A combined modeling approach to capture the physical interactions between pulp, charge and structure in a tumbling

Laura Suarez*, Pär Jonsén† and Samuel Hammarberg†

* Luleå University of Technology
Mechanics of Solid Materials, 971 87 Luleå, Sweden
e-mail: laura.suarez@ltu.se, web page: http://www.ltu.se

† Luleå University of Technology
Mechanics of Solid Materials, 971 87 Luleå, Sweden

ABSTRACT

Modeling the pulp and its interaction with both the charge and the mill lining in tumbling mills is an interesting challenge. A problematic matter is the metastable state in which tumbling mills often operate, because of the difficulty to balance the rate of replenishment of large ore particles from the feed with the required in the charge. Besides, wet tumbling mill operations are low efficient. Grinding is a multi-physics process with several factors having influence on the result. Some important properties that affect grinding efficiency are the filling rate, rotational speed, density and viscosity of the charge. As the mill rotates, the charge will move loading the grinding media and breaking the ore particles. Thus, understanding the motion of the charge within the mill is of importance and numerical modeling can be an efficient design tool to study complex industrial processes such as grinding.

Physically realistic methods are needed to close the gap between reality and numerical results in modeling of tumbling mills. The difficulty is that, the method to represent and reproduce its movements, is demanding and time consuming. A way of modeling wet grinding in tumbling mills by coupling different numerical methods has been presented by Jonsén et al. [1]. The author uses this method to explore the possibility to efficiently model and simulate the whole mill body, including the pulp and the charge movement. This is done through a solver based on the Particle Finite Element Method (PFEM) [2] implemented in LS-Dyna. It is a Lagrange based method that gives the opportunity to 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 to solve incompressible flow. To handle free surface flows, there is also a bi-phasic flow capability that involves modeling using a conservative level-set interface tracking technique.

PFEM and Discrete Element Method (DEM) solvers are coupled by means of a two-way coupling. The fluid PFEM-solver can predict the loading e.g. hydrostatic pressure of the pulp during charge motion. One interesting feature to study is the cyclic loading of the charge due to the lifter movements e.g. as the lifter hits the charge, the pressure increases and decreases when the lifter is about to leave. The opportunity to compare tumbling mill models with quantitative experimental data is rare, but a good opportunity for a fruitful validation. In this case, the experimentally determined driving torque signature and its mean value are compared to simulation results of different cases of study varying both the charge and fluid. PFEM as a fluid solver induces to more powerful and efficient simulations; then, results are in good agreement with experimental data. The method presented here unlocks the possibility to predict the volume of the mill high-energy zones and to optimize the lifter design and mill operating conditions. Furthermore, these results have potential to increase the efficiency of the overall milling process and reduce the specific energy consumption.

REFERENCES

[1] P. Jonsén 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] F.D., Pin, 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)