USING EXPERIMENTS AND SIMULATIONS TO CONQUER INDUSTRIAL SOLIDS FLOW PROBLEMS

Pieter Vonk and Eric Grolman
Envalior Specialty Materials
Geleen, The Netherlands

Envalior
Imagine the Future

PROBLEM #1

REPLACING DENSE-PHASE PNEUMATIC TRANSPORT WITH DILUTE-PHASE FOR MELAMINE (CRYST. POWDER)

Reason:

- new warehouse across the road

Changes:

- Larger distance
- Higher velocity (dense->dilute)
- Outside air replaces compressed air
- Some 90° bends introduced (to circumvent obstacles)

What went wrong:

- One-time involvement of solids expertise
- “Value” engineering

Envalior
Imagine the Future

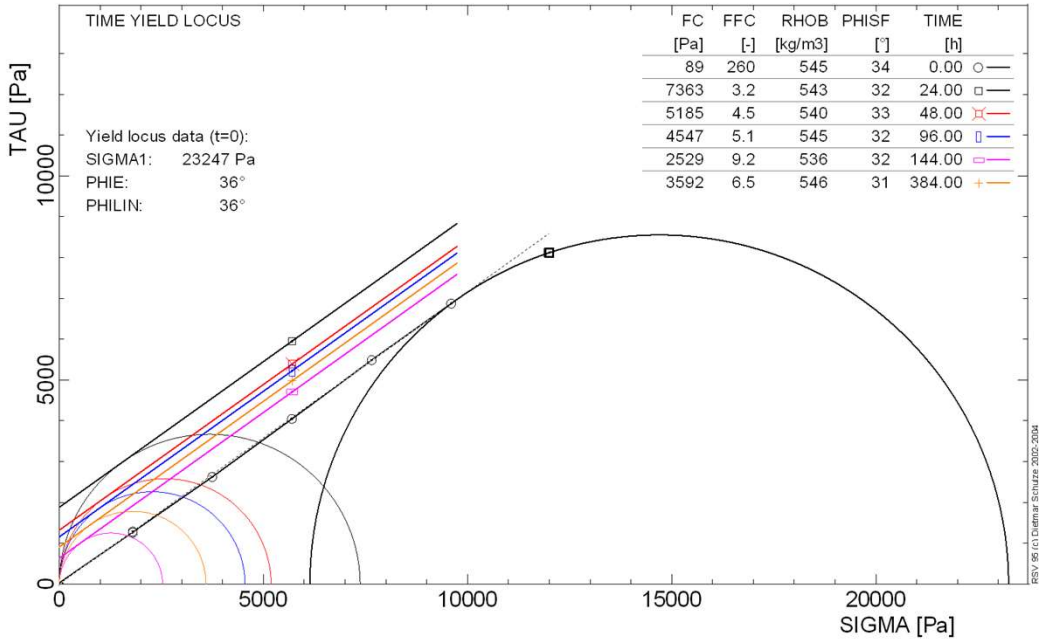
AGGREVATED POWDER PROBLEMS

More serious caking

STRENGTH GAINED DURING STORAGE

Melamine = bittle materials susceptible to attrition

- **Caking during storage**
- **Decrease of flow behavior**
- **Enhanced by moisture**



Envalior
Imagine the Future

PROBLEM #2

GELS in PA6 granules from newly built plant (under warrantee)

Gels = High Molecular weight (branched) material

Solid-State Post-Condensation in Nitrogen heated moving bed reactor

Gel count goes up over time

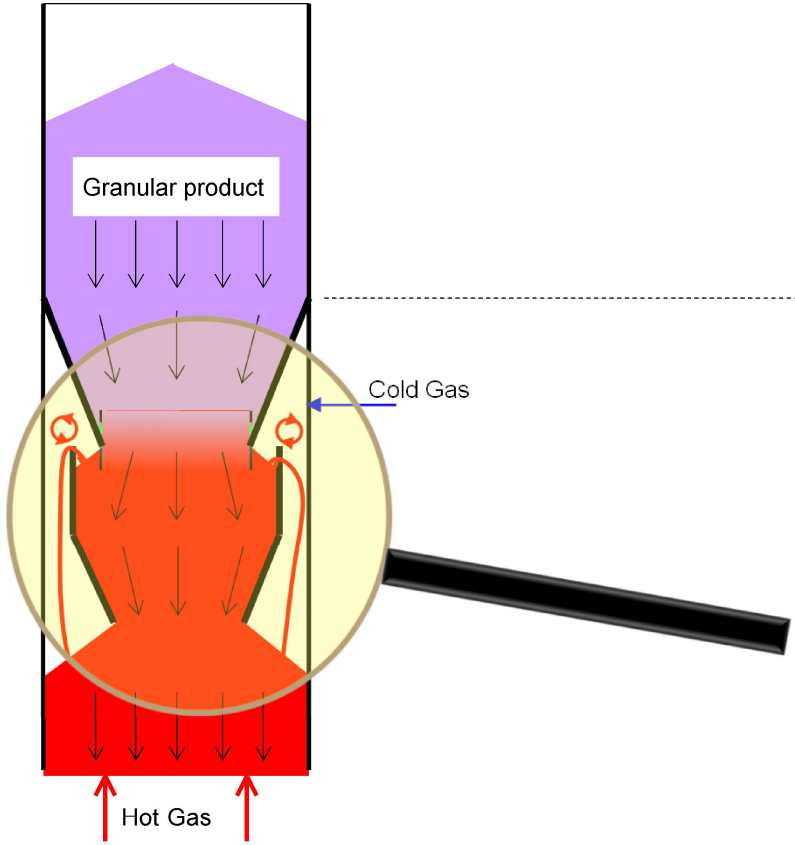
Reactor needs to be emptied every 2 weeks

Loss of production cost: ~4 M€/yr

2 WEEKS TO GIVE ADVICE FOR NEXT STEP

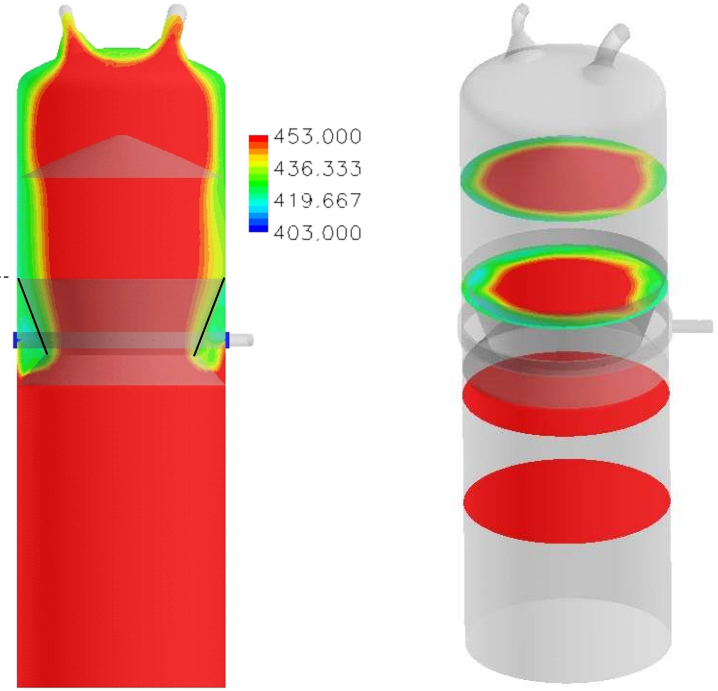
Envalior
Imagine the Future

Two temperature zones



Solution1: remove obstacles

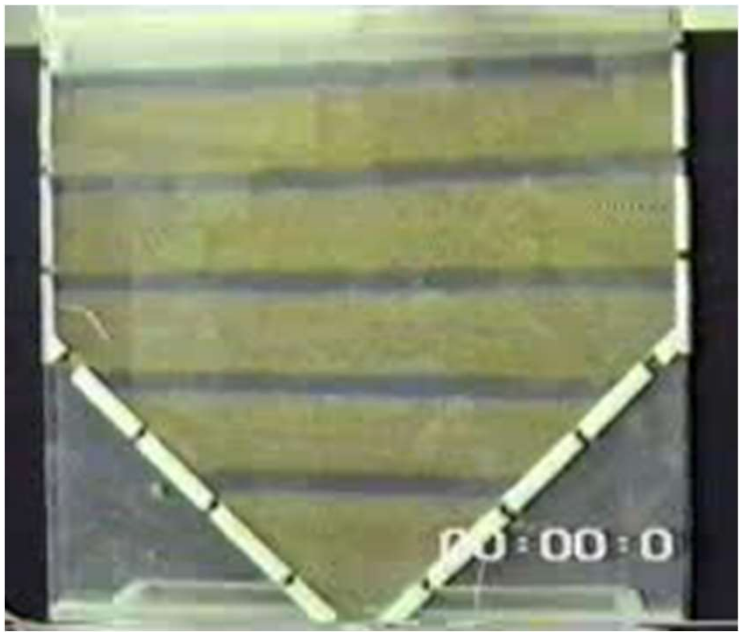
—> Gels replaced by lumps



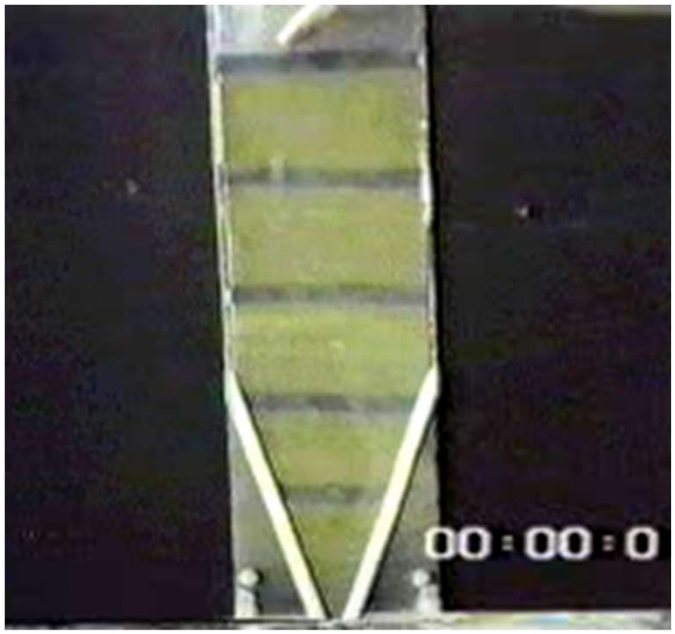
Envalior
Imagine the Future

Use the silo-flow experiment with colored bands

Core flow silo



Mass flow silo



(Prof. M. Rhodes, Monash U. Australia)

Envalior
Imagine the Future

COLD-FLOW EXPERIMENTS PA6 GRANULES IN 2D SILO, 10 CM DEEP

DEM FLOW SIMULATIONS

PREDICTING STAGNANT ZONES

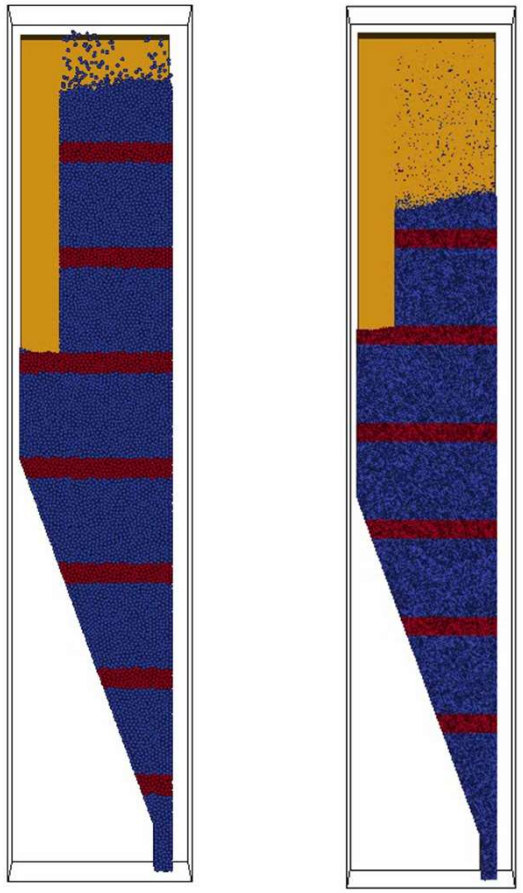
LIGGGHTS simulation package

Simple DEM interaction model

- **Restitution coefficient**
  - Less important for dense flow
- **Particle-particle friction coefficient**
- **Rolling friction coefficient**
- **Soft particles (reduction required time steps)**

Calibration of DEM parameters

- **Experimental characterization tests as input**



Envalior
Imagine the Future

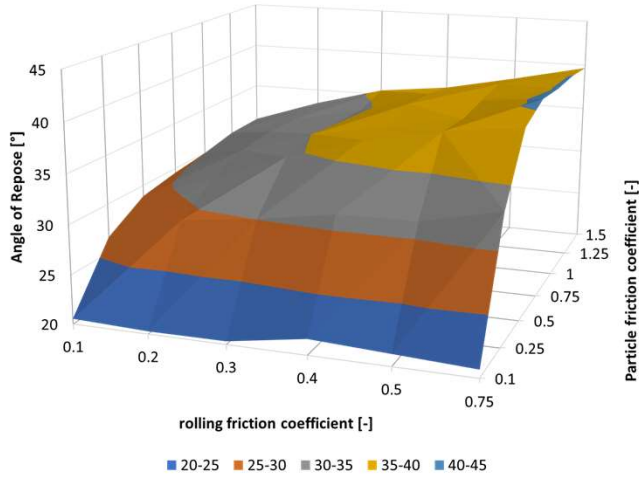
CALIBRATION OF DEM PARAMETERS

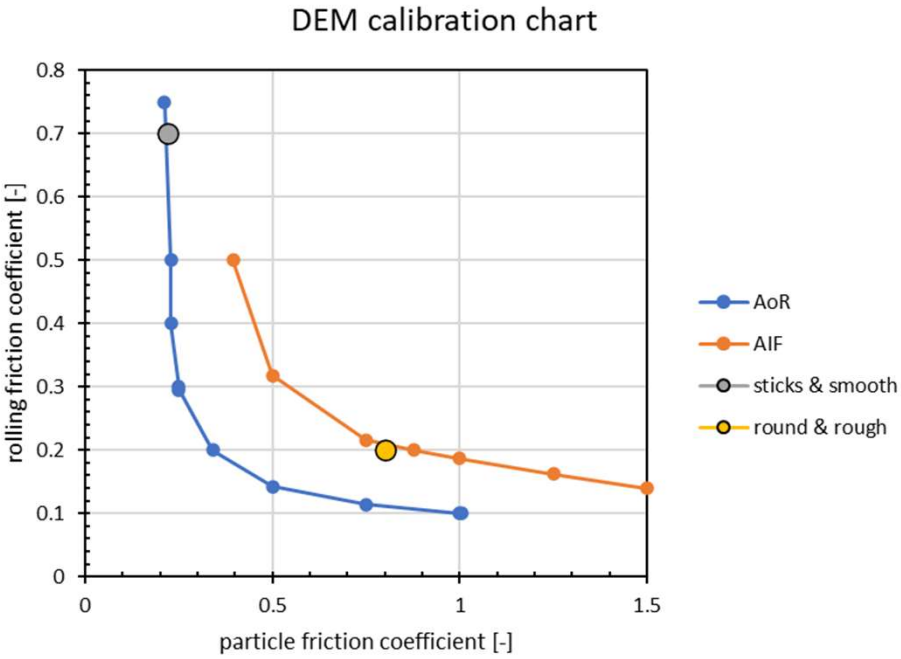
NON-COHESIVE MATERIALS

Particle interactions

Simulation Angle of Repose & Internal Friction

- **Mapping 3D surface**

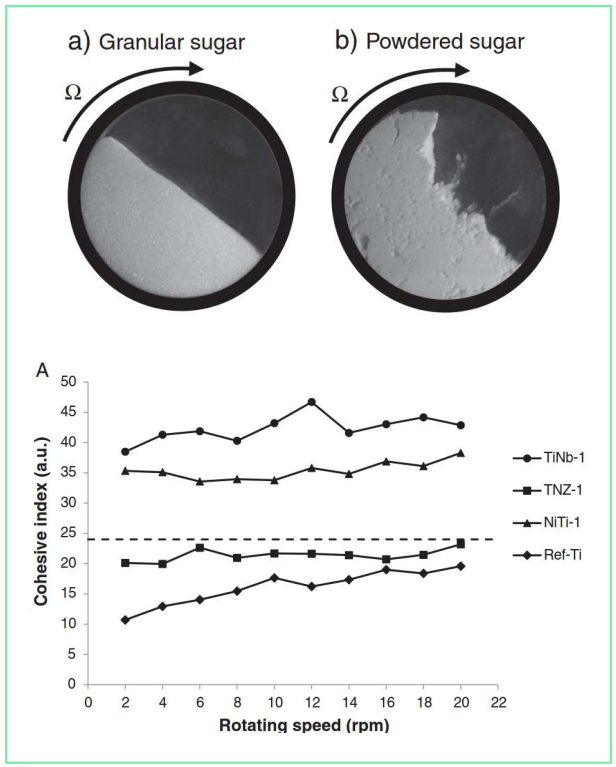


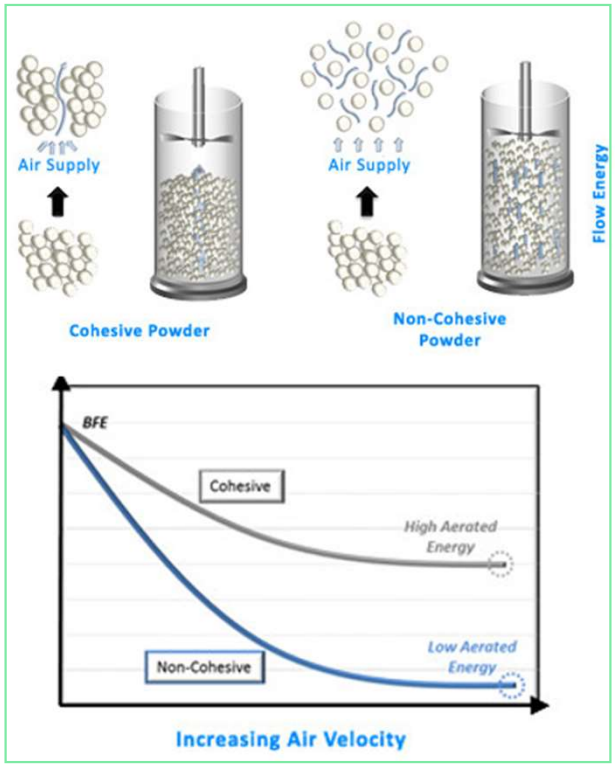


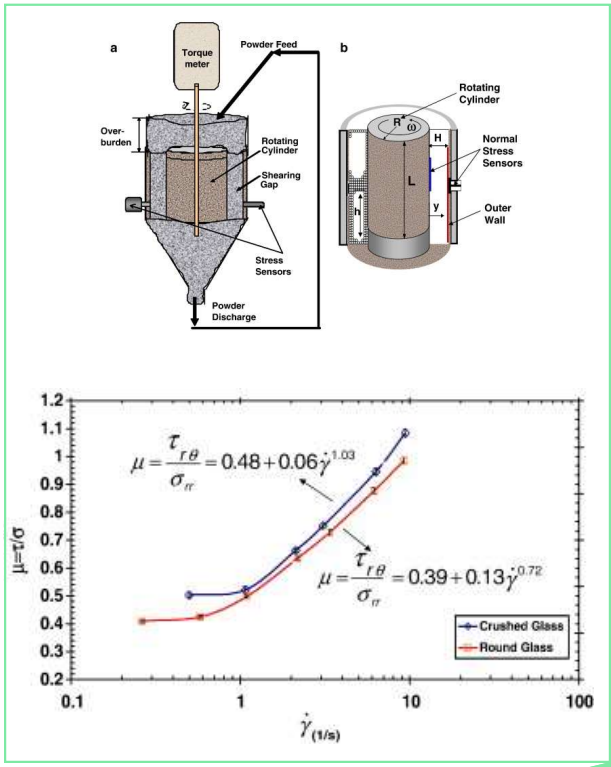
COHESIVE POWDERS REMAIN A CHALLENGE IN DEM

REQUIRES (AT LEAST ONE) ADDITIONAL MEASUREMENT(S)

How to calibrate cohesive interactions (including coarse graining)?







Envalior
Imagine the Future

SUMMARY AND CONCLUSIONS ON SOLIDS FLOW MODELING

Our Journey
Following IFPRI rheology model development with interest
Nucleation and Crystal growth implemented in CFD package
Attempts to implement dense solids rheology in CFD package (ANSYS CFX) unsuccessful
Exchange with TU/e on simulation
Adopted Liggghts and Open Foam open-source DEM and CFD packages

Challenges
The need for realistic large-scale solids flow modeling remains

- **For calculating flow profiles**
- **Design and optimize equipment**
- **Calculate residence times**
- **Combine outcome with reaction kinetics**
- **…**

Envalior
Imagine the Future