

5 MODELLING OF THE INTERACTION BETWEEN CHARGE AND LINING IN TUMBLING MILLS

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The comminution process in tumbling mills is complex and several parameters do significantly influence the effectiveness of the grinding operation. Many of these parameters are either difficult or laborious to measure. Grinding in tumbling mills is also an energy inefficient process; much of the energy is absorbed in low-impact contacts that do not break particles. An important point in optimising the process is to understand the charge motion within the mill. Both the breakage of ore particles, deflection of the lining and the wear of liners/ball media are closely linked to the charge motion. To include all phenomena that occur in a single numerical model is today not possible. However, some improvements of today's models can be identified, for example the structure of the mill (geometry and material composition) could be modelled with the finite element method (FEM). Coarse particles in the grinding medium could be modelled with the distinct element method (DEM) and the slurry can be modelled with some particle based continuum method e.g. smoothed particle hydrodynamics method (SPH). SPH has its strength in modelling free surface flow and very large deformations and is suitable for model fluid and granular flow. Each of these methods has its strength and weaknesses, but combined they may successfully model the main features of the grinding process.

5.1 Potential for the industry

The main scientific objective of this project is to combine element based methods like FEM together with particle based methods like DEM and SPH to a complete mill model. Such model should give a better understanding of the physical and mechanical behaviour of particulate material systems during grinding in a tumbling milling. This is very important in order to develop future high quality mineral products. The industrial benefits of the research will be improvements in mineral process plant performance through generic advances in knowledge and provision of engineering tools and methodologies. A numerical tool that captures some of the main features of the grinding process will be vital in the optimisation of the process and in product development. It should result in a better control of the grinding process and in improving the knowledge of the mechanical and physical behaviour of the whole comminution process.

5.2 Numerical modelling

DEM have been used in simulations of tumbling mill processes. A pure DEM model provides useful information on charge motion, collision forces, energy loss spectra and power consumption. This is important for improving the milling efficiency and gain more understanding of the process itself. For improved estimations of the complex nature of the milling process better and more physically precise models are desirable. For structural analysis the FEM is the most developed and used numerical method. The method originated from the need for solving complex elasticity and structural analysis problems in civil and aeronautical engineering. FEM is a numerical solution method based on continuum mechanics modelling, a constitutive relation for the actual material is described and the governing equations are solved. A variety of different constitutive models for a large number of materials are implemented in a modern finite element (FE) code.

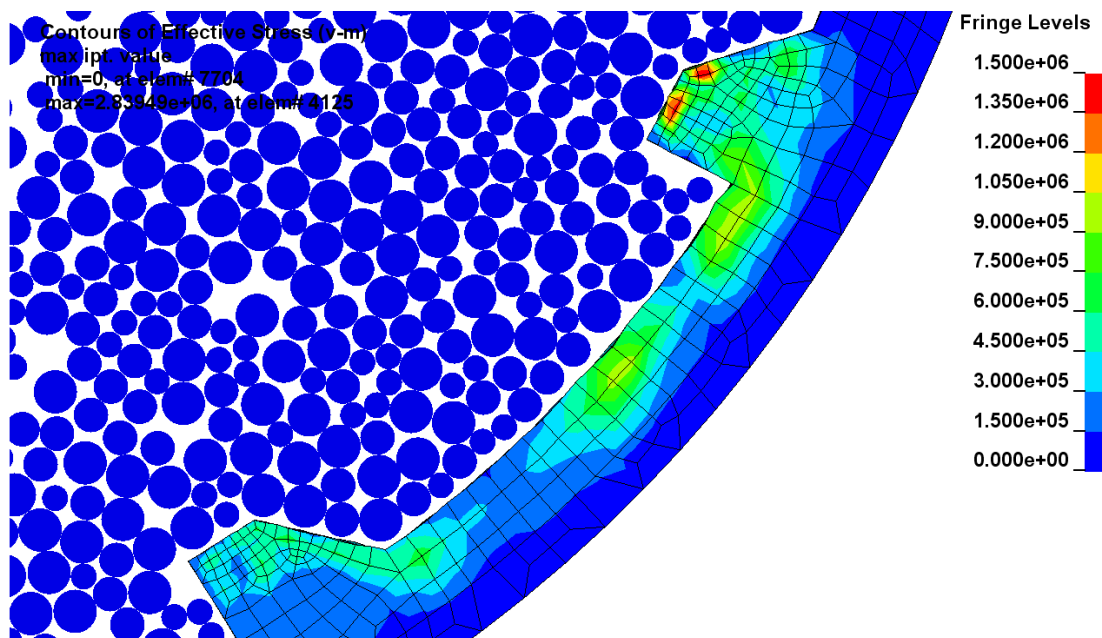


Figure 5-1. A snapshot of the von Mises' stress field for a part of the mill model during its passage through the charge.

Steps towards more physically correct numerical descriptions of mill systems are combined DEM-FEM models, see /Jonsén et al., 2009/ and /Jonsén et al., 2010/. With a DEM-FEM model structural response and its influence of the charge motion can be studied on the whole mill. Mechanical response of the mill structure is predicted by constitutive models included in the FE formulation. It also, predicts forces travelling in the lining and by that the echoes from consecutive lifter-charge hits. This gives an opportunity to validate signals from on-shell sensor types. Bending of the flexible rubber lifter and the corresponding stress field during its passage in the ball charge is shown in Figure 5-1. The major difference between DEM only and DEM-FEM models is that the latter give a direct coupling between force, stress and displacement for the whole mill system.

In the next step towards more physically correct models the slurry will be included. The smoothed particle hydrodynamics method is a mesh-free, point-based method for modelling fluid flows. The method can be combined with FEM and should be suitable for modelling slurry. Today, the SPH is used in areas such as fluid mechanics and solid mechanics (for example; free surface flow, incompressible flow, compressible flow, high velocity impact, penetration problems and high explosive detonation over and under water). The main advantage with SPH is the ability to virtually reproduce free surfaces, which is known to be a difficult problem in CFD with the classical Euler approach. The SPH method is an adaptive Lagrangian method, which means that in every time step the field function approximations are performed based on the current local set of distributed points. The mesh free formulation and the adaptive nature of the SPH method result in a method that handles extremely large deformations.

5.3 Validation

Validations of the numerical result are very important in the project. To ensure accurate behaviour of the models each step in the development has to be validated against experimental data. Experimental studies of Continuous Charge Measurement system (CCM) are exploited to validate the combined numerical models and to determine the material parameters. The industrial partners provide data to the models and initially data from pilot mill measurements has been used for the initial calibrations of the DEM-FEM model. In addition, the test work on pebble charges in the same pilot mill will provide data sets that will validate the accuracy of the combined numerical models.

REFERENCES

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