Tunnels, a New Potential Source of Energy: 3D Modeling of a Heat Exchanger Within Tunnel Lining

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Abstract

The drive to reduce carbon emissions and reliance on oil and gas has led to increasing use of alternative energy heating systems. The ground source heat pumps are an example of these systems. Recently, tunnels have been considered as a way of connecting building heat pump systems to the energy stored in the subsoil.

Due to the large interface area with the ground, this kind of engineering structure offers a great potential to extract heat from the surrounding ground as well as heat generated by the tunnel application (e.g. trains, passengers) for heating purpose in winter. Reciprocally, the energy extracted from buildings in summer for cooling purpose, and fatal energy from inside the tunnel, can be stored into the ground. This new-type system uses the tunnel lining as a reversible heat exchanger by means of incorporation of absorber pipes in which a heat exchange fluid is circulating. The energy can thus be applied for heating and cooling buildings by using suitable heat and distribution pumps.

The study is realized in the context of the "Grand Paris Express", with more than 200 km of projected underground railway for public transport in the Île-de-France region which will be constructed from 2016. It is based on numerical modeling of the heat transfer from the tunnel air and the surrounding ground to the liquid filled pipes in the tunnel concrete segments. The transfer is being computed with the help of the COMSOL® finite element software, using coupled thermo-hydro analysis in a 3D model. To carry on a parametric and periodic study, the model is calibrated against periods with different parameters (inlet temperature of the liquid, of the tunnel's air, hydraulic flow, thermal properties of the soil) for finding out the heat flux and the effect of this system on the temperature on concrete lining, embedded pipes and the surrounding rock. Results are generated in the form of various plots after running the analysis and show the feasibility of the concept.

Figures used in the abstract

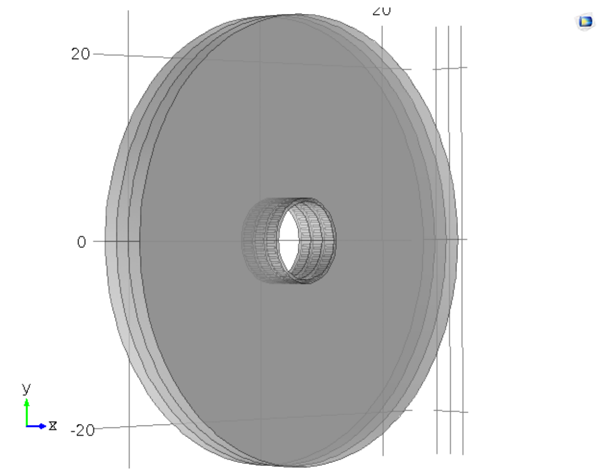

Figure 1: Model's geometry

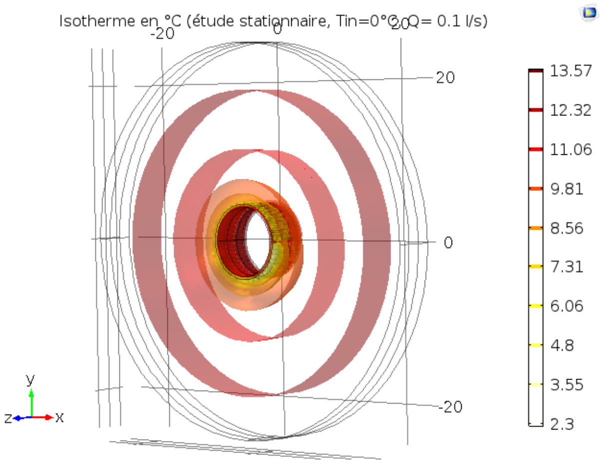

Figure 2: Isotherms

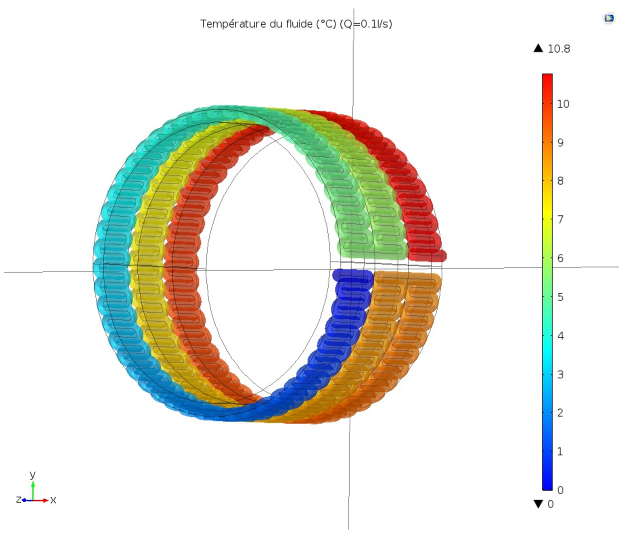

Figure 3: Fluid's temperature

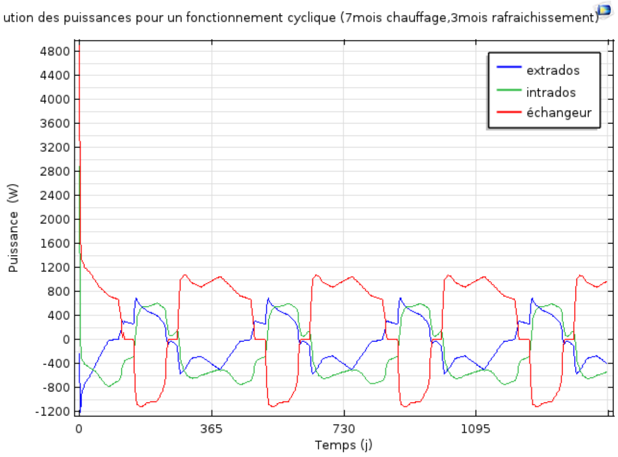

Figure 4: Evolution of heat flux with periodic simulation