Heat Transfer in Borehole Heat Exchangers from Laminar to Turbulent Conditions
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Introduction: Borehole heat exchangers (BHE) in connection with heat pumps and floor heating in many countries are becoming an alternative to conventional heating or cooling systems using fossil resources. Here the coaxial type is used, for which a cross-sectional view through the borehole is depicted in Figure 1.

Components and Couplings: The BHE itself is modelled by 1D models directed along the borehole, one for downflow and one for upflow. The coupled 1D models can be embedded in a 2D vertical cross-section or 3D model of the surrounding porous medium. A fluid flows through the inner pipe and the annular cross-section.

In all components we utilize heat transfer modes. For downflow and upflow we use heat transfer in fluids, for the ground heat transfer in porous media. The components are coupled in various ways by extrusions, which are sketched in Figure 2. Temperature differences are used to calculate source/sink-terms $j$ and boundary fluxes $j_s$. For conductances we adopted the formulae from FEFLOW (2014), which are well established for smooth pipe boundaries.

Application: For the location Hambühren salt dominates the geological profile: the overlying cap-layer has a thickness of 130 m. Figure 3 shows the cooling radius caused by the BHE after 30 a, while Figure 4 shows the temperature profiles of downflow and upflow pipes.

Conclusions: Using COMSOL Multiphysics® a model concept is developed that enables the simulation of coupled heat transfer in pipes and surrounding porous medium. Concerning the conductances we distinguish between laminar, turbulent and transitory regimes, valid for pipes with smooth walls.

Reference:

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