Geophysical Research Abstracts
Vol. 18, EGU2016-7579, 2016
EGU General Assembly 2016

A workflow for transferring heterogeneous complex geological models to consistent finite element models and application to a deep geothermal reservoir operation

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Geological models are the prerequisite of exploring possible use of the subsurface and evaluating induced impacts. Subsurface geological models often show strong complexity in geometry and hydraulic connectivity because of their heterogeneous nature. In order to model that complexity, the corner point grid approach has been applied by geologists for decades. The corner point grid utilizes a set of hexahedral blocks to represent geological formations. Due to the appearance of eroded geological layers, some edges of those blocks may be collapsed and the blocks thus degenerate. This leads to the inconsistency and the impossibility of using the corner point grid directly with a finite element based simulator. Therefore, in this study, we introduce a workflow for transferring heterogeneous geological models to consistent finite element models. In the corner point grid, the hexahedral blocks without collapsed edges are converted to hexahedral elements directly. But if they degenerate, each block is divided into prism, pyramid and tetrahedral elements based on individual degenerated situation. This approach consistently converts any degenerated corner point grid to a consistent hybrid finite element mesh. Along with the above converting scheme, the corresponding heterogeneous geological data, e.g. permeability and porosity, can be transferred as well. Moreover, well trajectories designed in the corner point grid can be resampled to the nodes in the finite element mesh, which represents the location for source terms along the well path.

As a proof of concept, we implement the workflow in the framework of transferring models from Petrel to the finite element OpenGeoSys simulator. As application scenario we choose a deep geothermal reservoir operation in the North German Basin. A well doublet is defined in a saline aquifer in the Rhaetian formation, which has a depth of roughly 4000 m. The geometric model shows all kinds of degenerated blocks due to eroded layers and the structure determined by salt tectonics. The operation time of the reservoir is set to 20 years, and in each year, hot water is extracted for 6 months at a rate of 150 m^3/h during the heating season. The injection well is operated at the same rate with a cooled water temperature of 40 ˚C. The simulation results show that this reservoir can produce water with an average temperature of 161.5 ˚C at the designed rate. During the operation, the cold water front propagates preferentially towards the extraction well. Thus, after 20 years, a temperature decrease of larger than 5 ˚C can be observed at a distance of 800 m from the injection well. In addition, due to heat conduction from neighboring strata, a temperature decrease of about 5 ˚C can be observed at the injection well.