Advances in Mining Simulation

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Mine scale finite element simulations are now a key design and planning tool for some of the world's largest and most challenging open pit and deep underground mining projects. Models with more than ten million degrees of freedom are regularly used for forecasting and probabilistic analysis of Life-of-Mine scenarios. These simulations, sometimes analysing decades of the extraction and continuing deformation of complex infrastructure, are run in less than a day on the Abaqus/Explicit parallel solver using 32 CPUs. The speed and benefits of high-similitude analysis has allowed Abaqus simulation to become more commonplace, and in some cases to be considered a requirement for sufficient analysis of high-value mine developments.

The next phase of improved simulation for mines will involve the incorporation of more detail and a more accurate representation of the governing physics of continuum-discontinuum problems, to attain improved similitude at all length scales. Two areas where significant improvements are expected in the very short term are in the simulation of the loads in masses of granular materials and in the behavior of elementary volumes of fractured rock.

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1. Introduction

The mining industry has only recently gained access to high similitude, three-dimensional Finite Element modeling. Initially, the new generation of FE models for mines were largely continuum models with few discontinuities. As recently as just a few years ago, this was sufficient to represent a genuine improvement over the status-quo, boundary element elastic and lower order Finite Difference approaches. The improvements over elastic modeling are obvious, but the main gains over the legacy non-linear approaches came from little more than better constitutive models (strain softening, dilation) appropriate boundary conditions, realistic 3D geometry, higher order elements and appropriately small excavation steps to capture the stress path. An example of such a mine scale model (8.5M degrees of freedom) is shown in Figure 1. Even these simple gains had not been realized using previous approaches, usually because of computational inefficiencies.

As the new FE approaches become the new status quo, mines will begin to demand the next incremental improvements, and these will likely come from more complex material behavior and phenomena at interacting length scales. The next step is in fact necessary because of the highly non-linear and complex behavior of rock. All length scales in rock are coupled, the material behavior in most mines spans a range from granular flow to solid continua and the excavations that are being analysed span length scales from metres to kilometers. It is essential to capture these inter-scale, coupled physics phenomena to achieve improved precision and reliability.

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