LULEÅ UNIVERSITY OF TECHNOLOGY

Modelling of the interaction between charge and lining in tumbling mills

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Outline

- Experimental measurement (pilot mill)
- Modelling strategy
- Results
- Conclusion
- Future work

Pilot mill Experiment

Length 1.22 m

Diameter 1.414 m

12 rubber lifters

Ginding ball diameter 10-30 mm

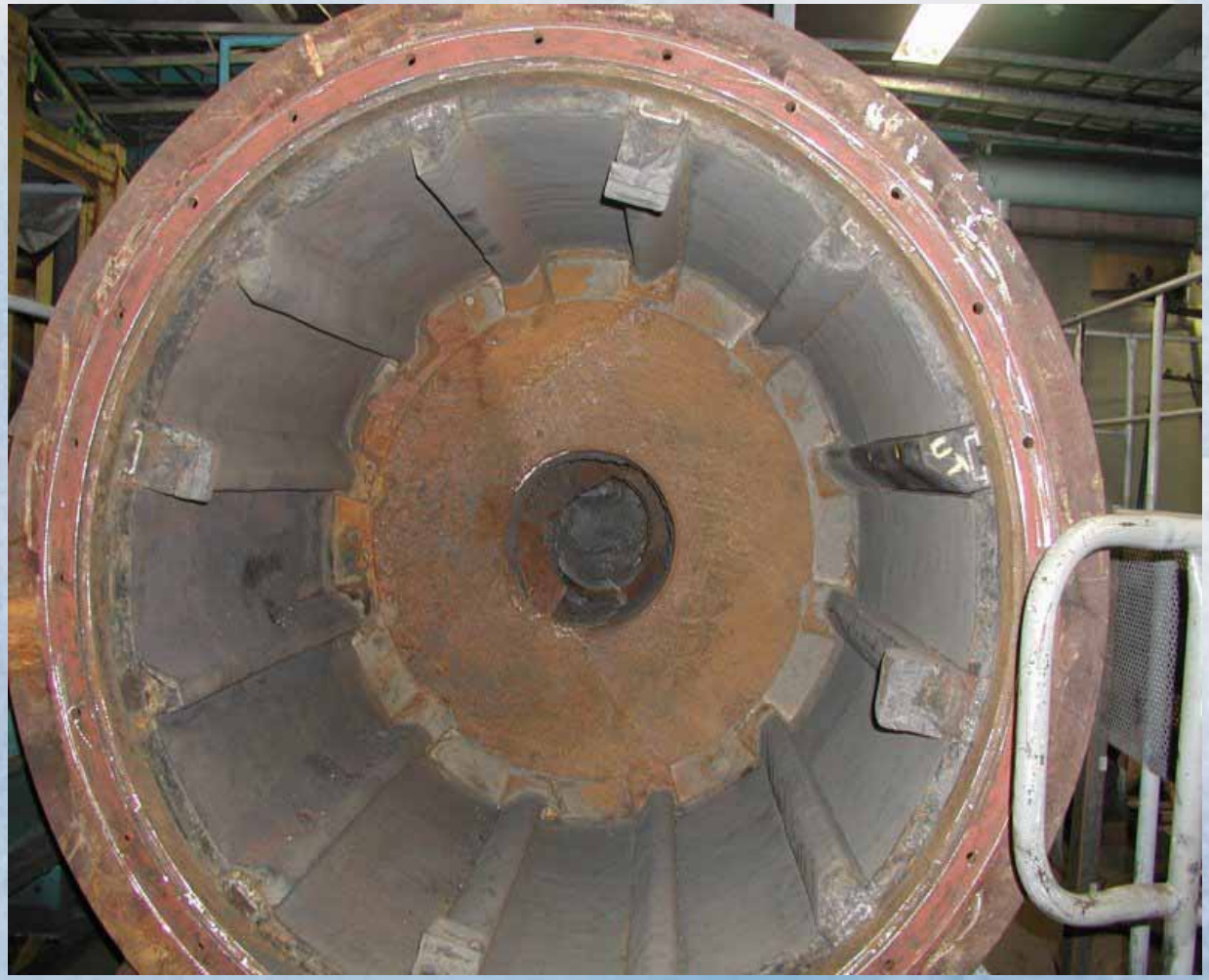
Feed rate 1.5 ton/h

Hematite pellet feed d_{50}=35 µm

Rotation speed 73% and 78% of n_c

Filling J=25% and J=35%

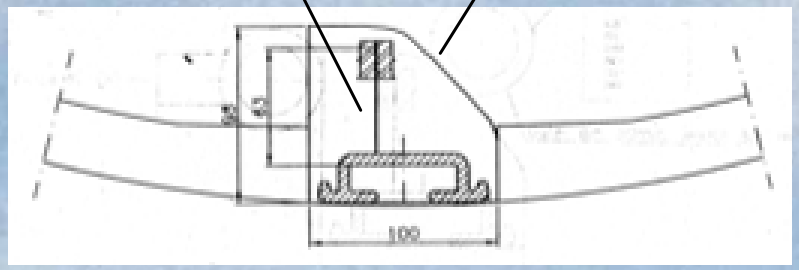
LKAB R&D, Malmberget, Sweden

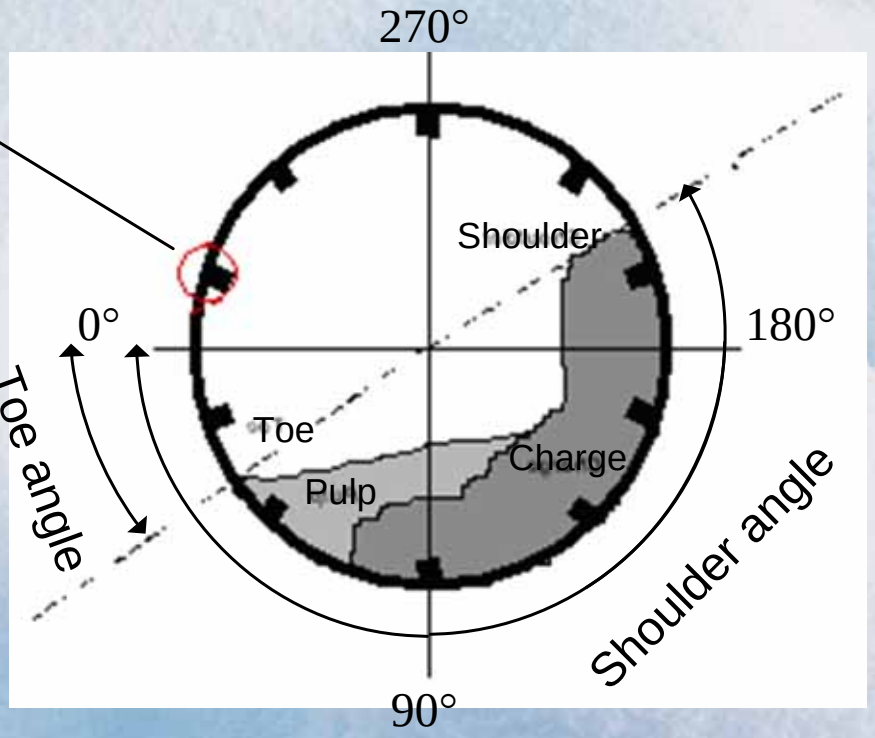


Rotating pilot mill

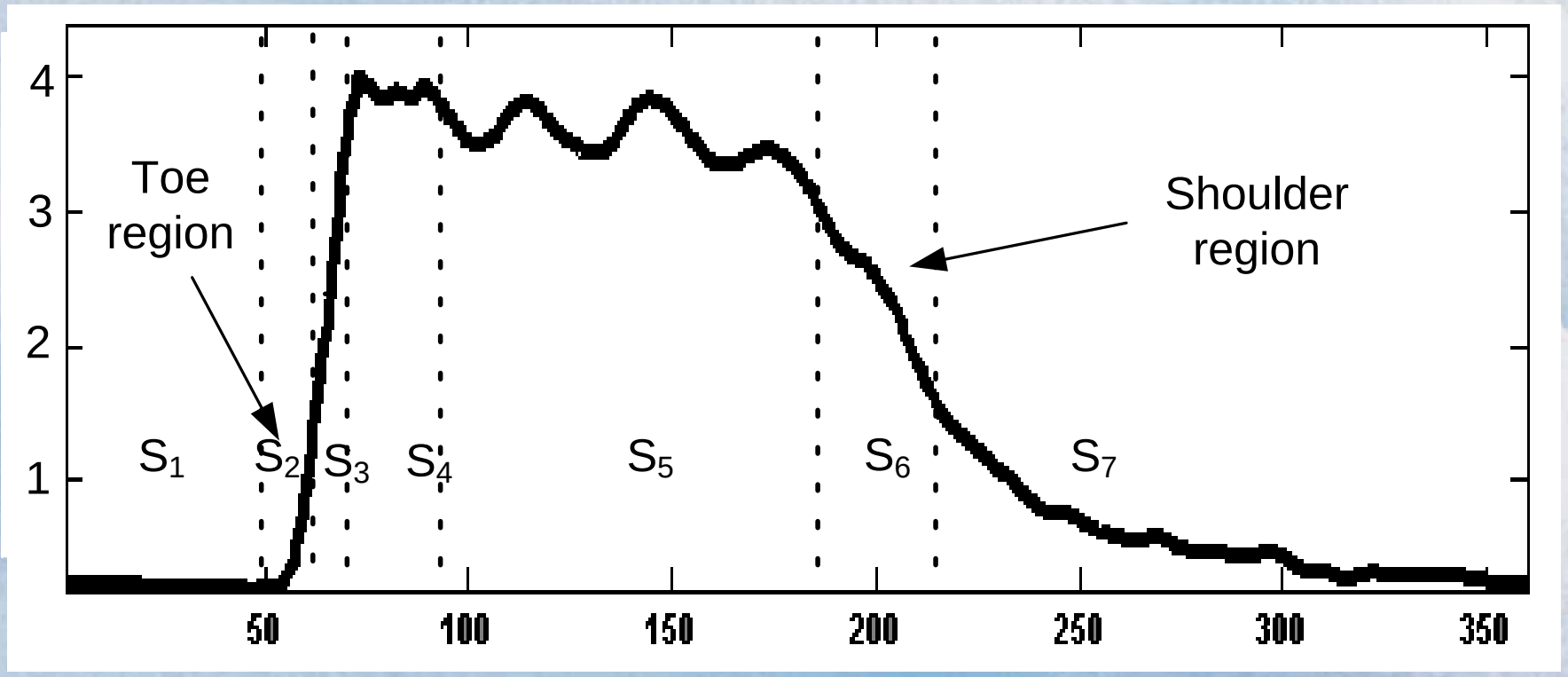
(1) Lifter bar

(2) Sensor





Measured lifter deflection



From Tano et. al.

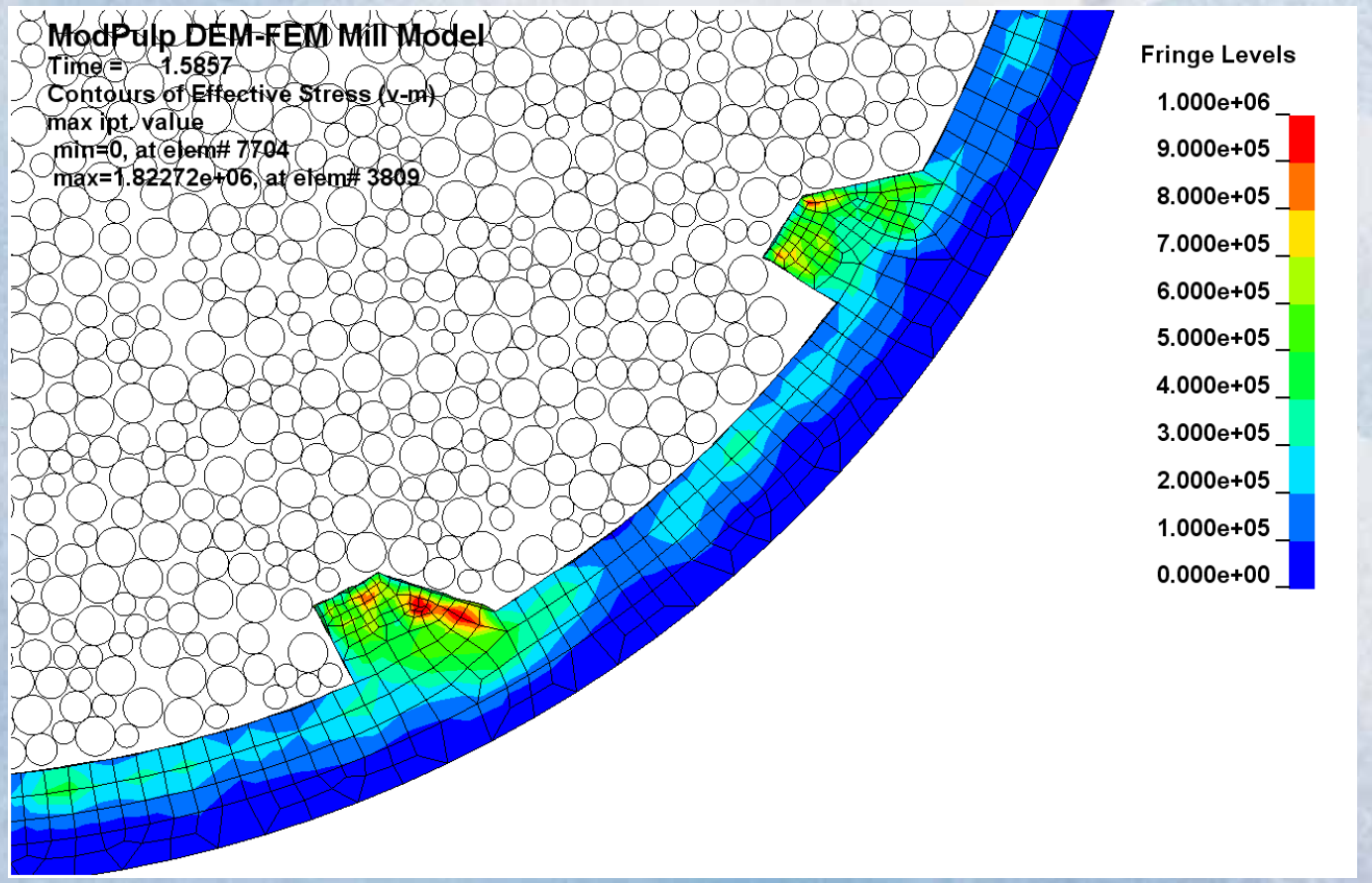
Project modelling strategy

- Combining different modelling techniques gives more physically realistic models
- Step by step increase the complexity in the models
- Each step in the development will be validated against experimental data

Project modelling strategy

- Charge is modelled with DEM or SPH
- Mill shell and lining are modelled with FEM
- Interaction between DEM and SPH particles and FEM structure is handled by a contact interface

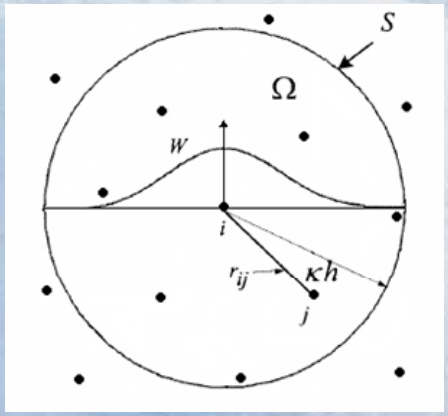
DEM-FEM



Charge level 25%, critical speed 73% (Von Mises Stress)

Smoothed Particle Hydrodynamics (SPH) method

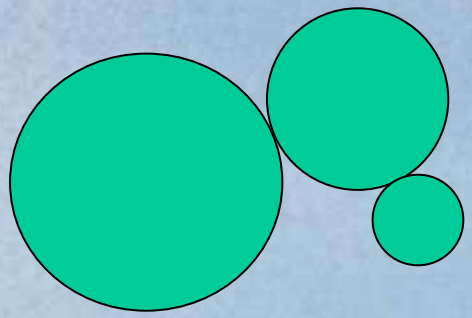
- Invented 1977
- Mesh free Lagrangian
- Particle representation
- Continuum method
- Extreme deformations
- Explicit time integration



SPH modelling for mill charge

- The length *h* of the smoothing function is set to a constant value corresponding to the ball radii
- The density is 7800 kg/m^3

- 6000 grinding balls are used in the model

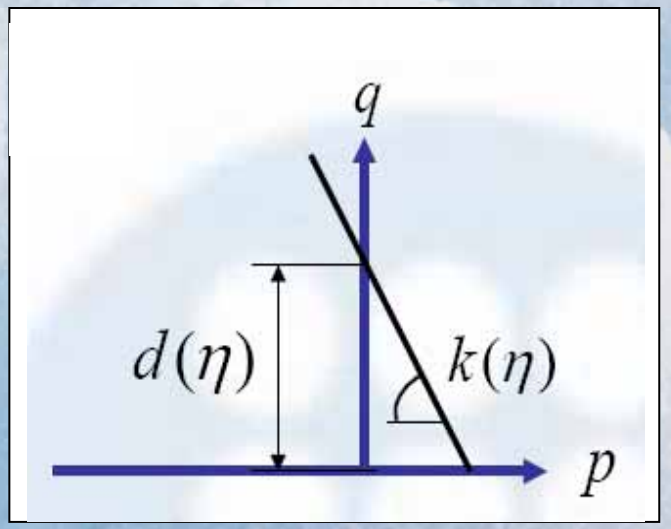


Constitutive model

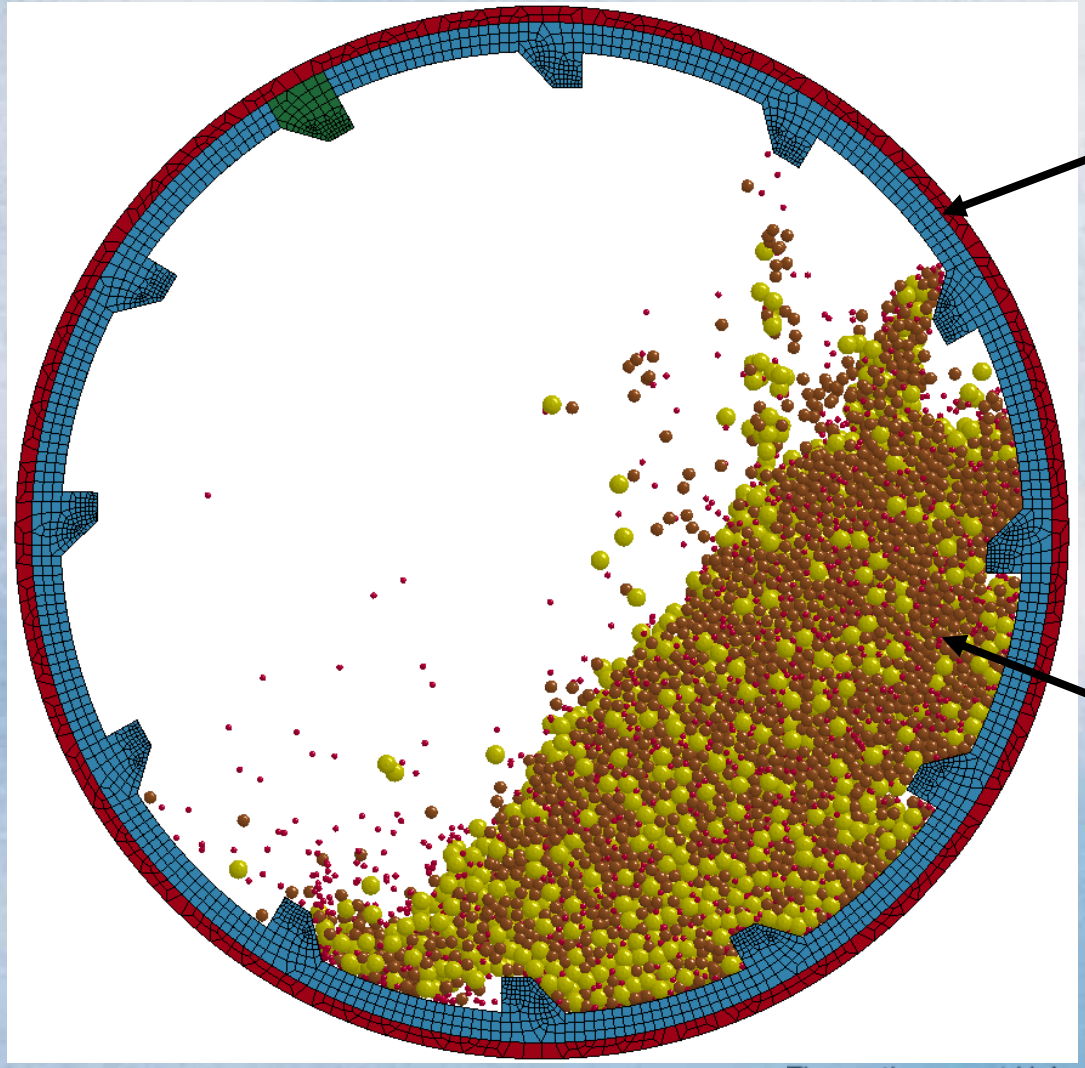
- Elastic plastic constitutive model
- Drucker Prager yield surface

$$f(p, J_2) = \sqrt{2J_2} + kp + d \leq 0$$

  - Internal friction, k
  - Cohesion, d



SPH-FEM Model



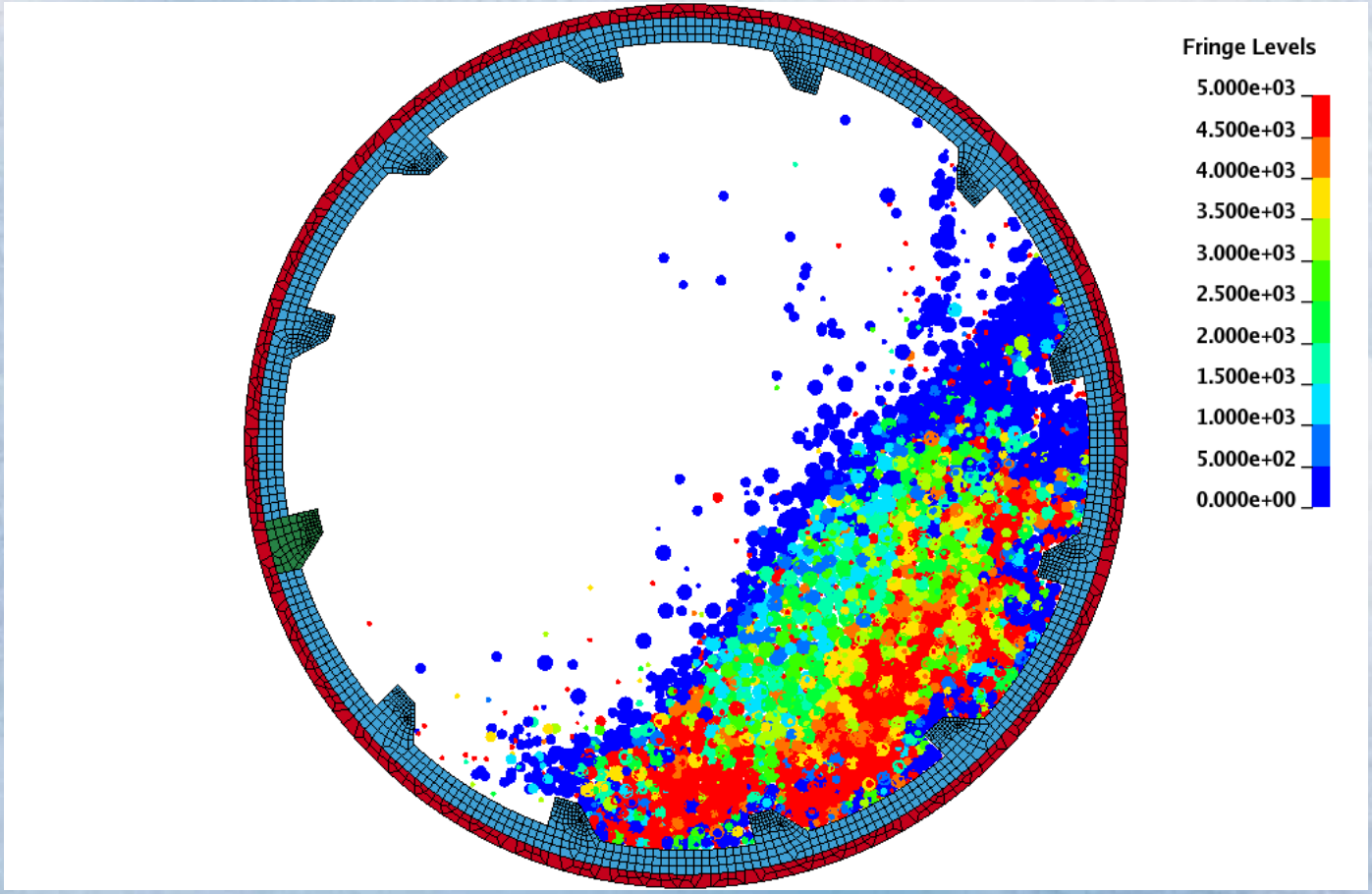
Structural parts of the mill (lifters, liners, shell) FEM

The ball charge is modelled with SPH

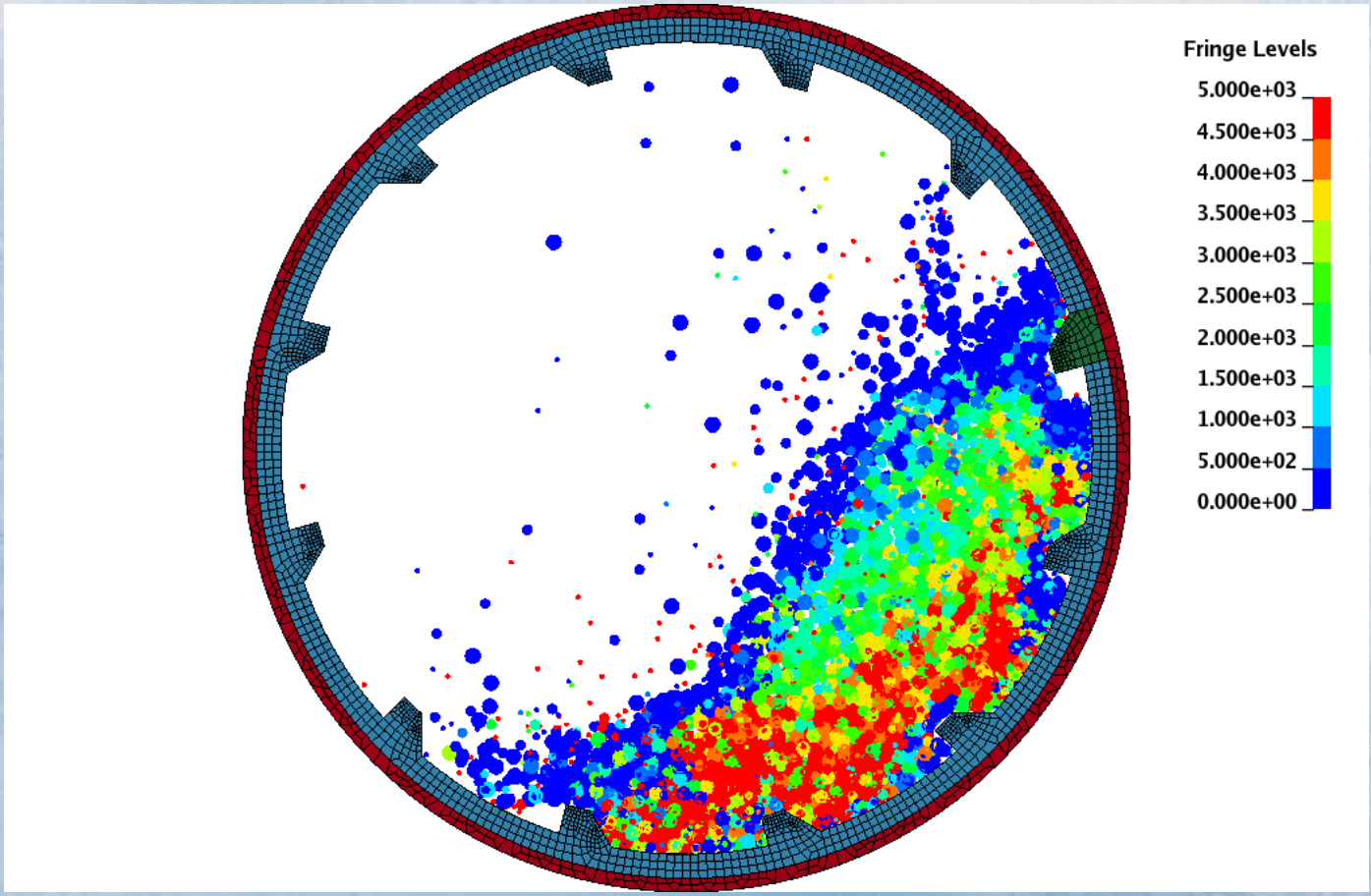
SPH-FEM Model

- For the elastic behaviour of the rubber a Blatz-Ko hyper-elastic model is used
- The friction coefficient between the rubber and the charge is $\mu = 0.9$
- 11620 solid (8 node) FE-elements in the model

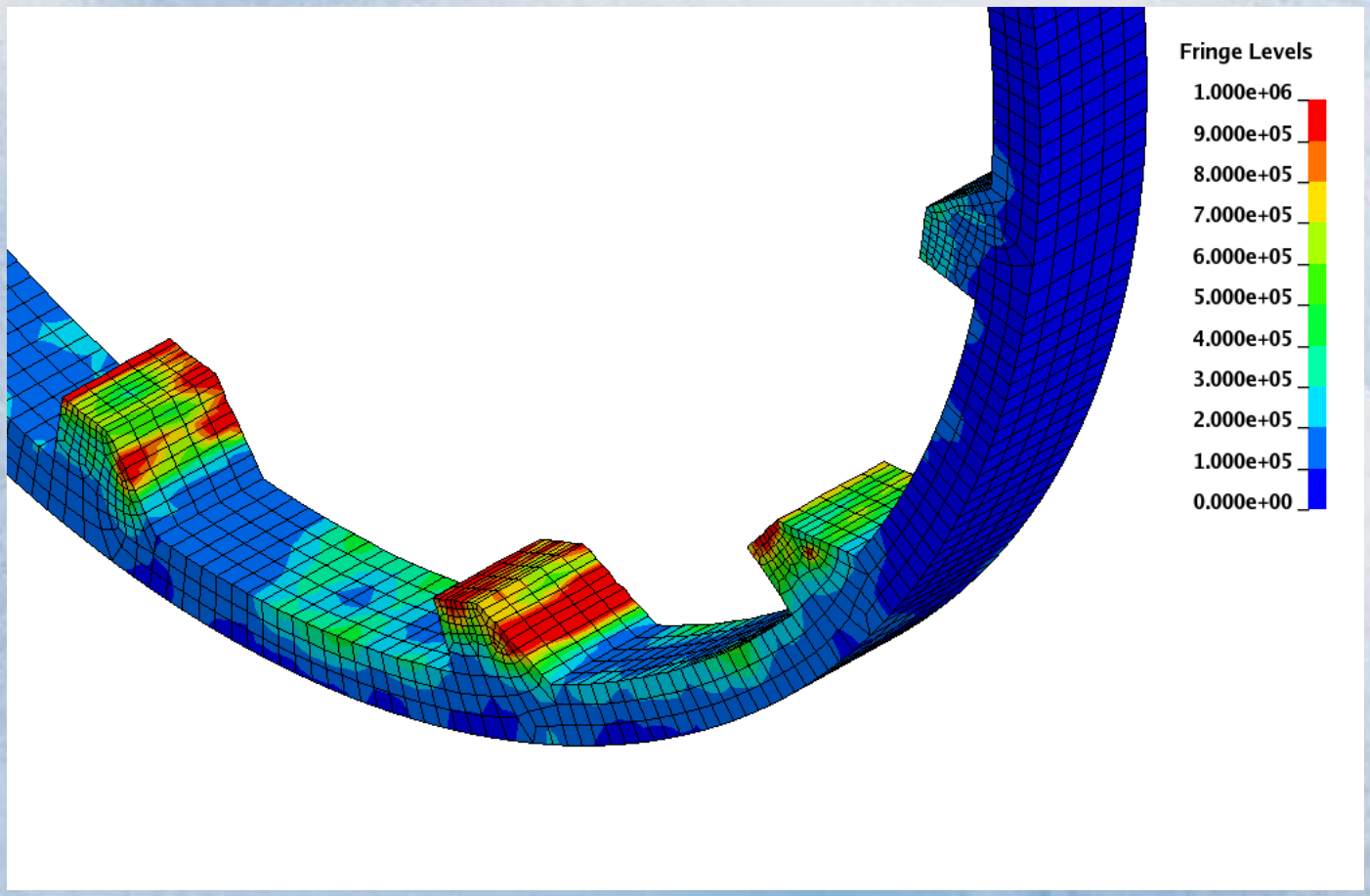
Pressure distribution in the charge



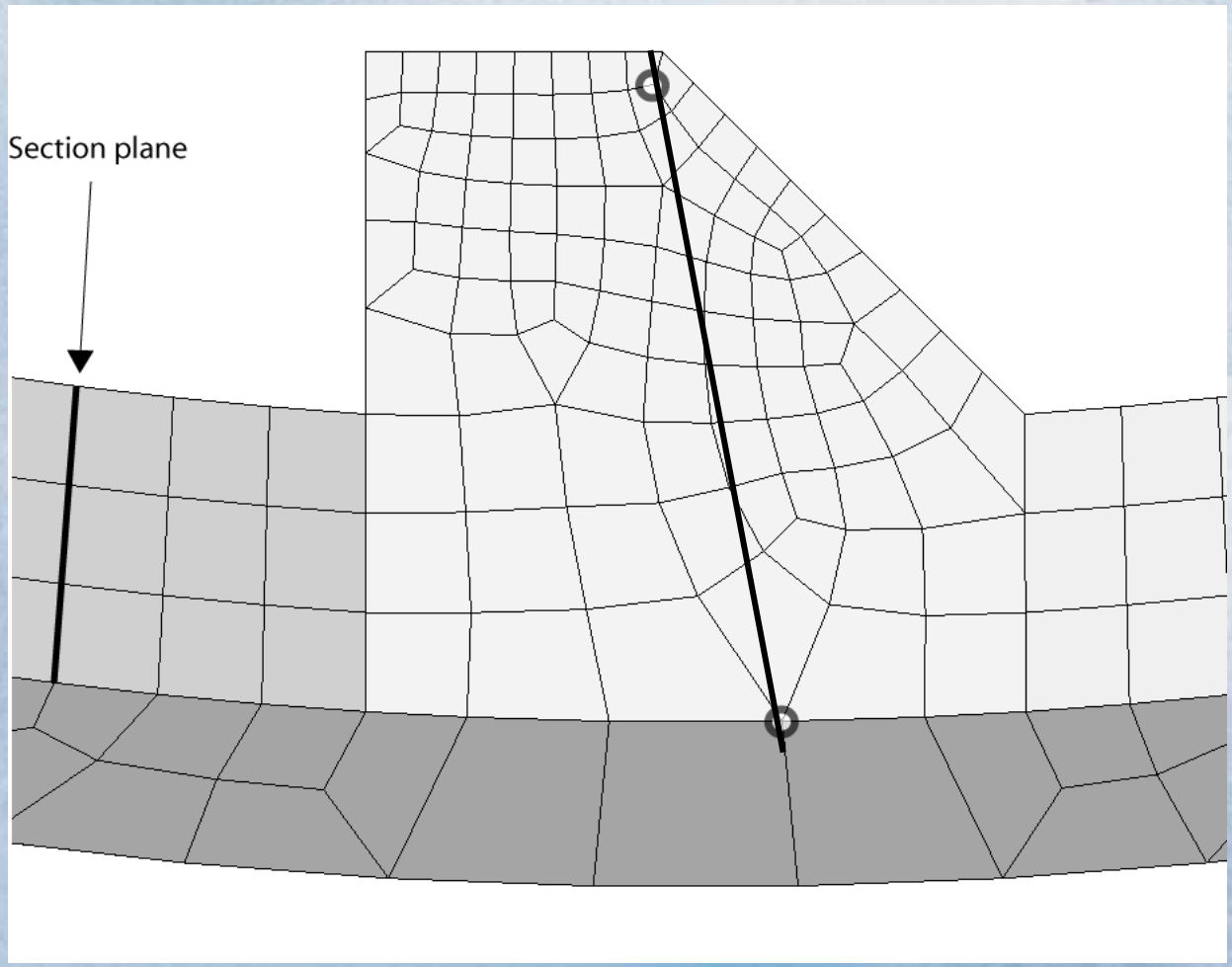
Shear stress distribution



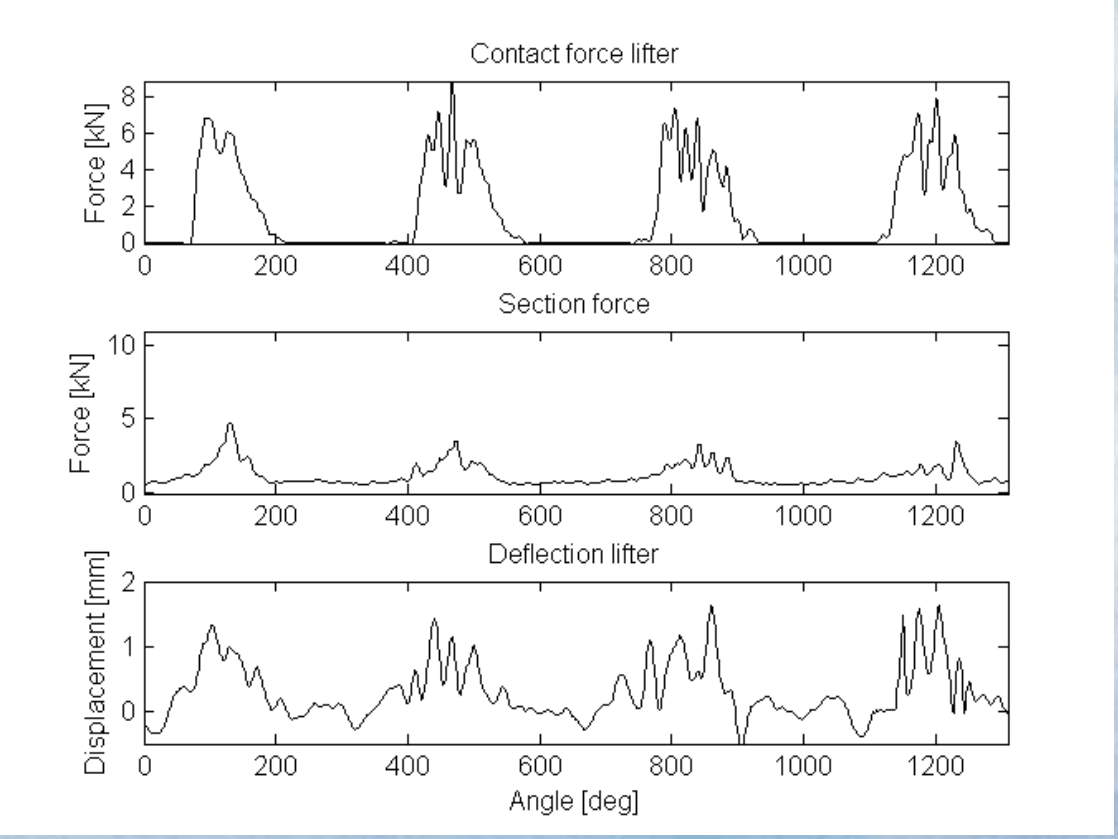
Von Mises stress on lining



Lifter

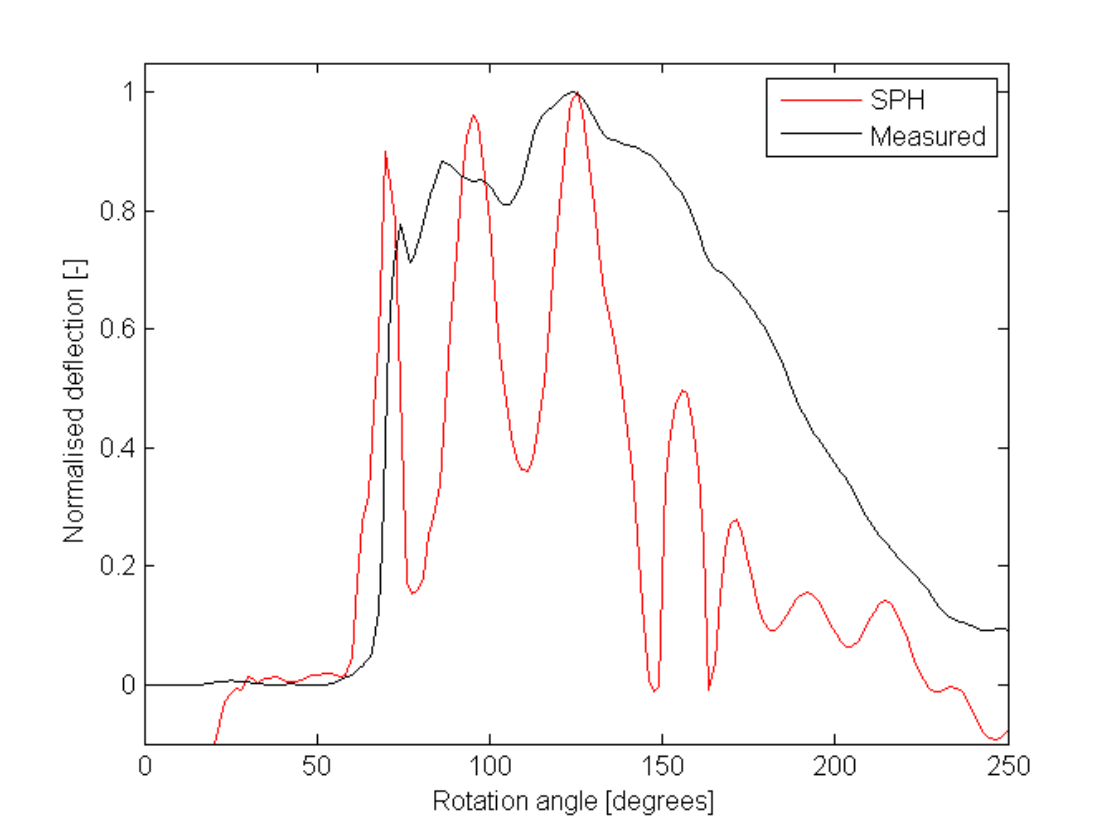


Response from four passages through the charge



10 - 30 mm

Lifter displacement fourth passage



Conclusion

- The SPH-FEM model makes it possible to predict charge pressure and shear stresses within the charge
- SPH-FEM models give a direct coupling between force, stress and displacement for the whole mill system
- Better correlation between experimental measurements and numerical models

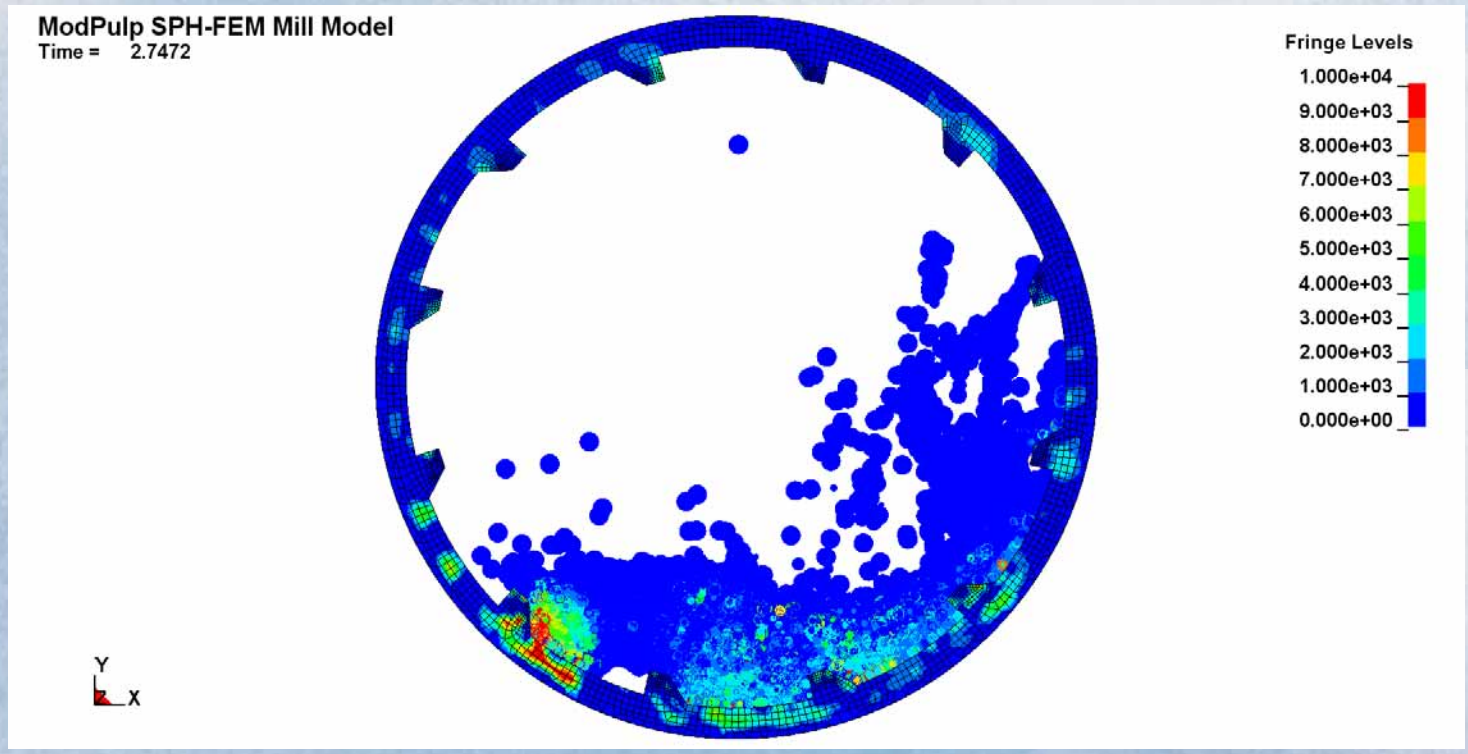
Conclusion

- Gives the opportunity study the influence of the whole mill structure and the charge
- Predict forces travelling in the lining, and by that makes modelling of on-shell sensor systems possible

Future work

- Continuum model of the pulp with a particle based methods e.g. SPH, PFEM etc.
- Model the interaction between pulp, charge and mill structure
- Validation

Results from pre-study SPH as fluid



Pressure distribution in charge and lining

Thank you for your kind attention!

Questions???