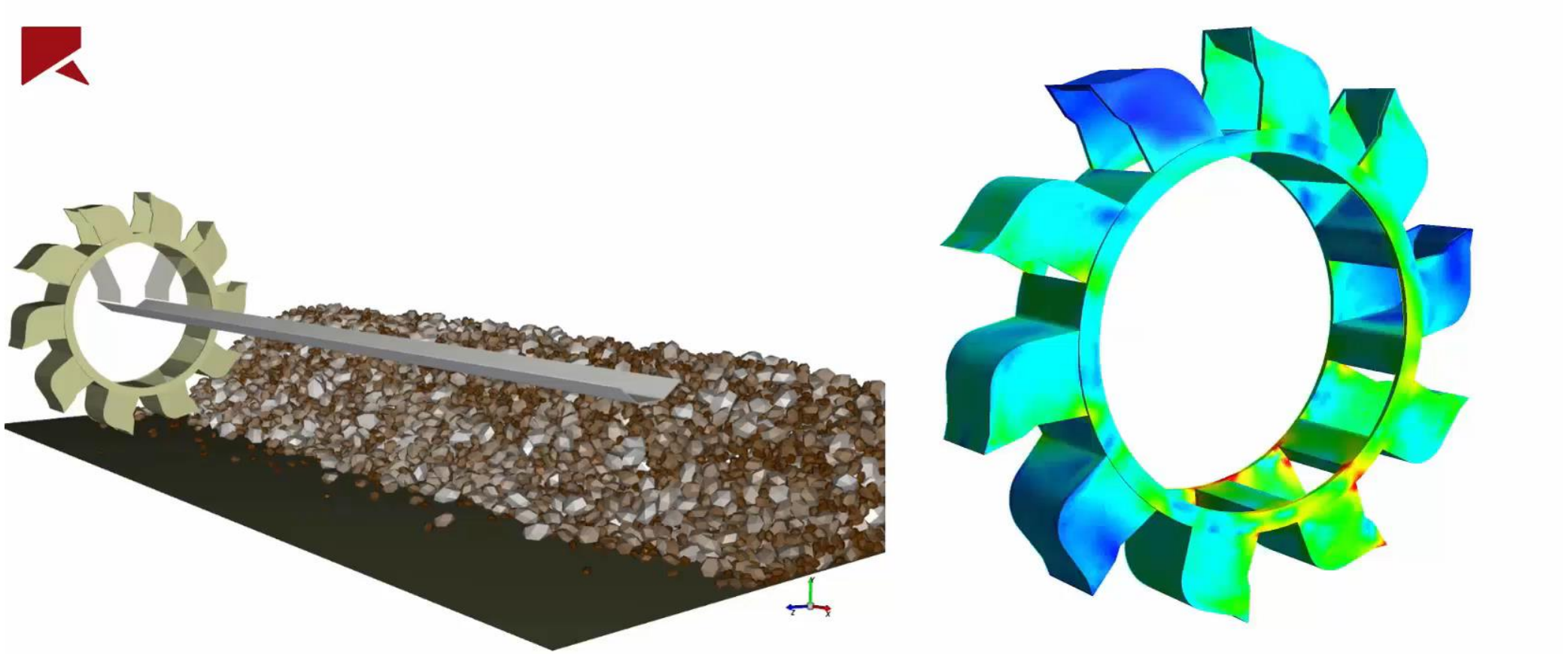




- Stresses and vibration analyses of a screen in ANSYS
- Inputs come from Rocky simulation

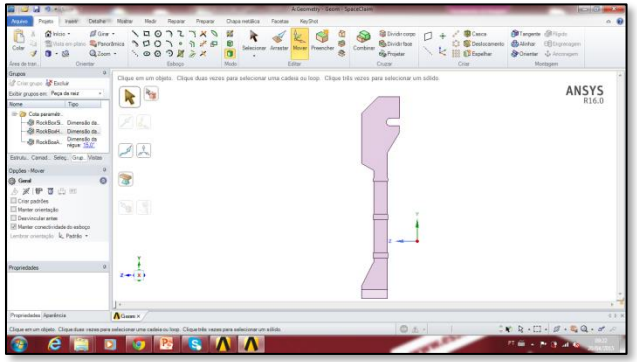
# Ansys Mechanical Coupling



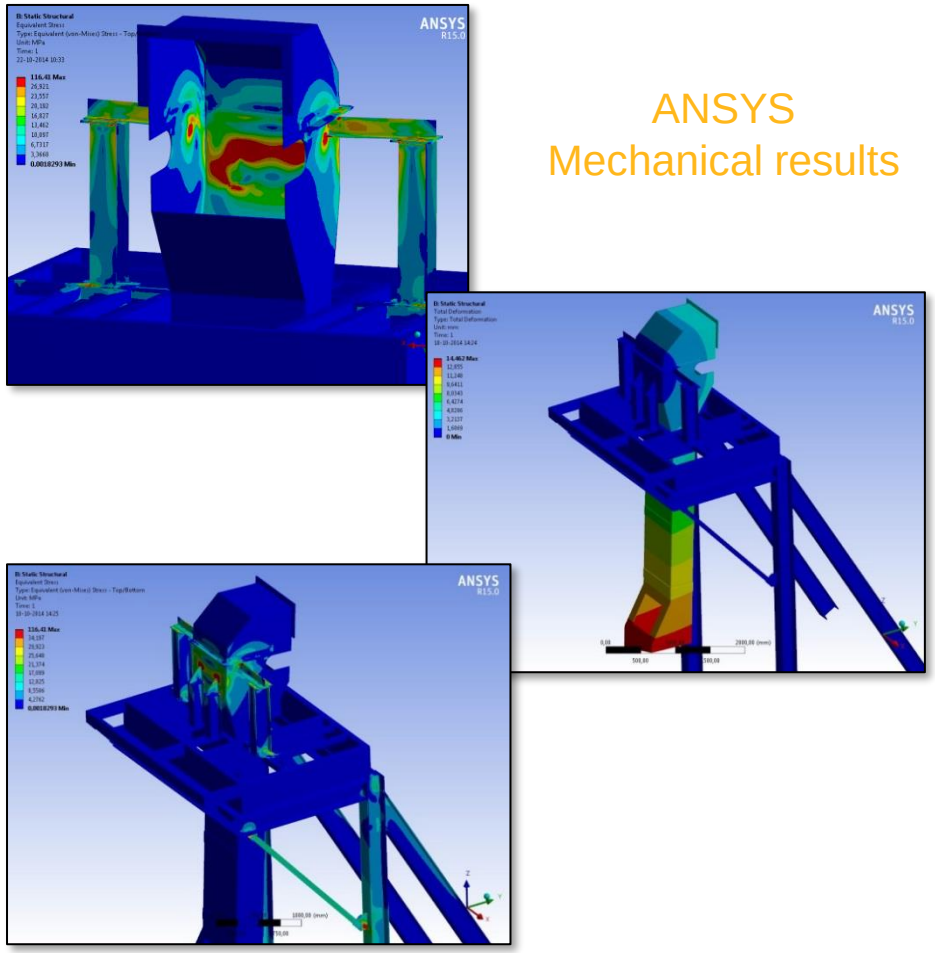
Bucket excavator: Solid induced loads captured accurately

# Structure Analysis of a Transfer Chute

- ANSYS Mechanical Coupling (FEA)




ANSYS
SpaceClaim Direct
Modeler

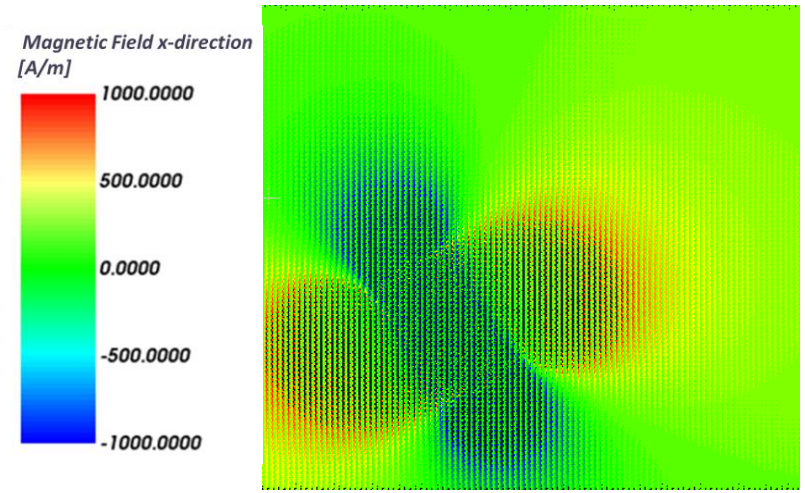




ANSYS
Mechanical results

# Electric Particles – Electromagnetic Coupling

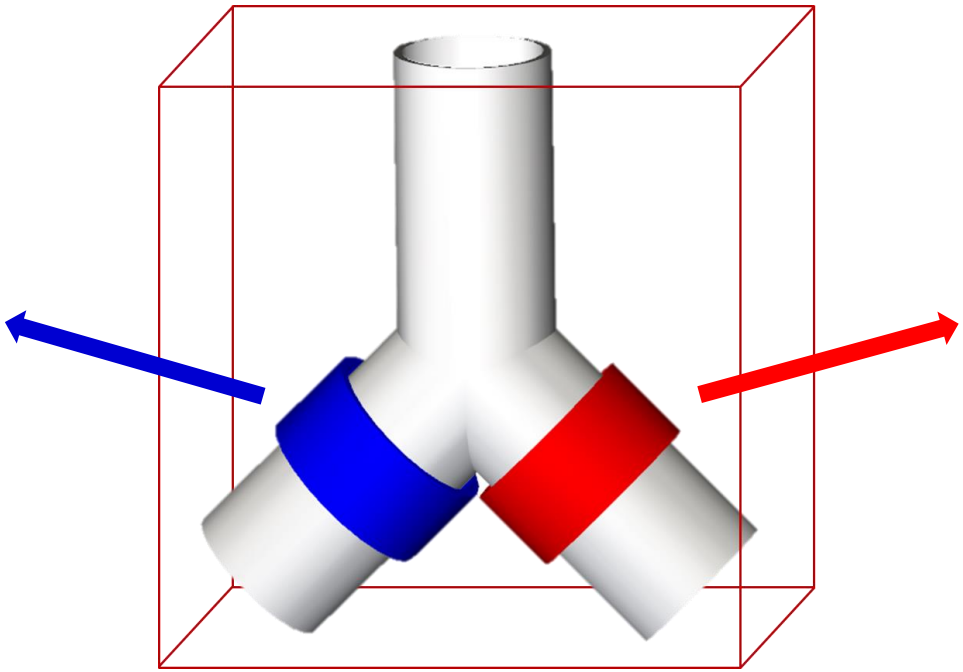
## Magnetic Fields are imported from Ansys Maxwell using Point Clouds

**Blue Ring** Magnetic Field Point Cloud (1)

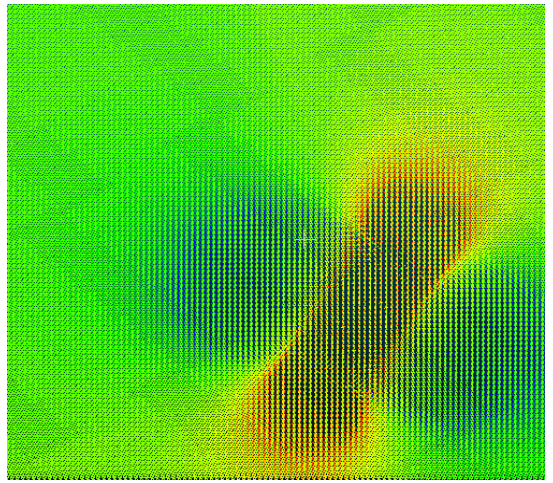



Volume Rendering of $H_x$

**Magnetic Fields applied to the marked cubical region**



**Red Ring** Magnetic Field Point Cloud (2)



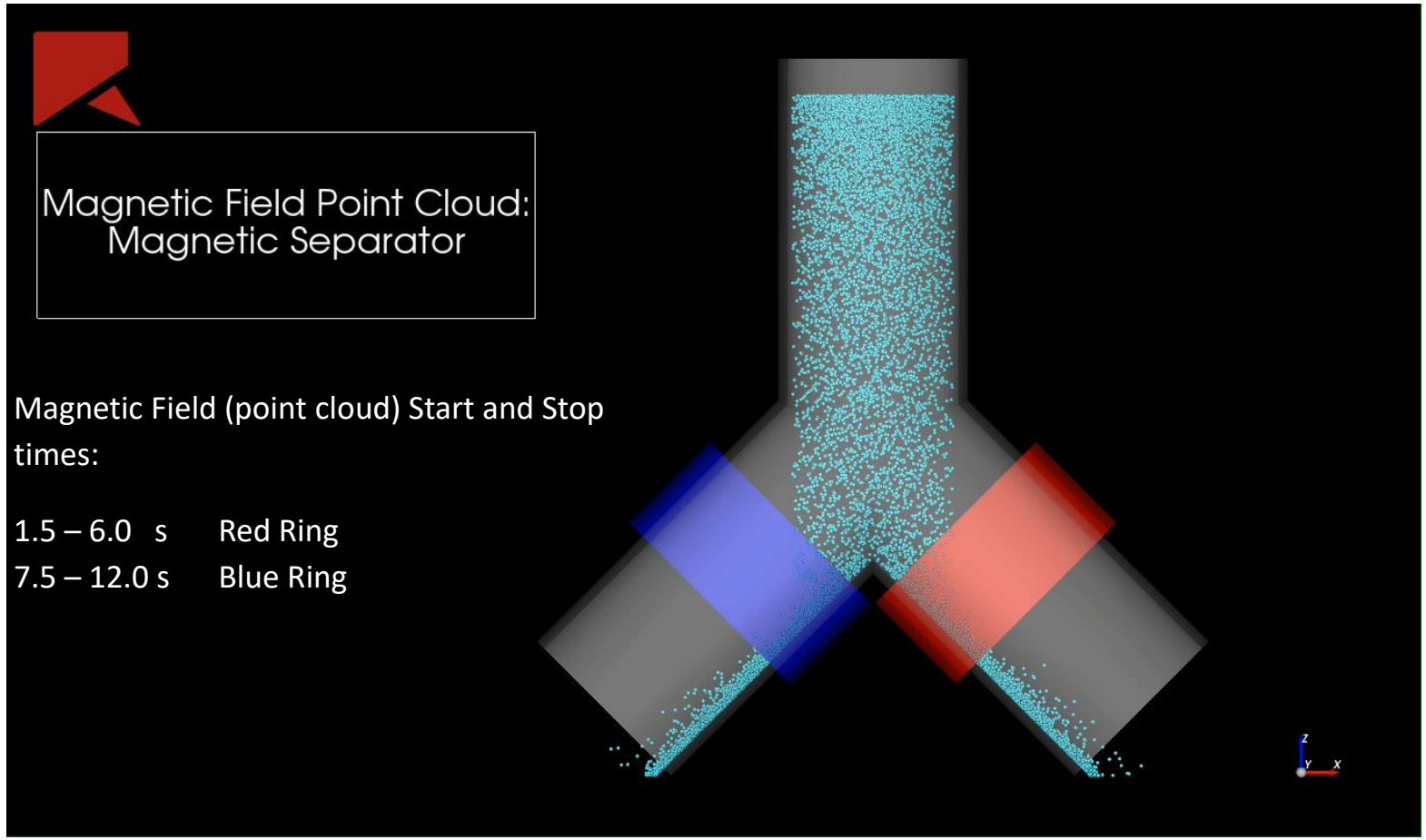
# Electric Particles – Electromagnetic Coupling

Magnetic Field is loaded using a Point Cloud

Magnetic Field force is added to particles as a custom Body Force

$$\vec{F} = q\vec{V} \times \vec{H}$$

$q$: Particle charge
$\vec{V}$: Particle Velocity
$\vec{H}$: Magnetic Field



# Electric Particles – Electrostatic Force

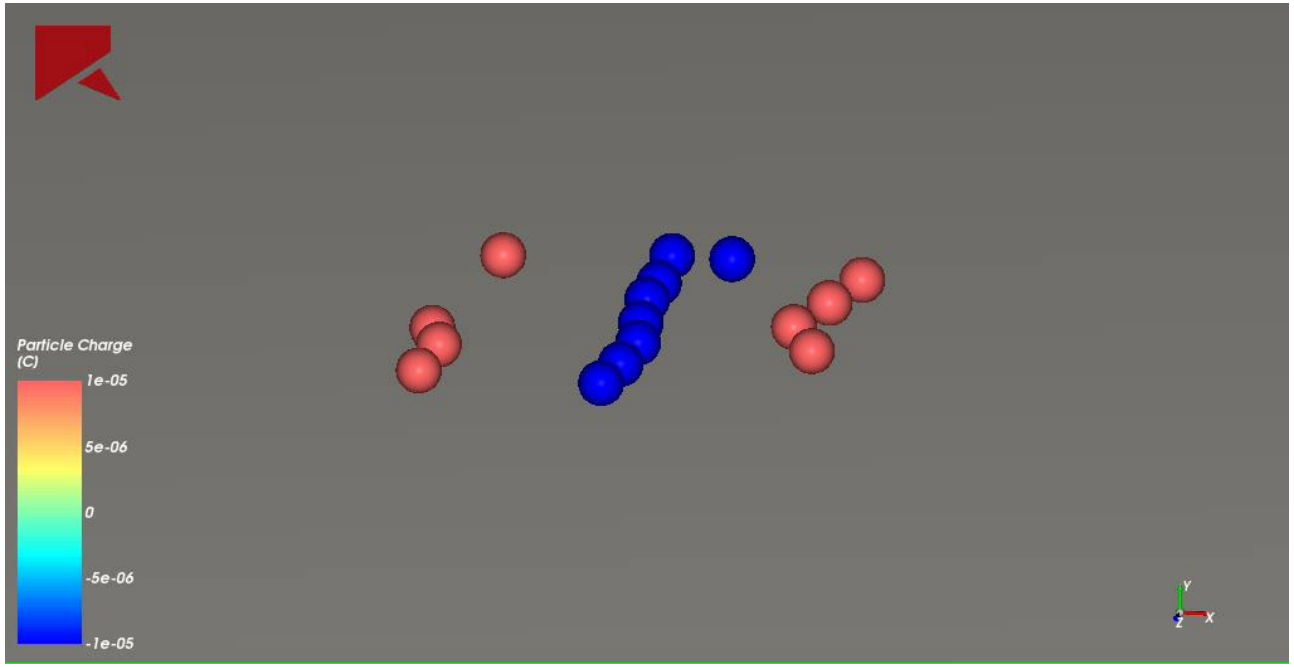
## Coulomb Law

$$F = \frac{q_1 q_2}{4\pi\varepsilon r^2}$$

$q$ = particle charge

$\varepsilon$ = absolute permittivity

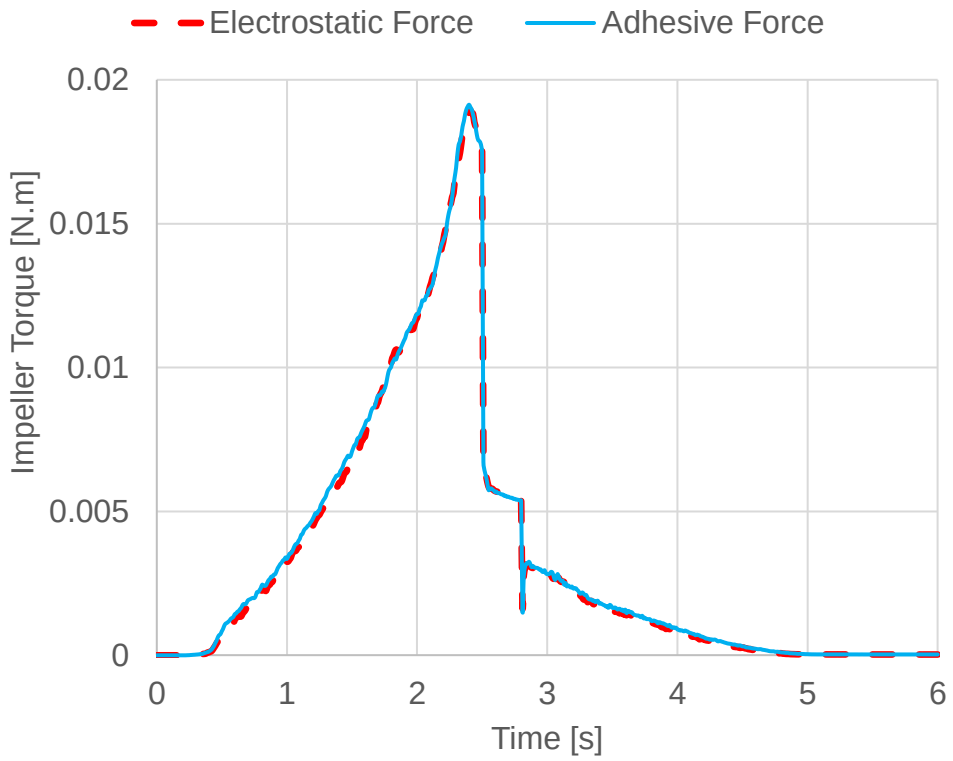
$r$ = distance between the two charges



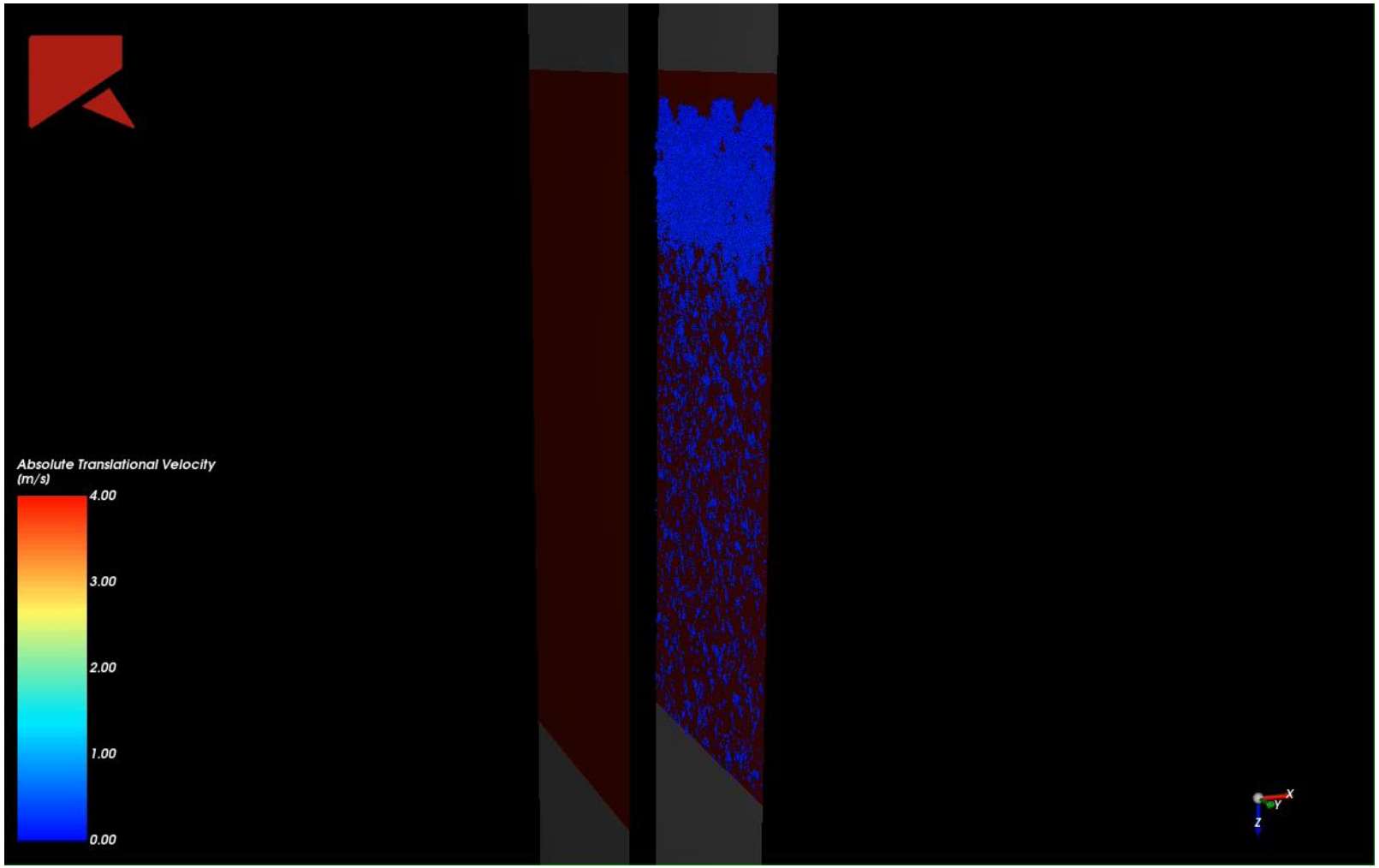
# Electric Particles – Electrostatic Force

Adhesive Force

Electrostatics Force



# Electric Particles – Electrostatic Precipitator



# Electric Particles – Tribocharging

## Empirical Formulas

$$q = q_0 e^{-\alpha t} + q_s(1 - e^{-\alpha t})$$

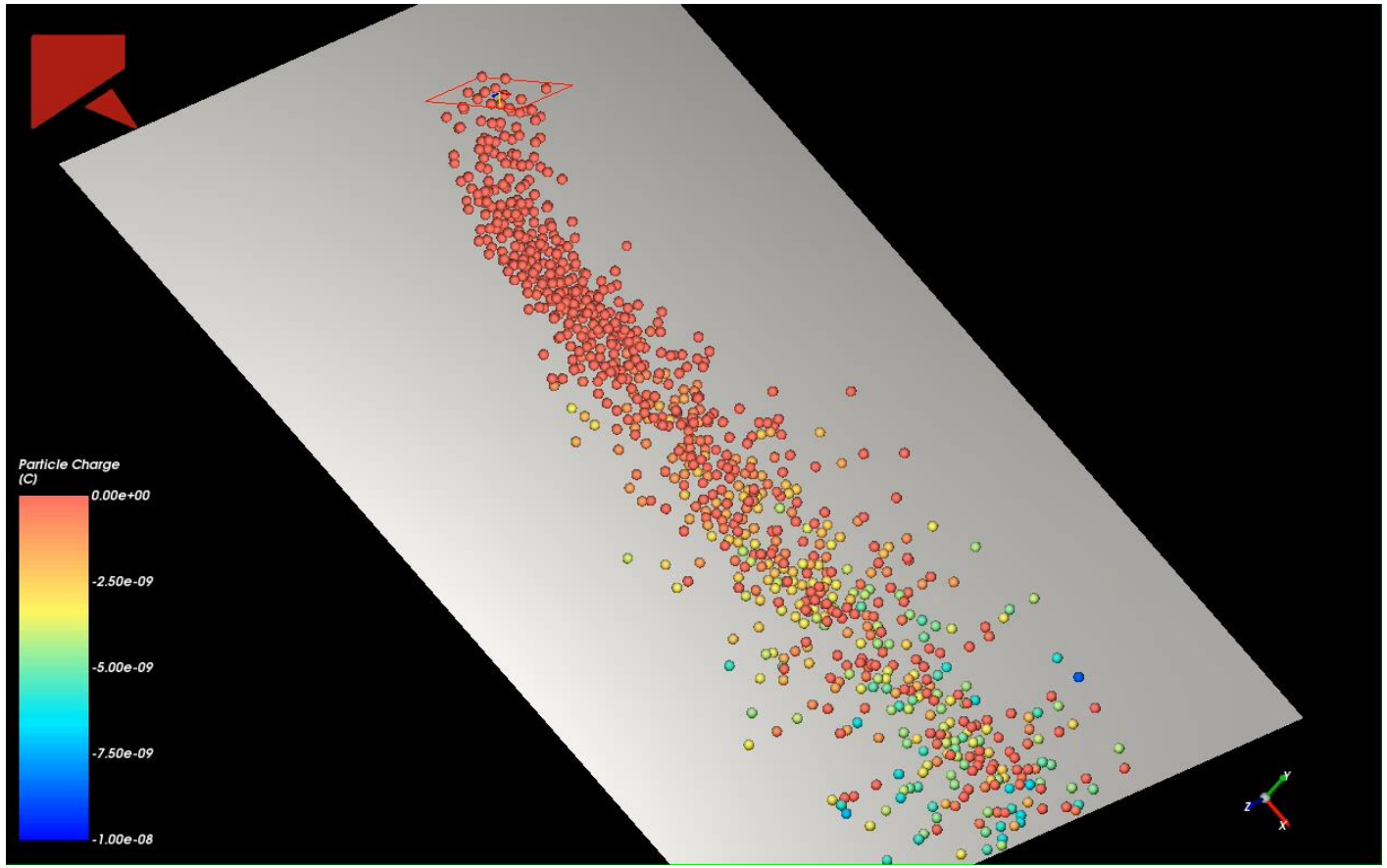
$q$ = final particle charge

$q_0$ = initial particle charge

$q_s$ = saturation particle charge

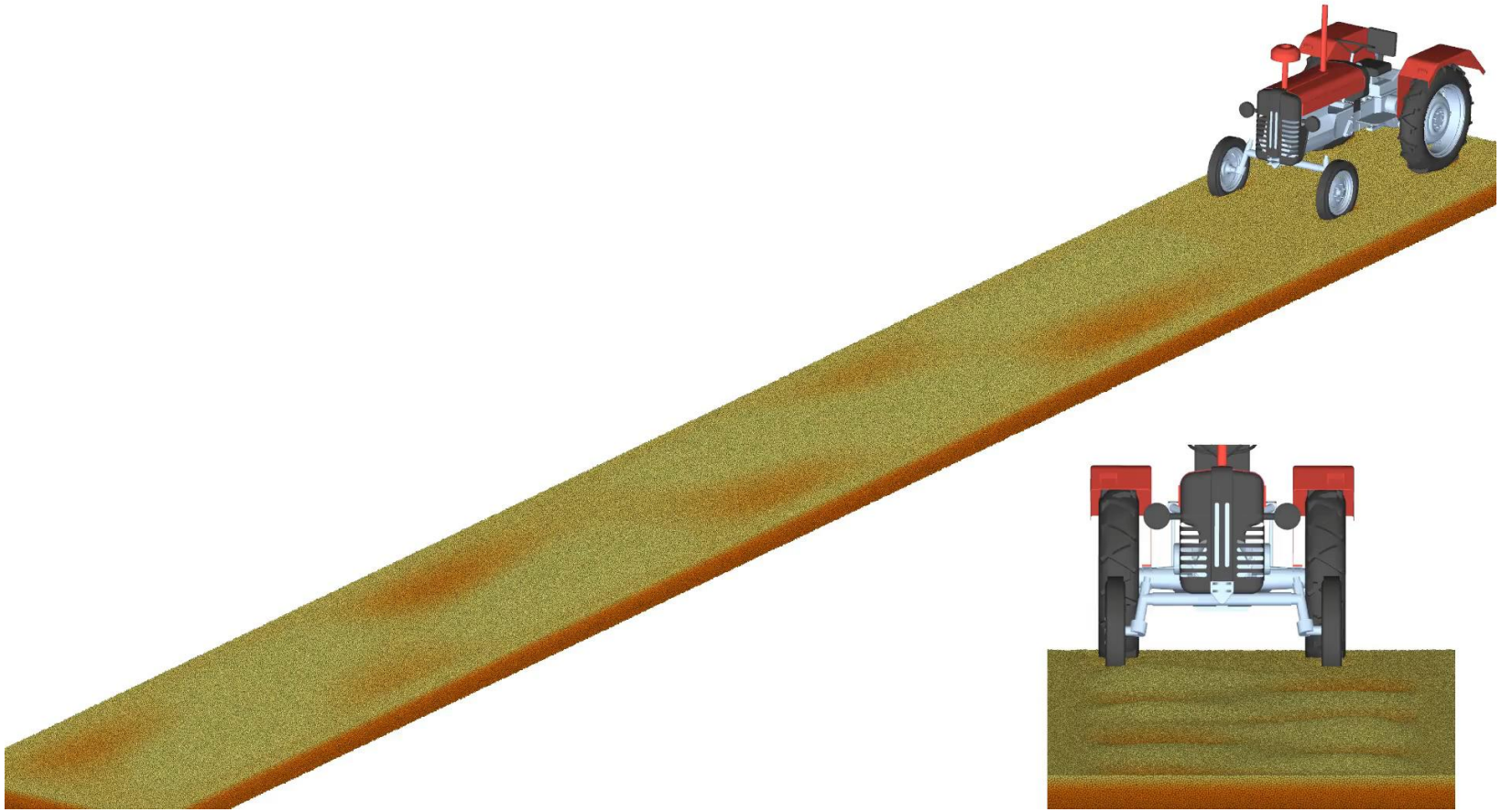
$\alpha$ = generation coefficient

$t$ = time



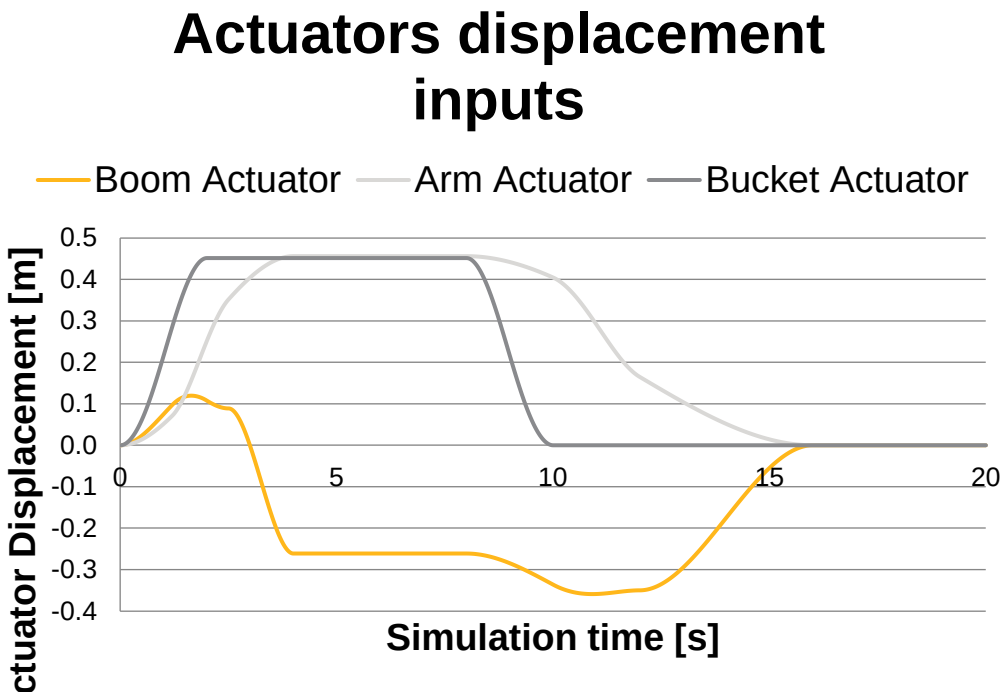
# Ansys Motion 2-way Coupling

## Complex Nested & Chained Motions



# Ansys Motion 2-way Coupling

## Actuators Defined Motion

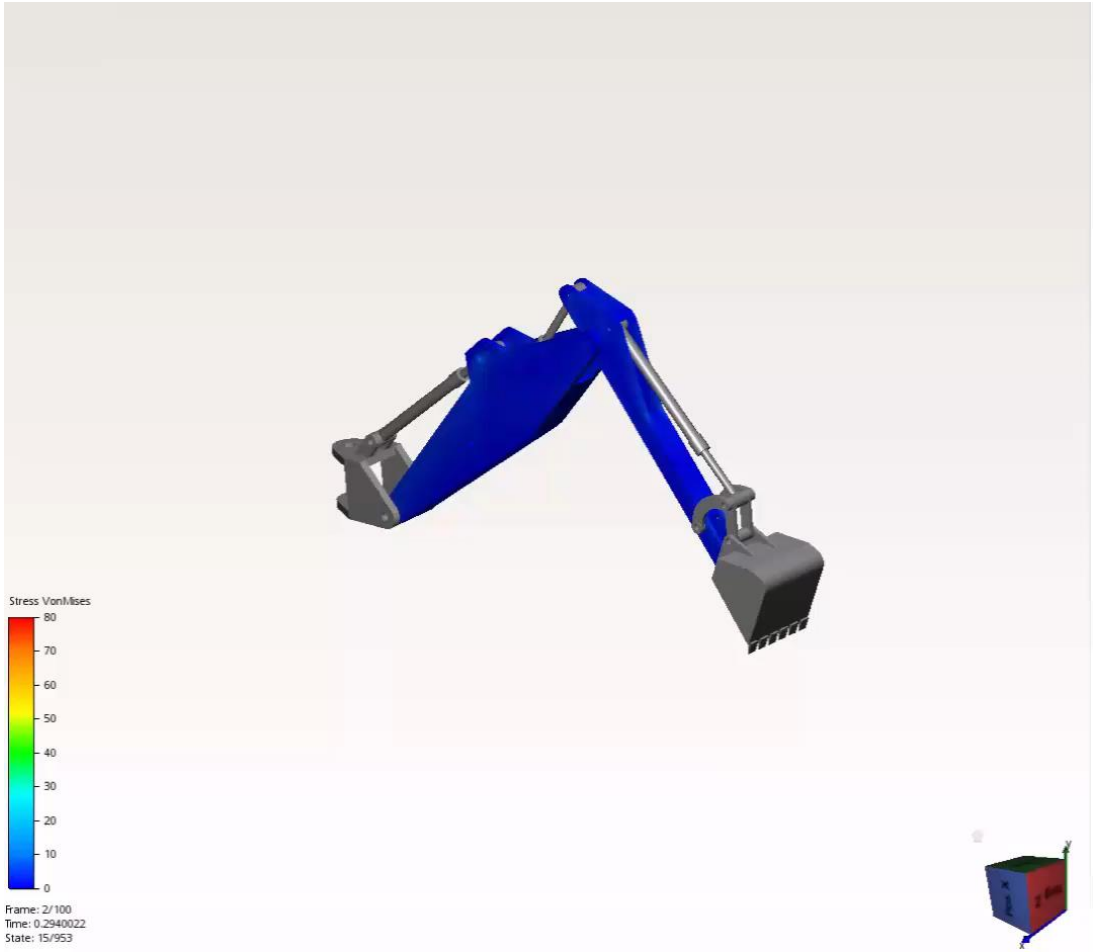



# Rocky DEM + Ansys Motion

## Stresses and Flexible Geometry

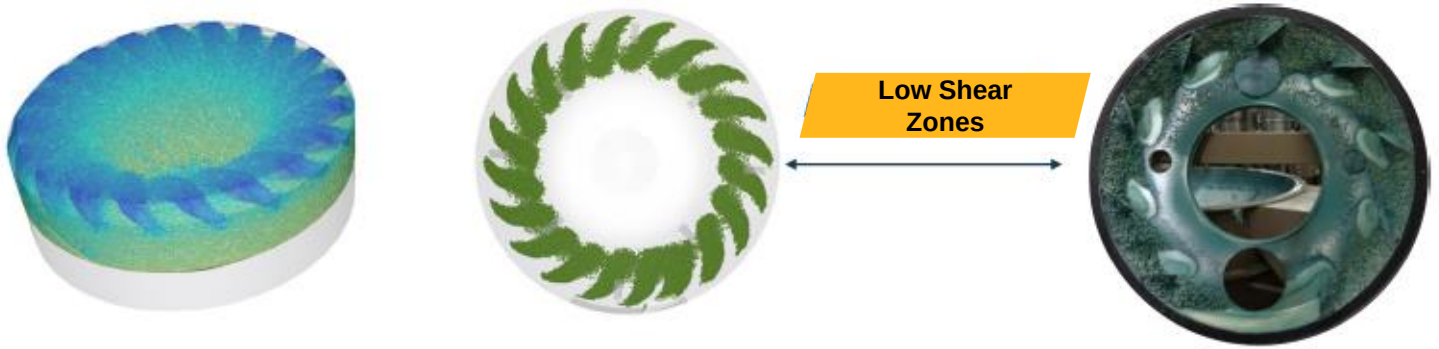
**Stress and Deformation analysis**

**Closed Chain Linkage**




** Stress and Deformation computed by Ansys Motion*

# Design Optimization with Ansys optiSLang


**Optimization Problem**

$$\min_{D} \left[ \text{Low Shear Zones}, \quad \frac{1}{\text{Lacey Mixing Index}}, \quad t_{\text{Discharge}} \right]$$

**Software toolbox**

Ansys SpaceClaim
- Parametric CAD using SpaceClaim scripting.
- Geometry discretization

Ansys ROCKY
- DEM solver
- Post processing using python scripting

Ansys / DYNARDO optiSLang
- Process automation
- Sensitivity studies
- Surrogate modeling
- Optimization

Courtesy of Bayer AG - Dr. Rakulan Sivanesapillai, Damien Brewer and Michael Ostendorf - WOST 2021

# Design Optimization with Ansys optiSLang

**Automated Screening of parametric SpaceClaim CADs**

**Selected Design**

***Before***

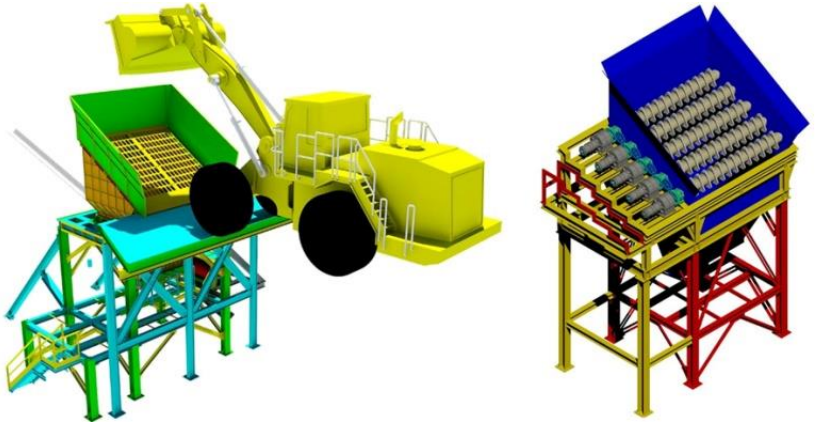
***After***

Courtesy of Bayer AG - Dr. Rakulan Sivanesapillai, Damien Brewer and Michael Ostendorf - WOST 2021

# ANSYS and Rocky generate savings for VALE

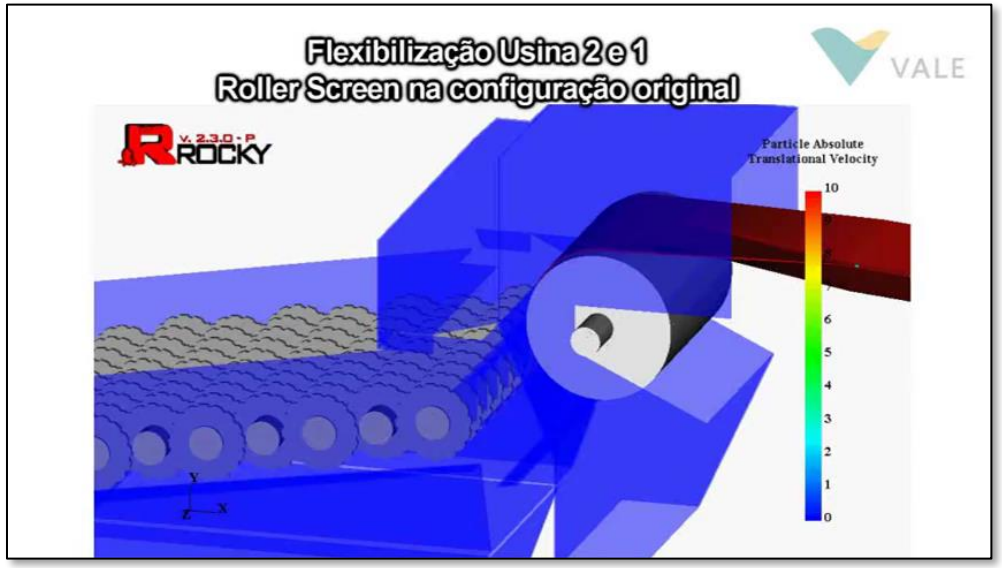
## Challenge

- To improve the efficiency of the equipment
- To reduce the need to clean plant material out of the hoppers' screens
- To increase productivity



## Solution

- ANSYS and Rocky coupling used to simulate the flow of ore and understand its impact upon existing plant equipment
- A more efficient  system of rotating disks was developed
- Transmission system was redesigned and support structures were adapted accordingly




## Benefits

- Economic returns of over US$ 100 million in 3 months
- Time spent on the development  reduced by 70%
- Production increased by 11.4%

# BOMAG uses Rocky to improve Asphalt Plant Equipment

BOMAG MARINI LATIN AMERICA
FAYAT GROUP

## Challenge

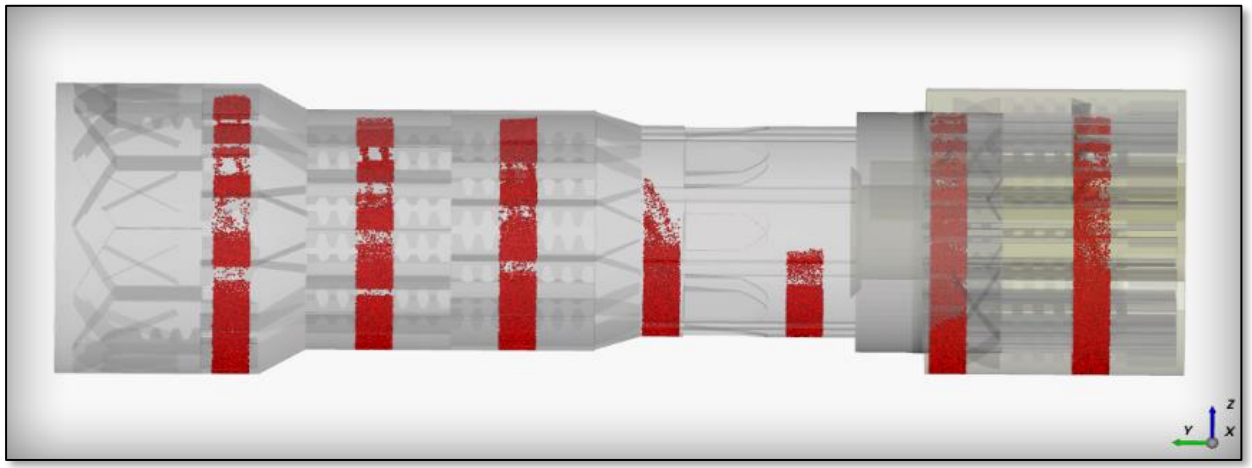
- To understand the material behavior inside an Asphalt Plant
- To test different designs for equipment modification
- To increase productivity

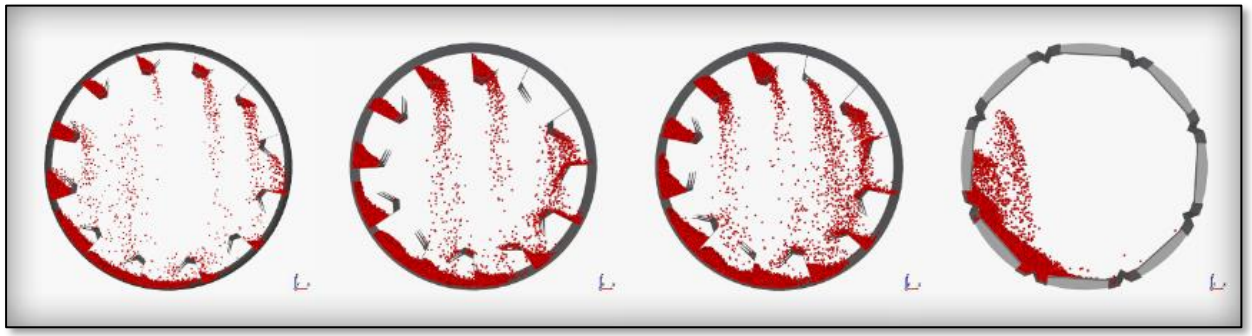
## Solution

- Rocky DEM analyses allowed a better understanding of the behavior of the particulate material
- Qualitative and quantitative post-processing tools led to a detailed evaluation of the particulate flux considering different designs of the equipment

## Benefits

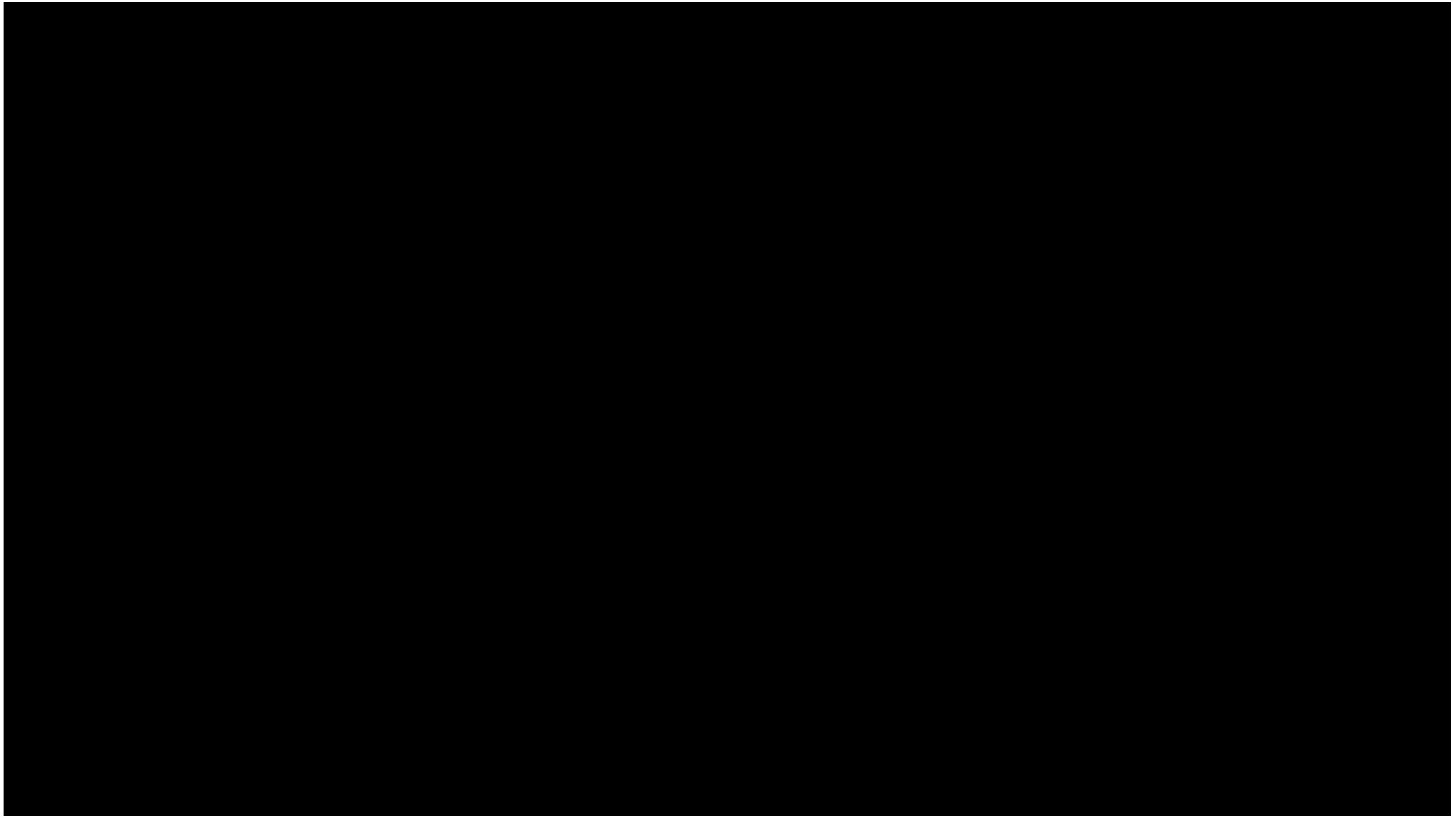
- Simulations considering different designs for the fins in the mixing zone of the Multi Paddle Pug Mill mixer were carried out
- The results enabled an evaluation of the residence time of the particles in the equipment, a key parameter for the process





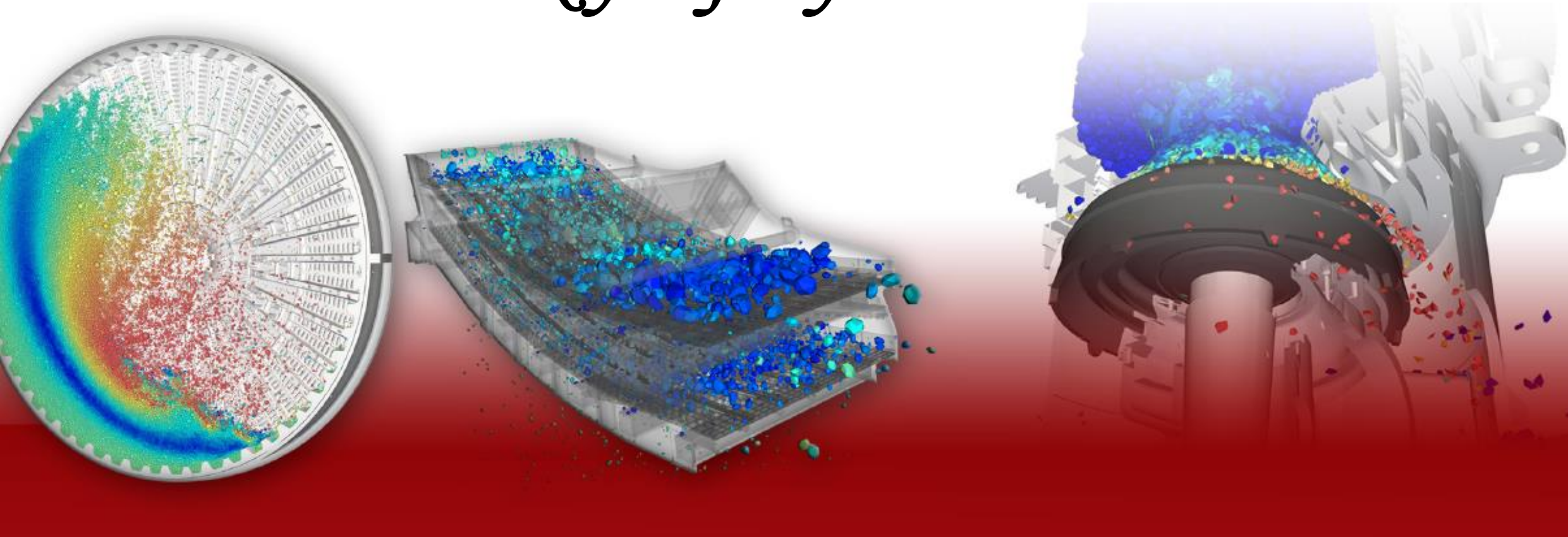
Ansys

# Codelco Chile



CADMEN

*Thank you for your attention.*

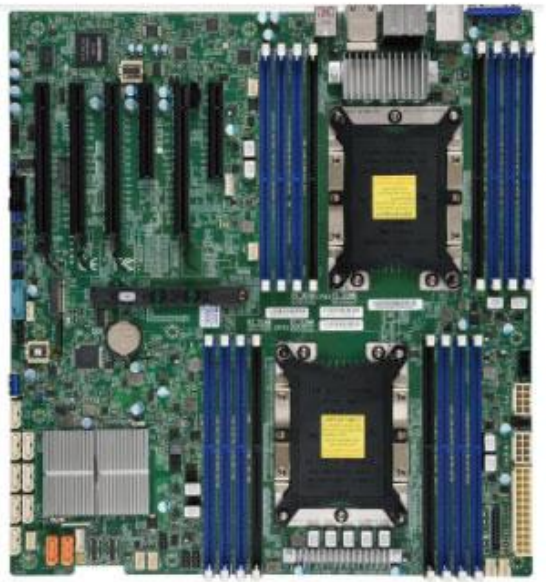


CADMEN 虎門科技 | Ansys精英合作夥伴

Ansys 2022/R1 Engineering What's Ahead.

# 新技術線上研討會

| | | |
|---|---|---|
| 4/7 (四) 14:00-14:40 | Ansys CFD 進階應用_TurboWorkflow 新技術線上研討會 | 李奕璋 |
| 4/7 (四) 15:00-15:40 | Ansys Rocky 新技術線上研討會 (Ansys Fluent、Motion & OptiSLang 耦合應用技術) | 林健文 |
| 4/7 (四) 16:00-16:40 | Ansys GRANTA 碳足跡應用與產業成功案例分享- 新技術線上研討會 | 李易軒 |

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