Multi-physics modelling and validation of interactions between pulp, charge and mill structure in tumbling mills

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ABSTRACT

Wet grinding in tumbling mills is a multi-physical process including interesting modelling challenges. In the mill, there are numerous free surfaces and the pulp fluid simultaneously interacts with both the charge and the mill structure. Previously, these interactions for wet grinding systems have been modelled using a combination of discrete element method (DEM) for grinding balls, smoothed particle hydrodynamics (SPH) for fluids and the finite element method (FEM) for the structure. This approach is not very stable and long computation times are needed. In this work, the fluids are modelled with a Lagrange based method called incompressible computational fluid dynamics (ICFD). The method is based on the particle finite element method (PFEM) but can in this configuration interact with both FEM and DEM. In the studied wet milling system, ICFD is used to represent the pulp fluid domain which can be either water only, or a magnetite pulp. Both fluids are used in predicting the behaviour for graded and mono-size charges.

Four different cases are numerically modelled and validated against experimentally measured driving torque signatures from an instrumented small-scale batch ball mill equipped with an accurate torque meter. The internal working of the charge and the physical interaction between the charge and the mill structure is studied. The combined ICFD-DEM-FEM model presented here can predict responses from the mill structure, as well as the pulp liquid flow and pressure. The simulated charge movement is also compared with high speed video of the charge movement for a number of cases. Numerical results are in good agreement with experimental measurements. Also, the ICFD method is an efficient method which provides stability and robustness to the fluid model allowing larger time steps and implicit integration.

References

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