MODELLING AND VALIDATION OF THE INTERACTIONS BETWEEN PULP, CHARGE AND MILL STRUCTURE IN A FULL-BODY MODEL TUMBLING MILL

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Grinding in tumbling mills is a process to reduce the particle size of extracted ore and is regularly used in concentrating plants. It is a multi-physics process with many factors affecting the result. Major challenges for today's wet tumbling mill operations are to both increase the efficiency and obtain the right product properties. For tumbling mills, therefore, understanding of the charge motion within the mill is of importance. Tumbling mill systems consist of the mill lining, grinding balls, grinding media, and pulp that each need suitable numerical models to simulate correctly their physical behaviour. However, to efficiently model wet grinding in tumbling mills is a difficult task because of the complex behaviour of the pulp with free surfaces and large deformations. The difficulty is usually that the method to represent and reproduce its movements is computationally demanding and time consuming. A novel way to model wet grinding in tumbling mills via coupling of different numerical methods have been presented by Jonsén et al. [1]. In this work, the method in [1] is used to explore the possibility to efficiently model and simulate the whole mill body, including the pulp and the charge movement. This is done with a solver based on the particle finite element method (PFEM) [2] implemented in LS-Dyna. PFEM is a Lagrange based method that gives the opportunity to efficiently model the pulp free surface flow, and its interaction with grinding balls and mill structure. It uses an arbitrary Lagrangian Eulerian (ALE) approach in combination with an automatic volume mesher and finite element shape functions for solving incompressible flow. To handle free surface flows, there is also a bi-phasic flow capability that involves modelling using a conservative level-set interface tracking technique. In this case, the ICFD and DEM solvers are coupled via a two-way coupling.

The charge movement will induce loading on the grinding media in a tumbling mill. Some important properties that will affect the grinding efficiency are the filling rate, rotational speed, density and viscosity. By the usage of a fluid PFEM-solver, the pressure can be predicted in the pulp during charge motion. A snapshot of the pressure distribution in front of the lifter as it travels through the graded charge with a magnetite pulp is obtained at the five o'clock position in Figure 1. The figure illustrates the pressure distribution along the lifter, mill shell and the mill end at the same time. From the pressure distribution it is observed that pressure increase in front and close to the mill shell follows the lifters during the passage through the charge. One interesting feature that simulation can be used to study is the cyclic loading of the charge due to the lifter movements. As the lifter hits the charge, the pressure increases, but it decline as the lifter is about to leave the charge.

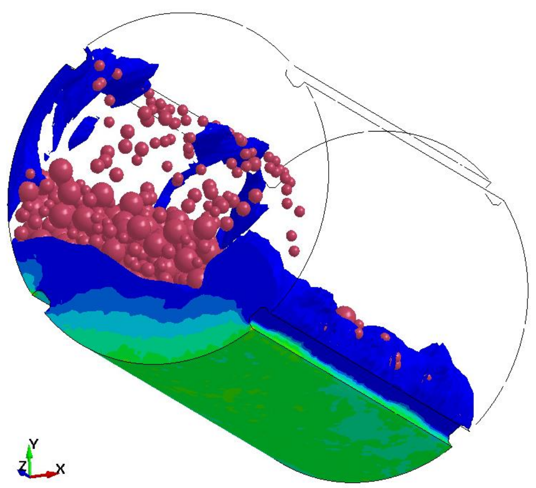

Figure 1: A snapshot of the pulp pressure distribution during grinding

Validation is done against experimentally measured driving torque signatures from an instrumented small-scale batch ball mill equipped with an accurate torque meter, and charge movements captured from high-speed video. Numerical results are in good agreement with experimental torque measurements.

References

[1] Jonsén, P. et al., Preliminary validation of a new way to model physical interactions between pulp, charge and mill structure in tumbling mills. Minerals Engineering, 130, 76-84 (2019)

[2] Pin, F.D. et al., The ALE/Lagrangian Particle Finite Element Method: A new approach to computation of free-surface flows and fluid–object interactions, Computers & Fluids, 36, 27–38. (2007)

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