Modelling of the interaction between charge and lining in tumbling mills (ModPulp)

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Bergforsk

Objective

- Capture the physical interaction between charge, pulp and lining in tumbling mills
- Create the possibility to realistically model grinding systems with fine particles

ModPulp

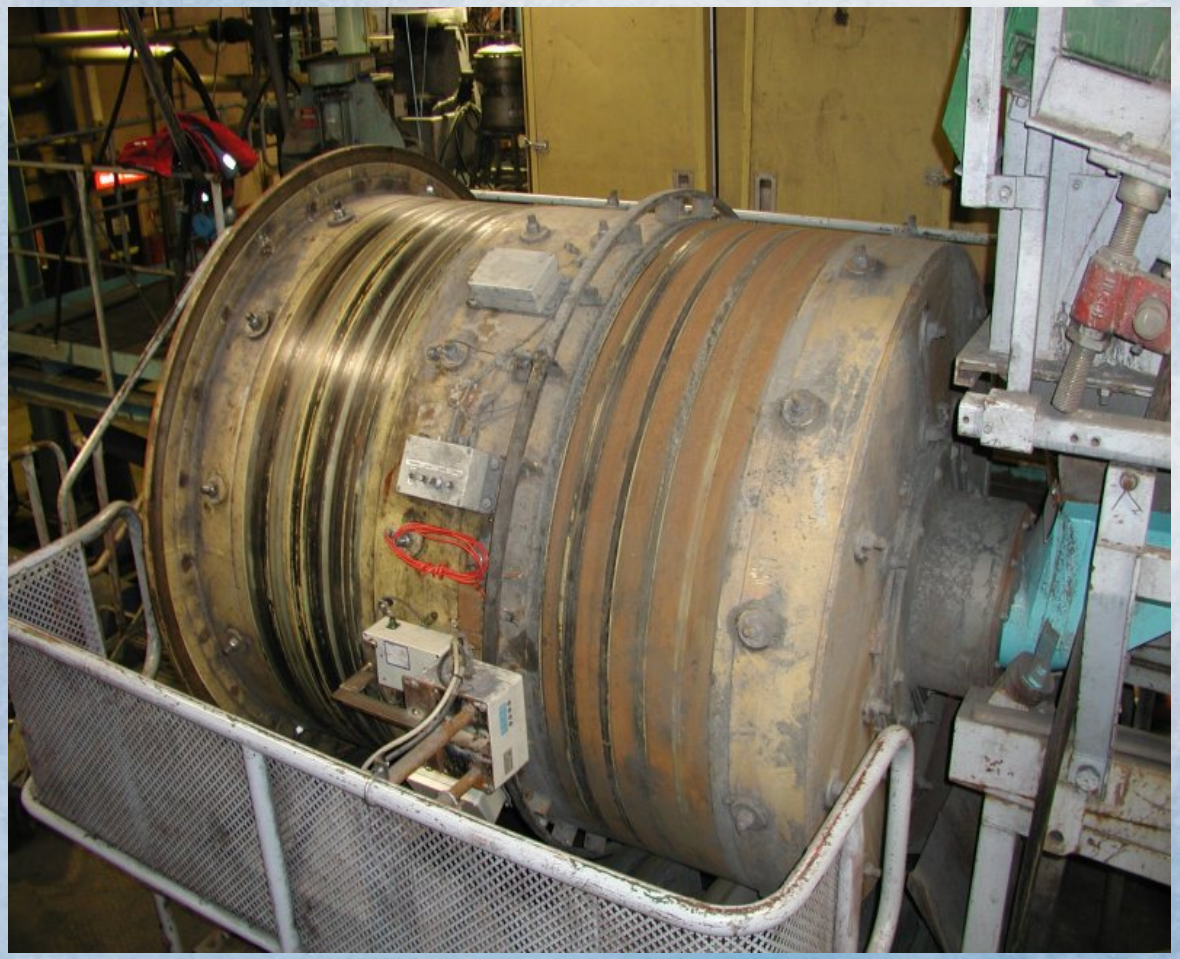
- Funded by Vinnova within Gruvforskningsprogrammet

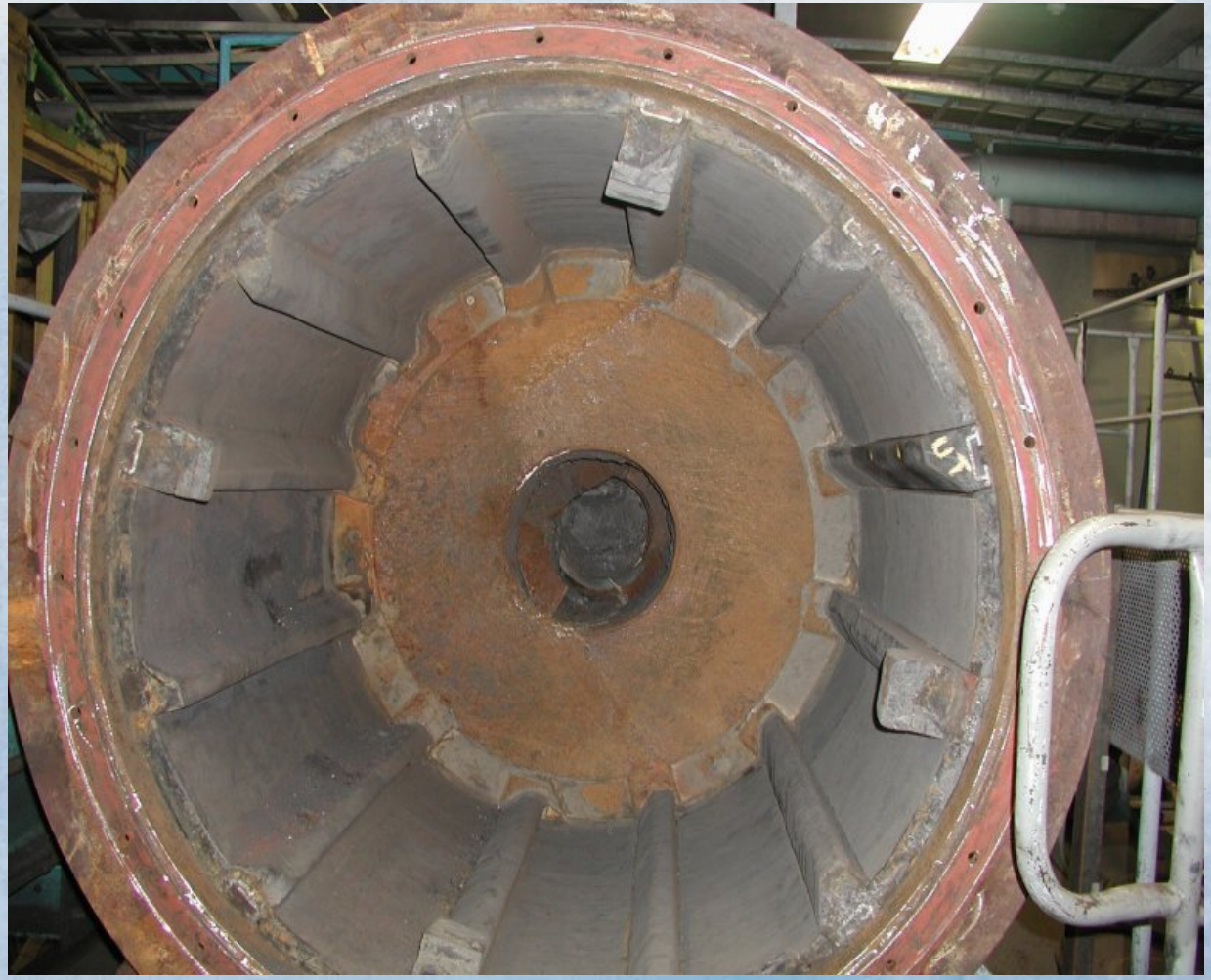
- Cooperation between
  LTU Div. Solid Mechanics, Div. Mineral Processing
  LKAB
  Boliden AB

Outline

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

Pilot mill

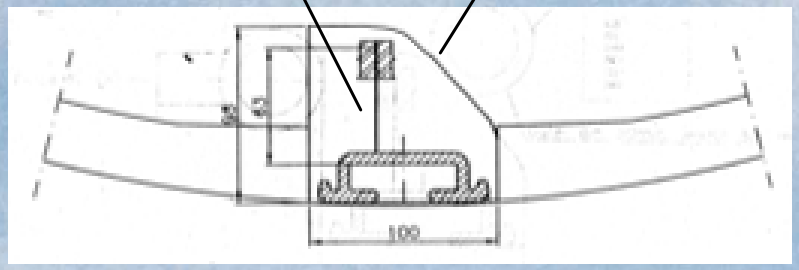


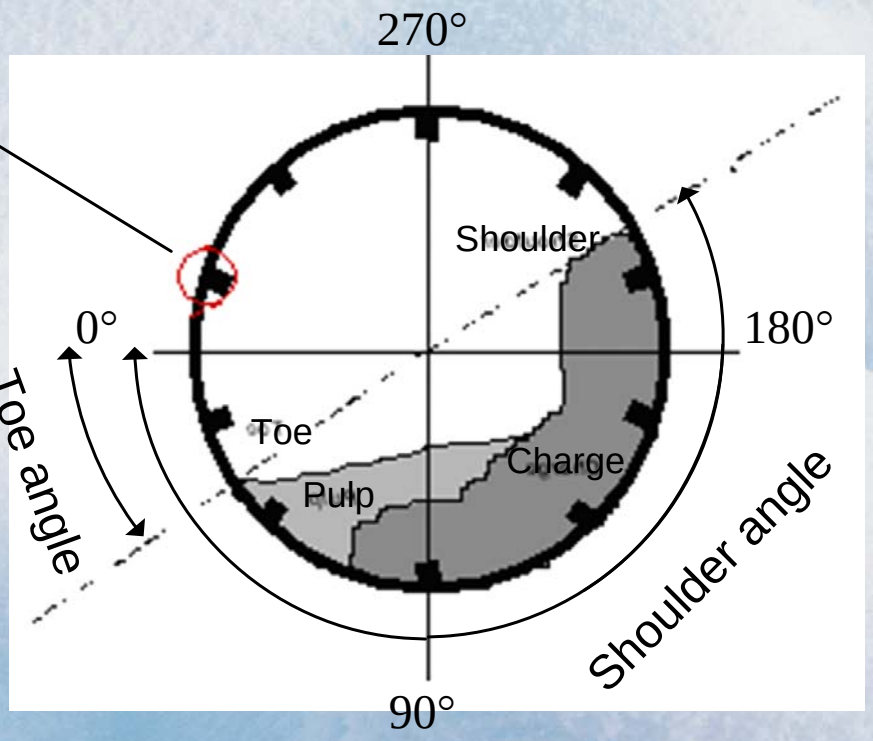


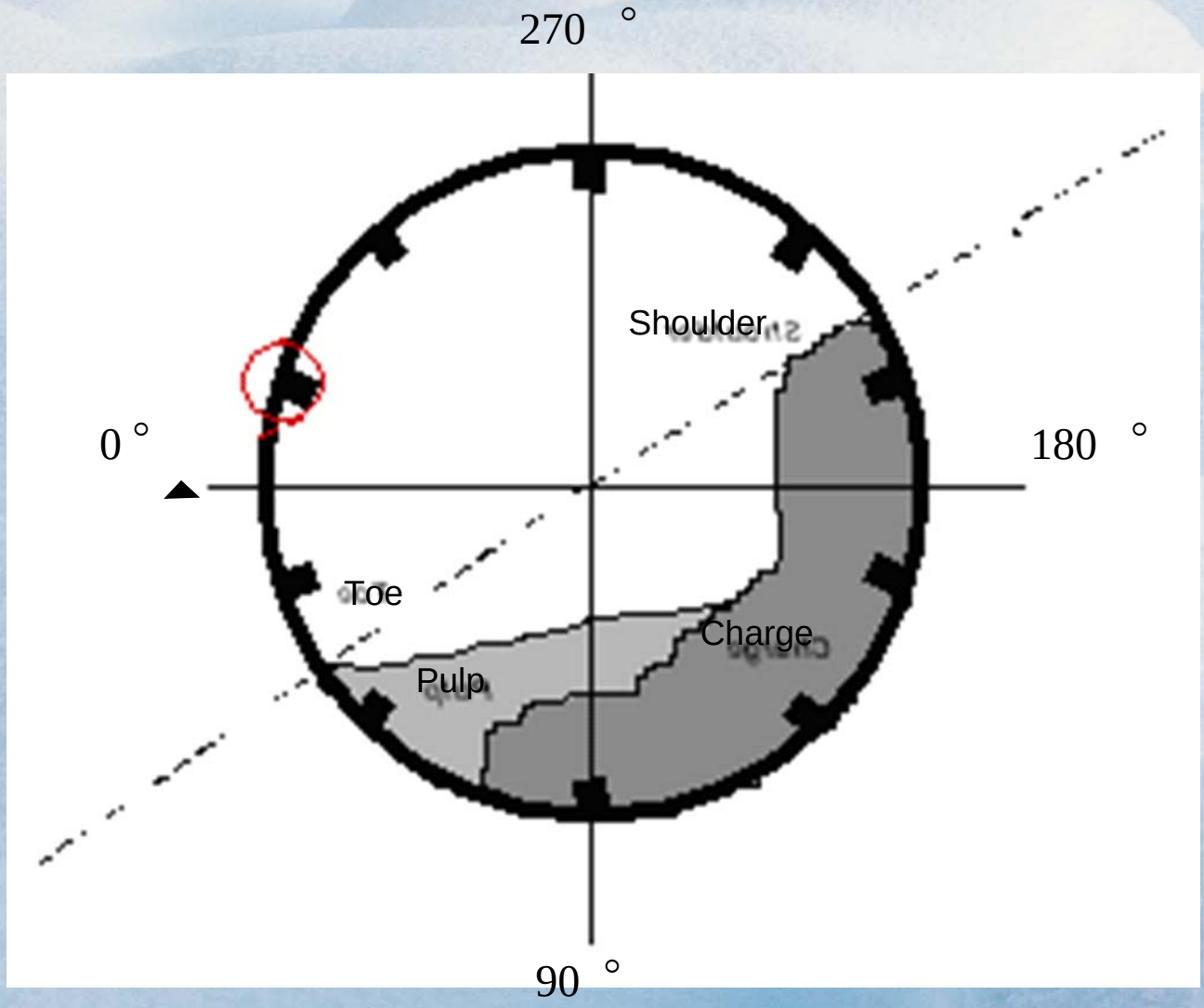
Rotating pilot mill

(1) Lifter bar

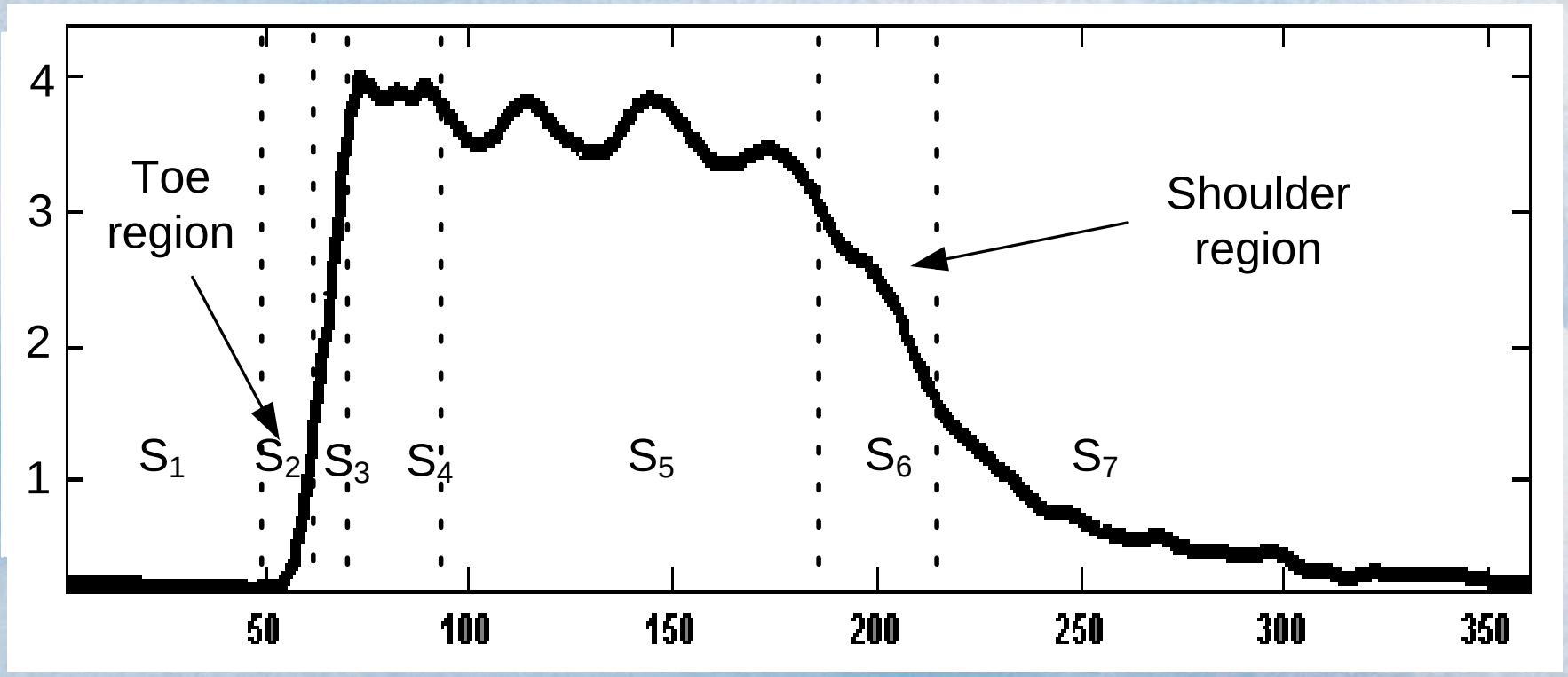
(2) Sensor






270 °
0 °
180 °
90 °
Shoulder
Toe
Charge
Pulp

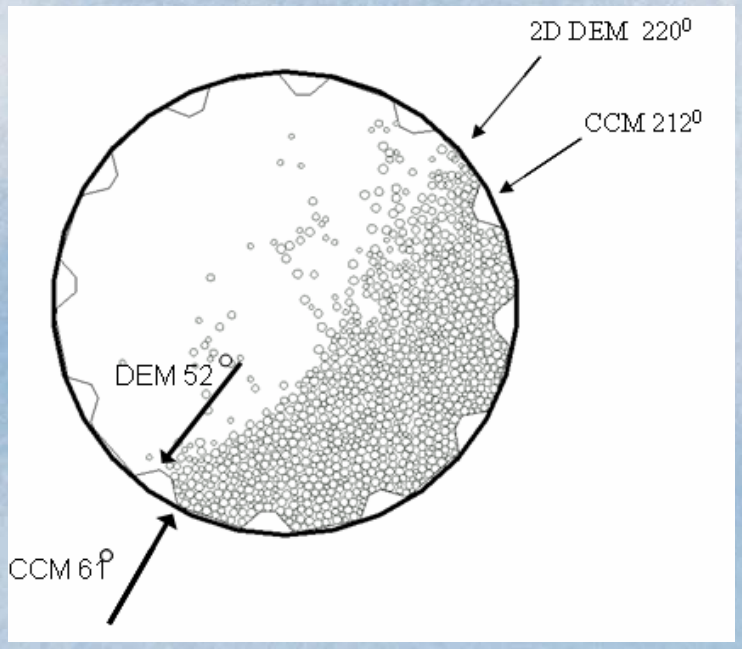
Measured lifter deflection

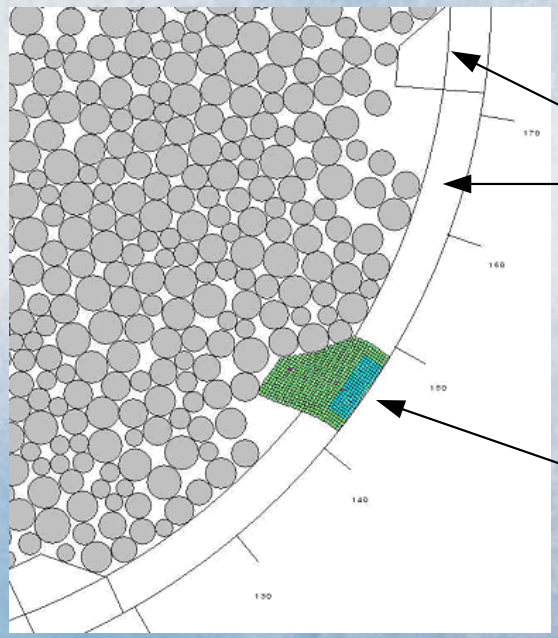


From Tano et. al.

Modelling and simulation of rotating mills

Traditionally modelling with DEM & rigid walls





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

Modelling strategy

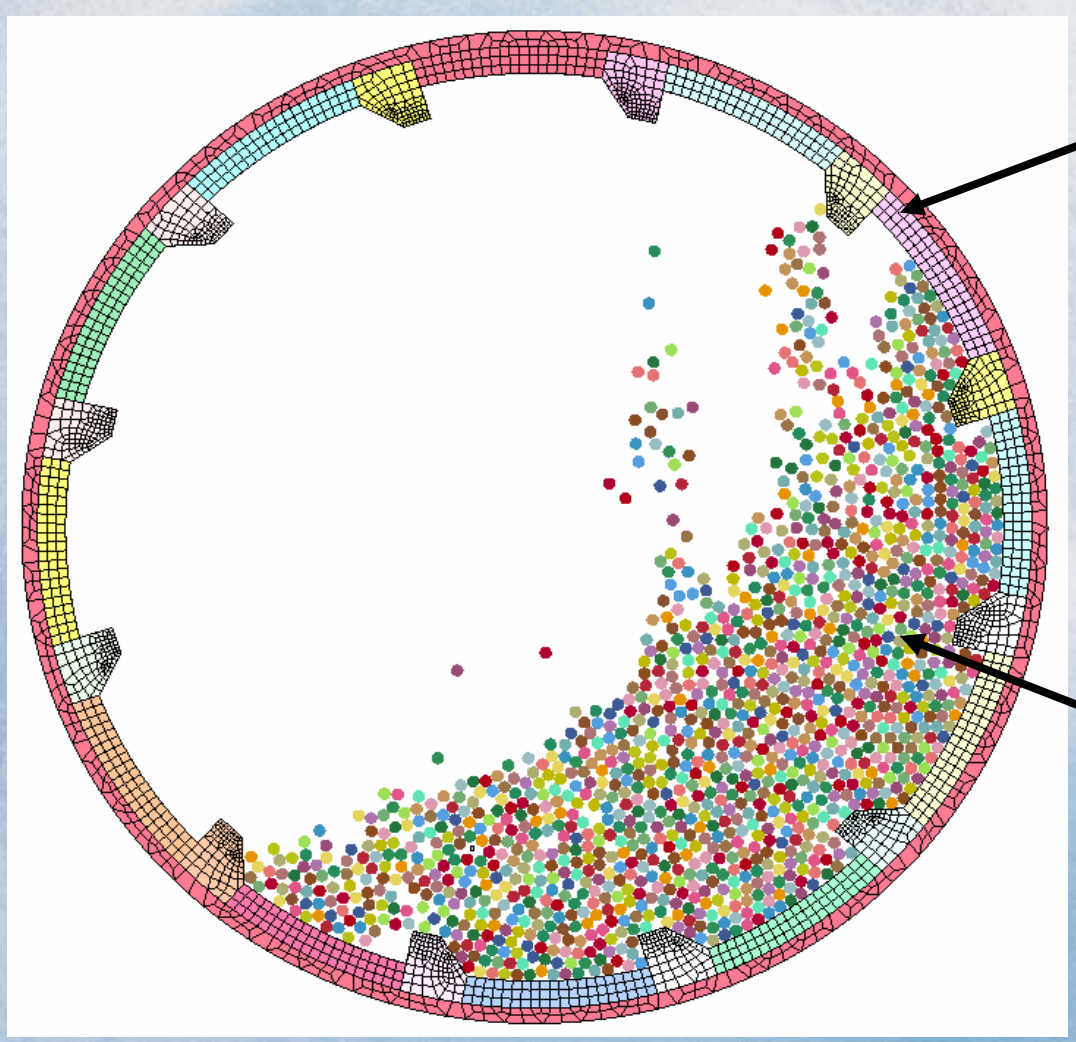
- Charge is modelled with DEM
- Mill shell and lining are modelled with FEM
- Interaction between DEM particles and FEM structure is handled by a contact interface

Structure Modelling

- FEM – a numerical solution method based on continuum mechanics modelling

- FEM – well developed and contains a large number of models for different materials.

DEM-FEM Model



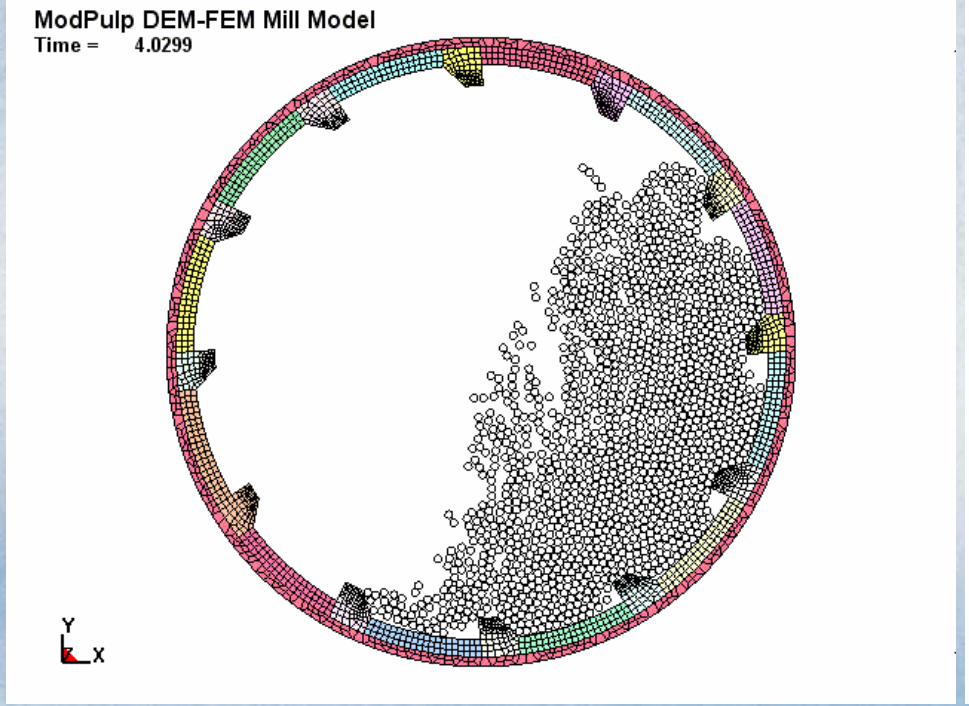
Structural parts of the mill (lifters, liners, shell) FEM

The ball charge is modelled with DEM

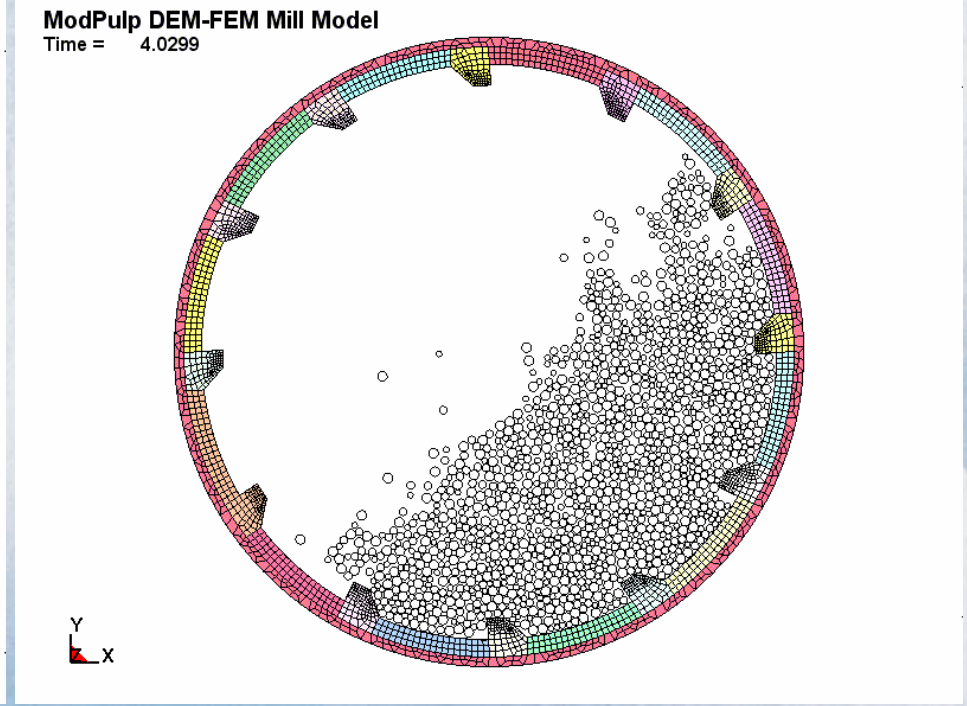
DEM-FEM Model

- 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 0.9
- The internal friction coefficient is 0.5

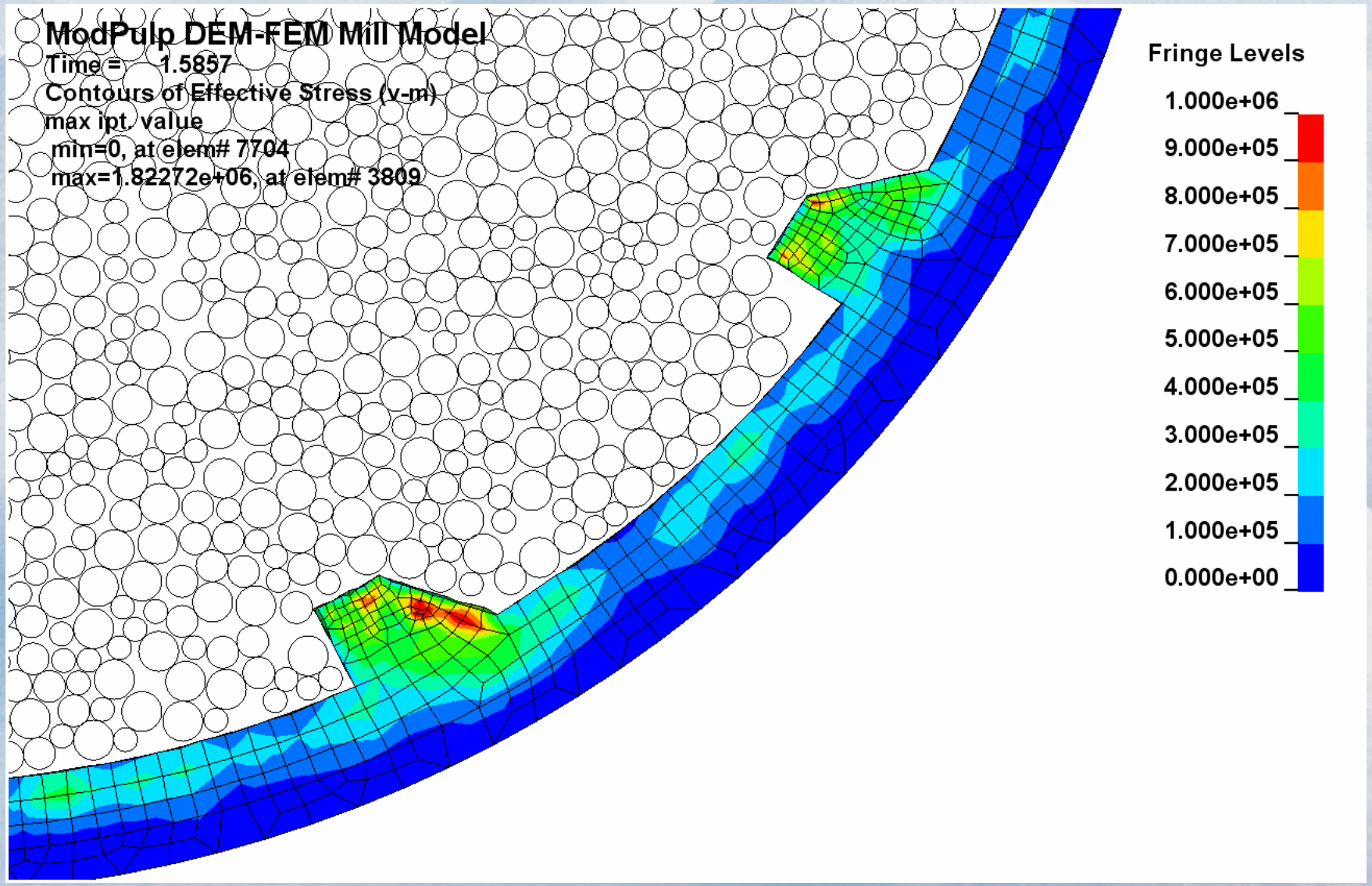
20 mm

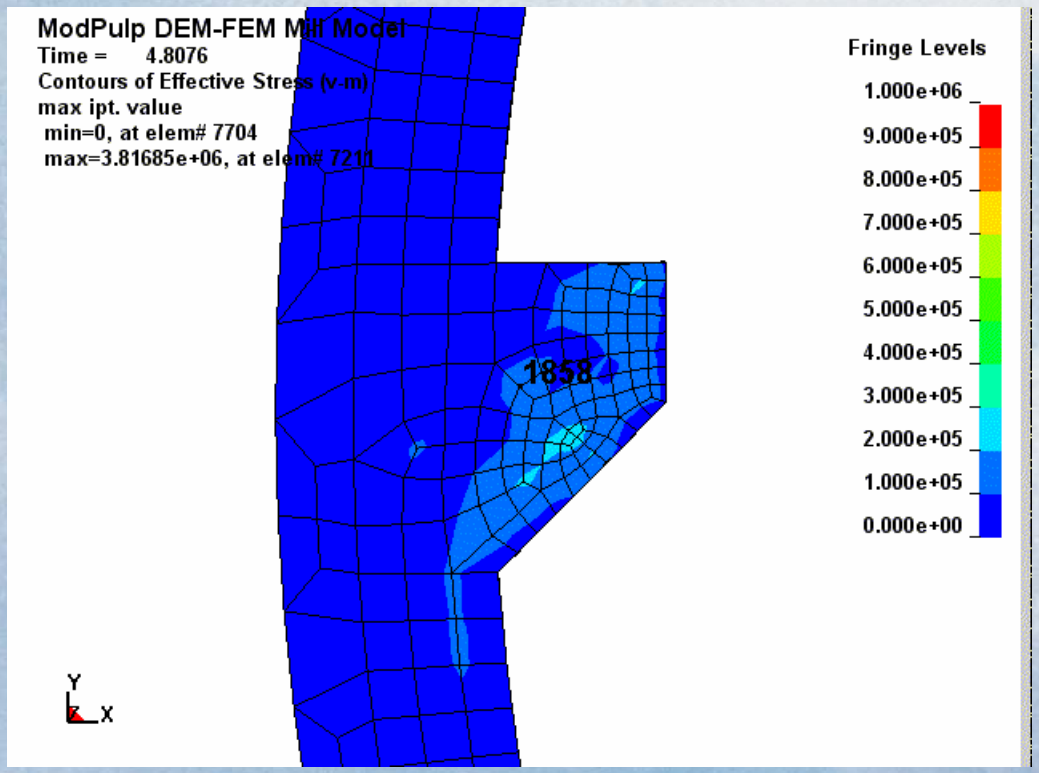


15 - 25 mm

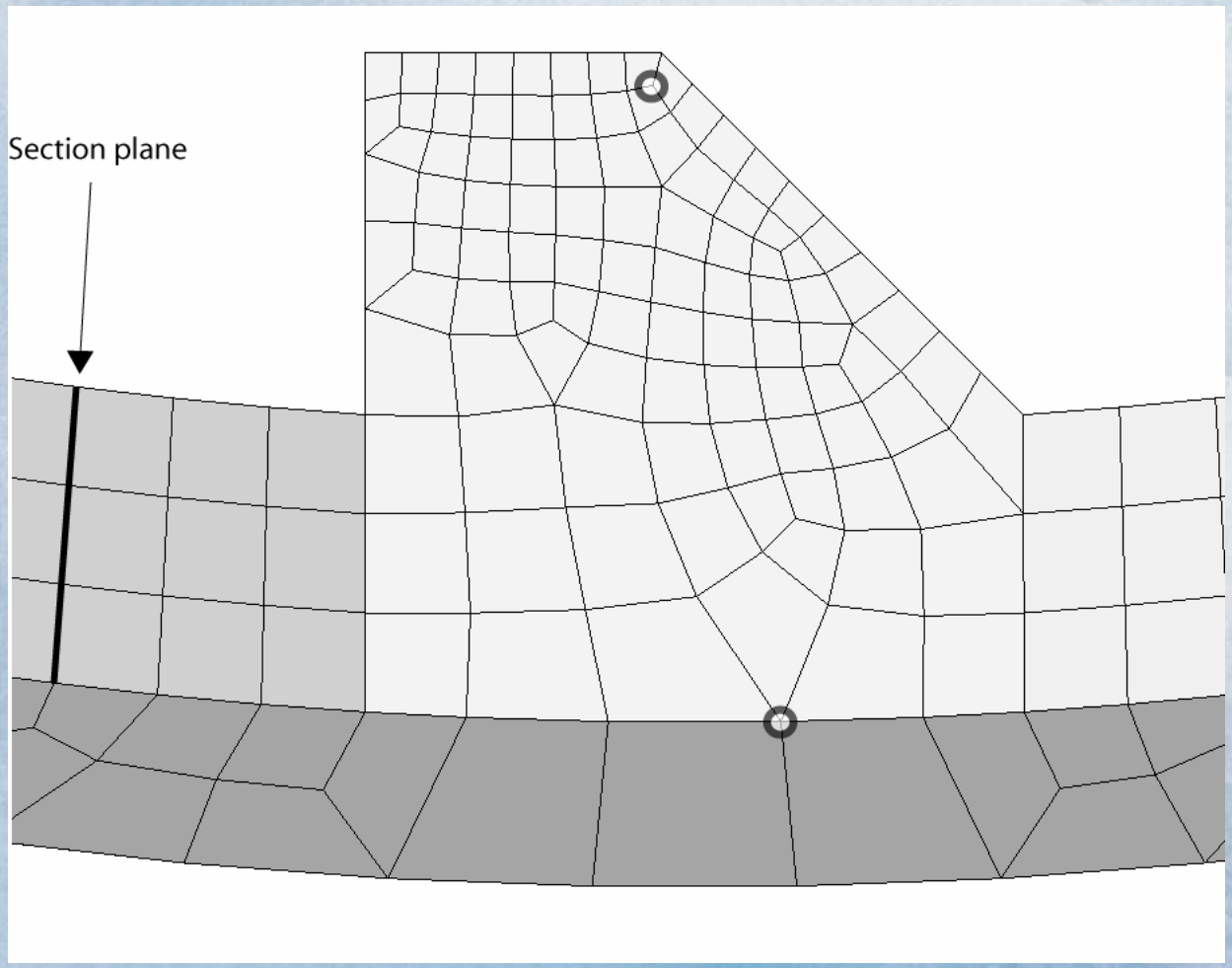


Charge level 25%, critical speed 73%

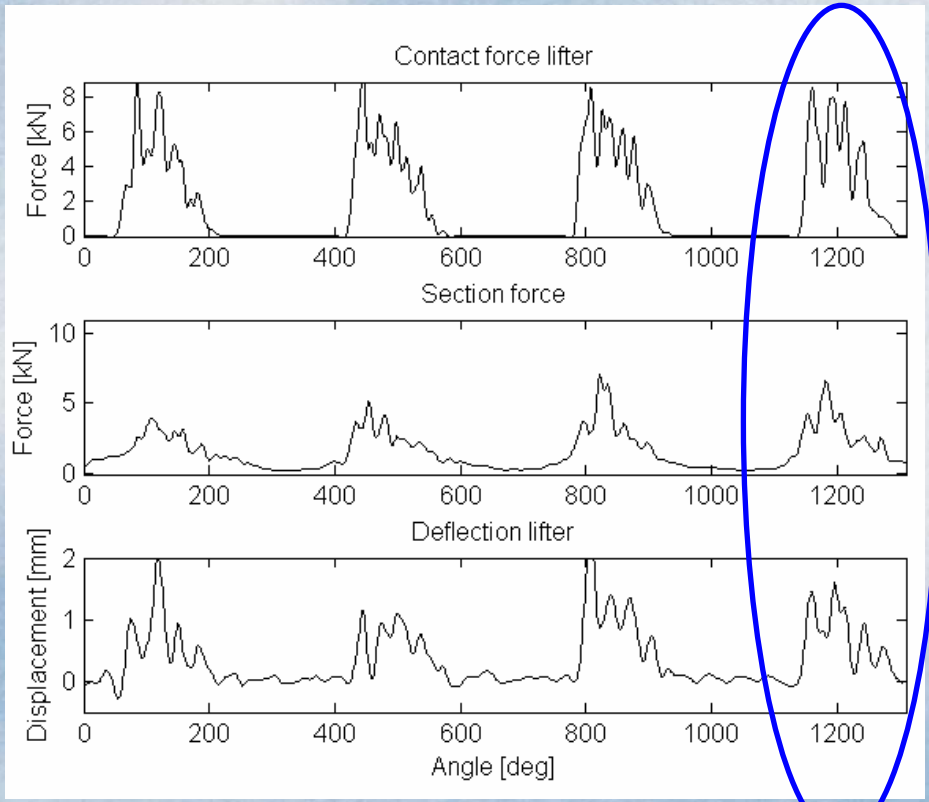

ModPulp DEM-FEM Mill Model
Time = 1.5857
Contours of Effective Stress (v-m)
max ipt. value
min=0, at elem# 7704
max=1.82272e+06, at elem# 3809
Fringe Levels
1.000e+06
9.000e+05
8.000e+05
7.000e+05
6.000e+05
5.000e+05
4.000e+05
3.000e+05
2.000e+05
1.000e+05
0.000e+00


ModPulp DEM-FEM Mill Model
Time = 4.8076
Contours of Effective Stress (v-m)
max ipt. value
min=0, at elem# 7704
max=3.81685e+06, at elem# 7211
1858
Fringe Levels
1.000e+06
9.000e+05
8.000e+05
7.000e+05
6.000e+05
5.000e+05
4.000e+05
3.000e+05
2.000e+05
1.000e+05
0.000e+00
Y
Z
X

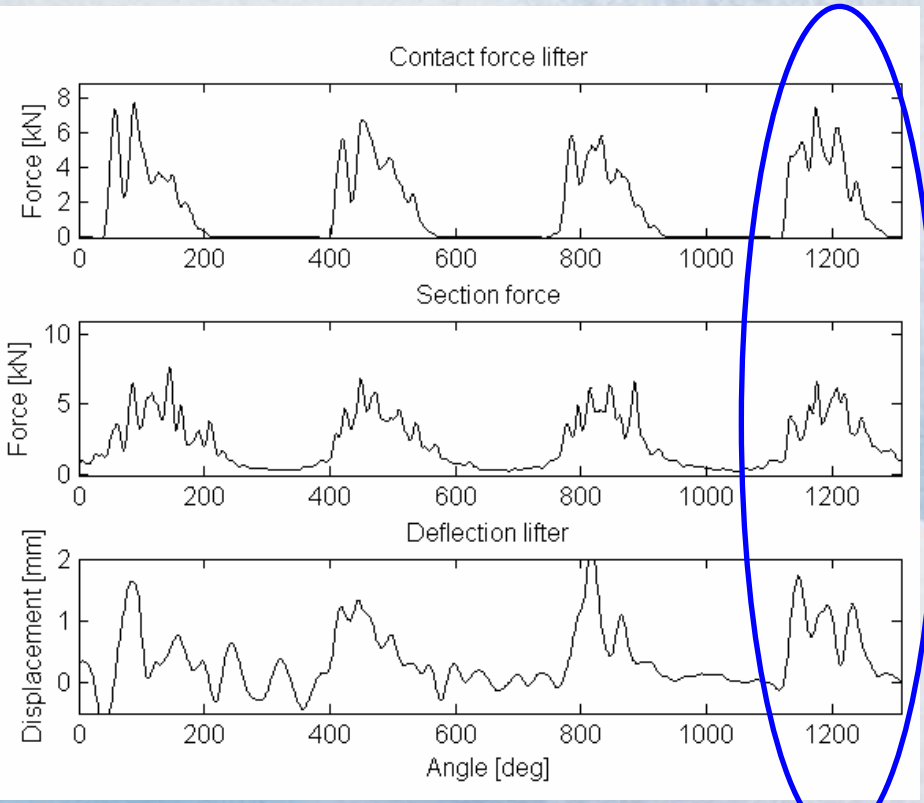
Lifter



Response from four passages through the charge

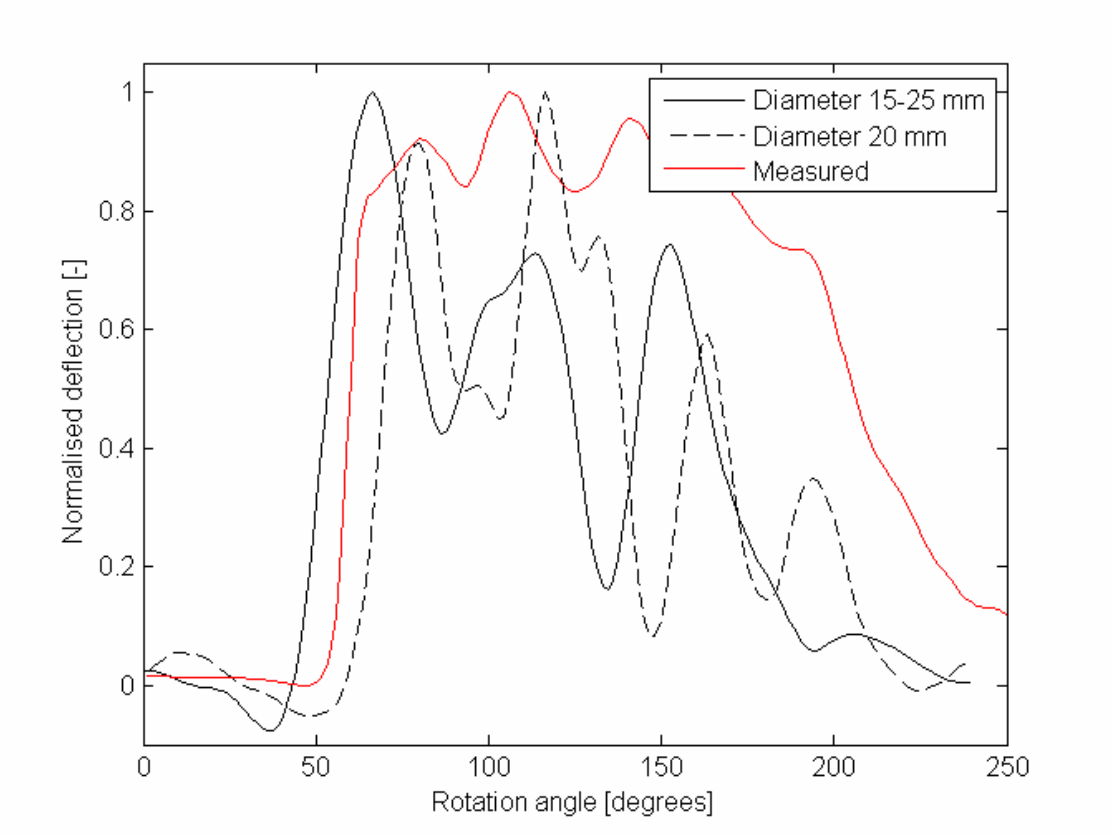


20 mm



15 - 25 mm

Lifter displacement fourth passage



Conclusion

- DEM-FEM models give a direct coupling between force, stress and displacement for the whole mill system
- Difference is the packing of the charges result in different stiffness of the charge
- Better correlation between experimental measurements and numerical models

Conclusion

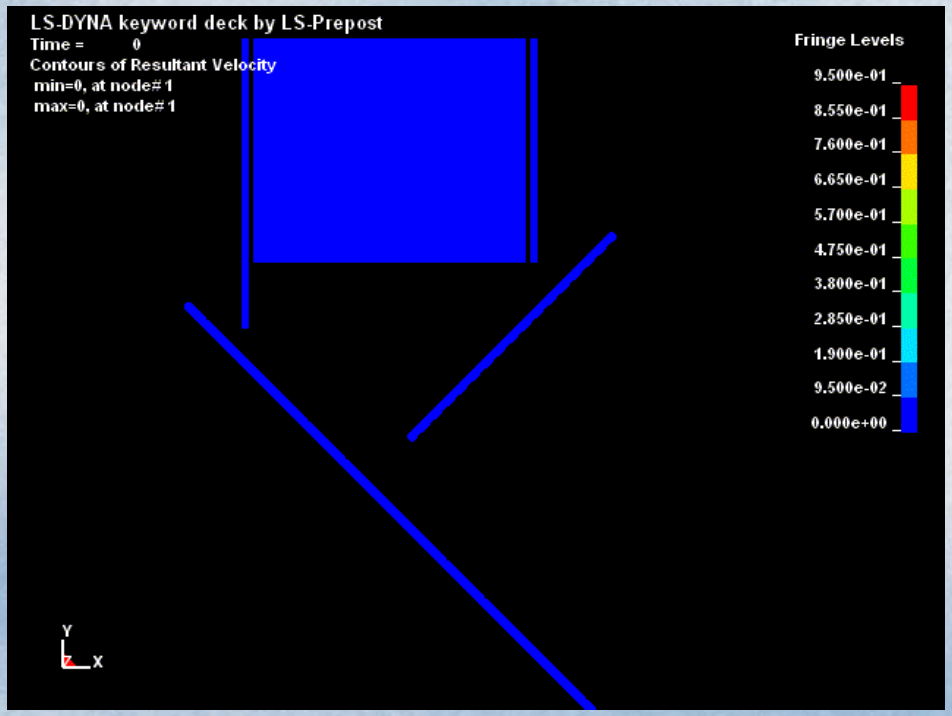
- Gives the opportunity study the influence of the whole mill structure
- Predict forces travelling in the lining, and by that makes modelling of on-shell sensor systems possible

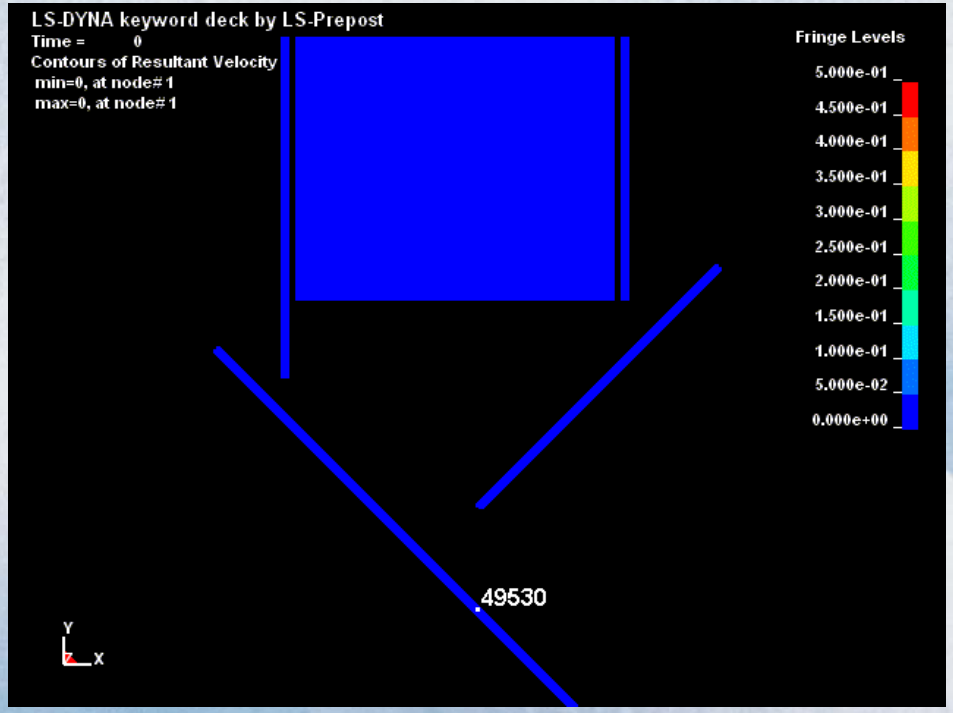
Future work

- Continuum model of the pulp with a particle based methods e.g. SPH, PFEM etc.

- Model the interaction between pulp, charge and mill structure

Example SPH

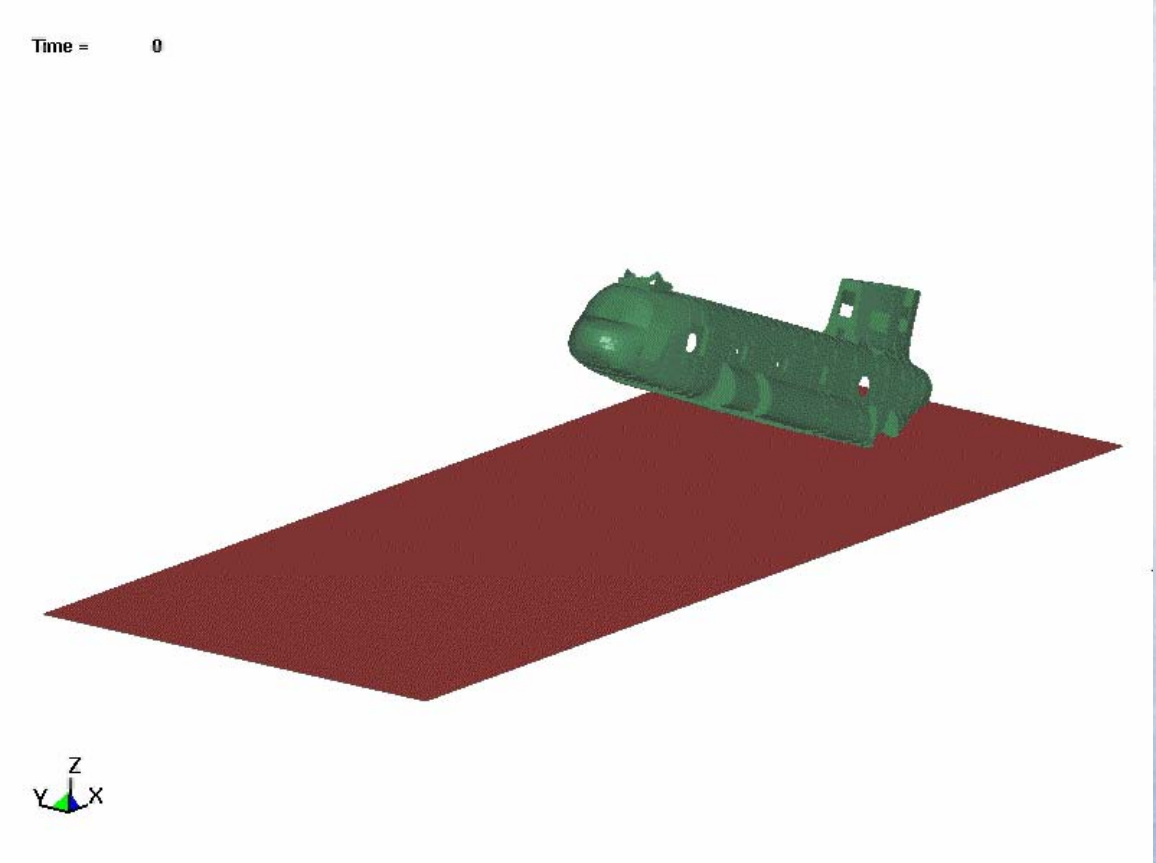




k=0.1

k=0.8

Ditching



THANK YOU