A NUMERICAL STUDY OF DEEP BOREHOLE HEAT EXCHANGERS IN UNCONVENTIONAL GEOTHERMAL SYSTEMS

Research on unconventional geothermal systems has been increased with the Iceland Deep Drilling project (IDDP). Deep Borehole Heat Exchangers (DBHE), conventionally applied in low-medium temperature zones (Alimonti et al., 2018), can offer alternative solutions to recover the heat from these unconventional geothermal resources.

The purpose of this study is to assess the DBHE potential and its influence near shallow magmatic object using conditions from the IDDP-1 well, which reached a magma intrusion at a depth of 2 100m.

Method and Materials

- 2 Computational Fluid Dynamics (CFD) axisymmetric models of 2 hypothetical DBHE (Kohl et al. 2000) (**Fig.1**) are considered, based on the IDDP-1 conditions, where 3 porous regions are defined with thermal properties of fluids and materials listed in **Table 1**.
- From initial local T-P gradients (**Fig. 2**), transient simulations are run using the k-Ɛ Realizable turbulence model (Ansys.2016) in the DBHE.
- The Darcy law is applied in the porous media: $\nabla p = -\frac{\mu}{\alpha}\,\vec{v}$, where v is the velocity, μ the viscosity and α the permeability.

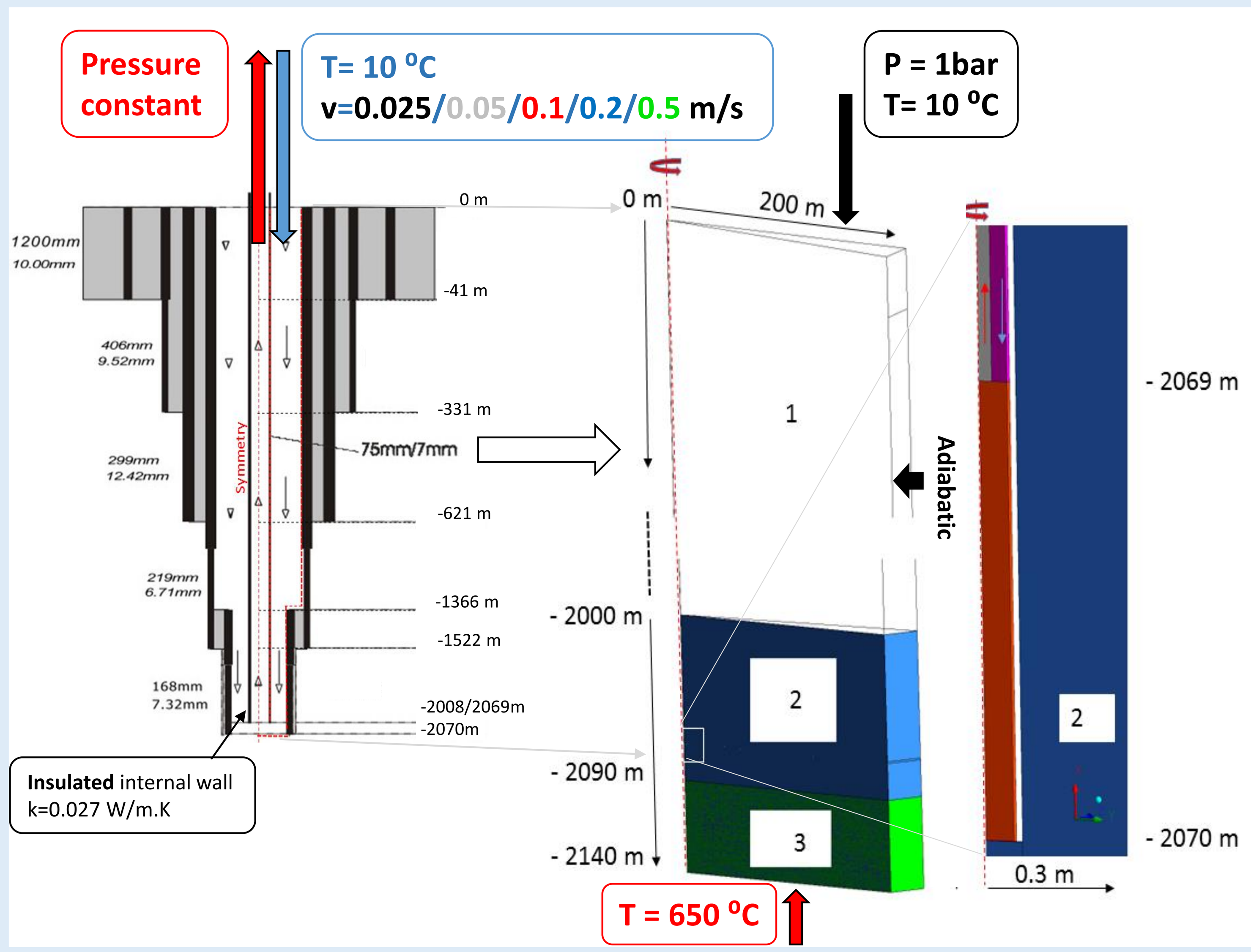

Figure 1: Left - Full Weissbad DBHE description and simulated domain (red dashed-lines), modified from Kohl et al. 2000. **Right -** Axisymmetric DBHE model showing all 3 porous zones, as detailed in Table 1, and boundary conditions. The far right pictures shows a closer view of the bottom hole area for Design 2.

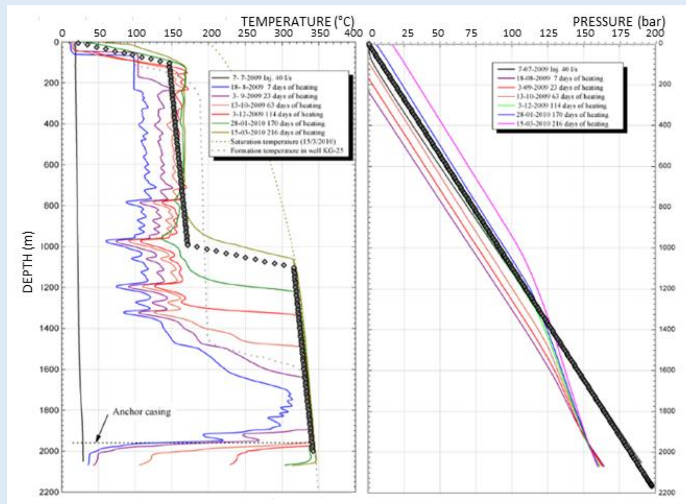

Figure 2: Temperature and Pressure initial conditions compared to data measured in the IDDP-1 (up to 2km).

Properties	Density (kg/m³)	Thermal conductivity (W/m.K)	Heat Capacity (J/kg.K)
Water	998.2	0.6	4182
Cement	3150	3.0	2000
Casing	7848	46.9	3500
Porous Zone Properties	1	2	3
Porosity %	1	10	1
Permeability α (m^{-2})	10^{-20}	10^{-14}	10^{-20}
DBHE Design	1	2	
BHE depth	2008-2070	2069-2070	

Table 1: Thermal properties considered in the CFD model (extracted from Axelsson et al. 2014 and Kohl et al. 2000).

Results

- A maximum T°C is obtained after a short time, higher when the injection velocity is high (**Fig.3**).
- Pseudo-steady state conditions are reached after 18 months.
- The long-term T°C production varies in the range of 2.54 – 3.19% between the two designs.
- Thermal losses in the central pipe are higher when the velocity injection is high (**Fig.4**). Thus, its insulation is less efficient for lower velocity values but the DBHE recovers more heat.
- Below the bottom part of the central pipe, the vertical temperature rises but no water circulates.
- For Design 2, at the bottom hole, the horizontal cooling perturbation grows radially from 15 m to 45 m between 1 and 10 years of production (**Fig.5**).

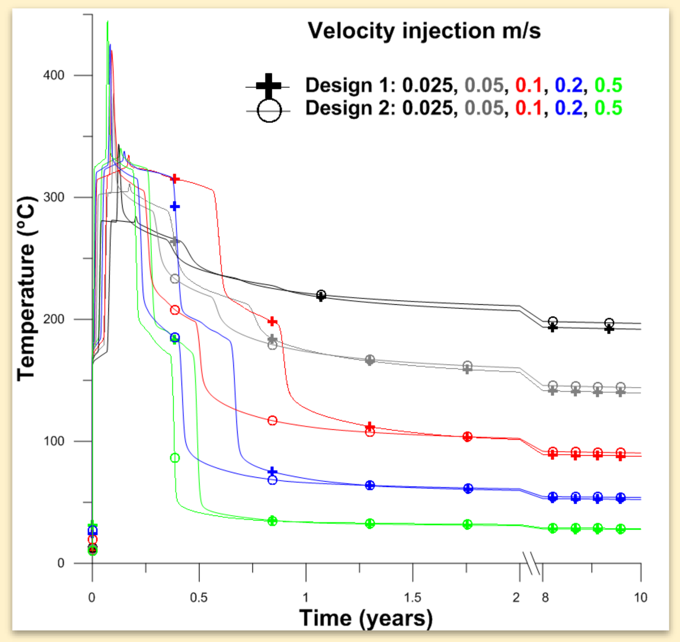

Figure 3: Temperature production at the surface

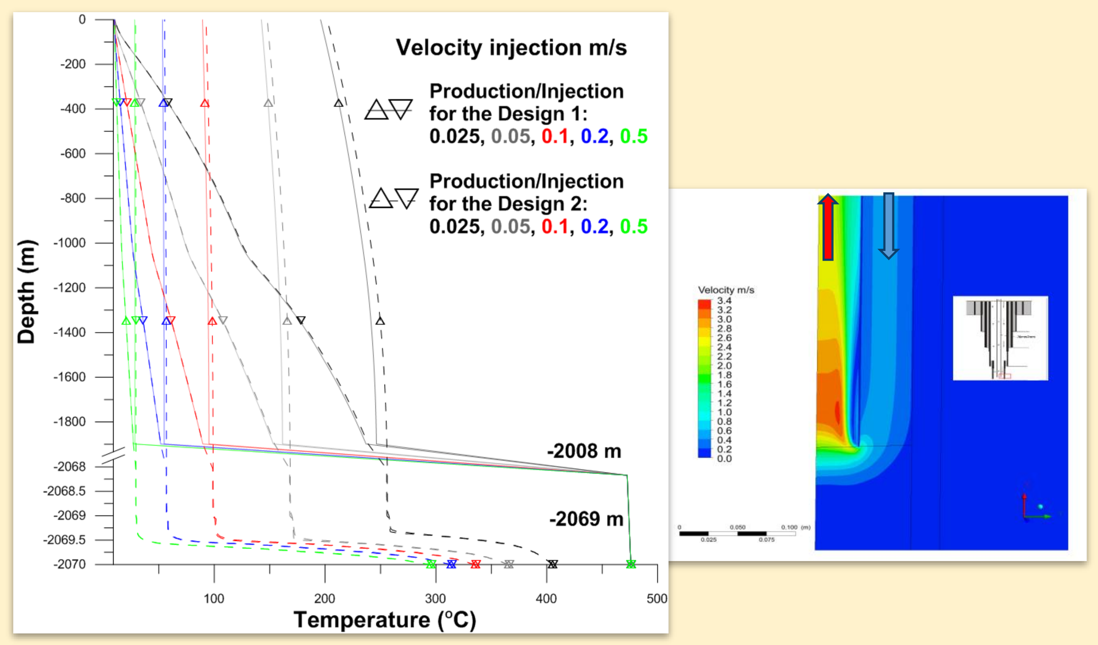

Figure 4: Left - Vertical temperature distribution after 10 years in both injection and production wells for the two designs. **Right** - Velocity distribution in the bottom hole around -2069 m for Design 2.

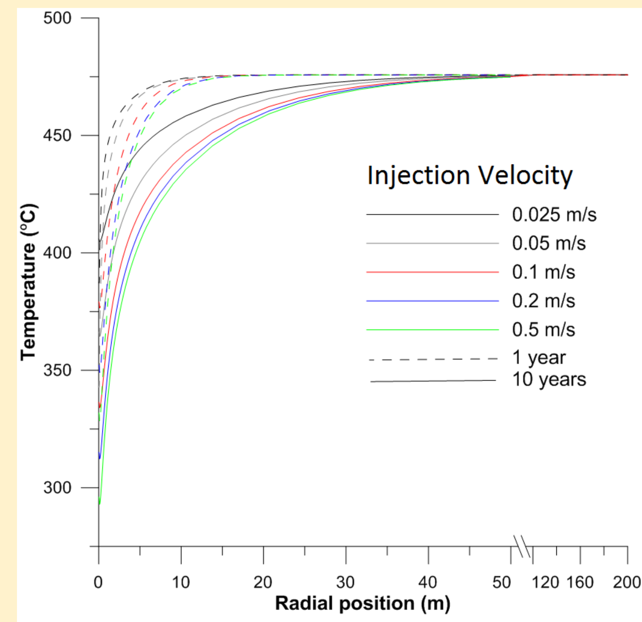

Figure 5: Radial-Temperature distribution at -2070 m for the Design 2 at 1 and 10 years

Conclusion

- The DBHE produces a very high and sudden temperature in the first operating months, but the heat declines rapidly until a pseudo-steady state equilibrium is reached.
- Extending the depth of the internal well improves the long-term output power but provides a horizontal cooling perturbation near the bottom hole up to 40 m after 10 years.
- The lower technical risks of DBHEs can be subject to a complete economic analysis to mitigate the lower output per well (**Fig.6**) compared to the estimated 20-35 MWe for a conventional open-well in the IDDP-1 settings (Pálsson et al.2014).

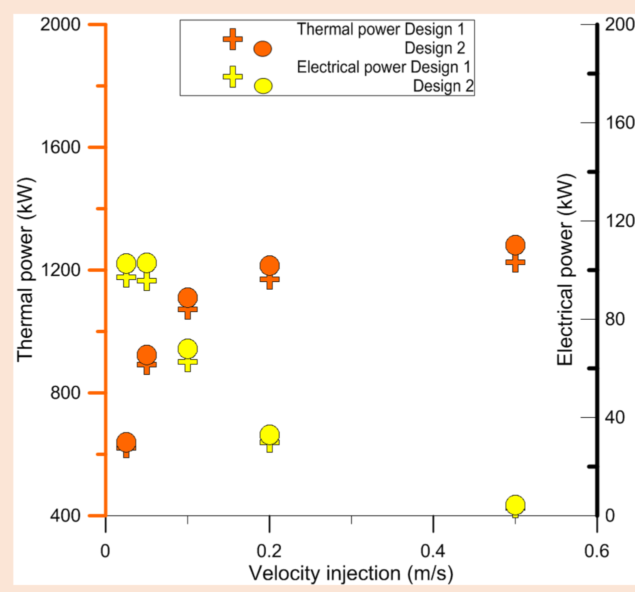

Figure 6: Thermal and Electrical power produced at 10 years using an Organic Rankine Cycle power plant.

References

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