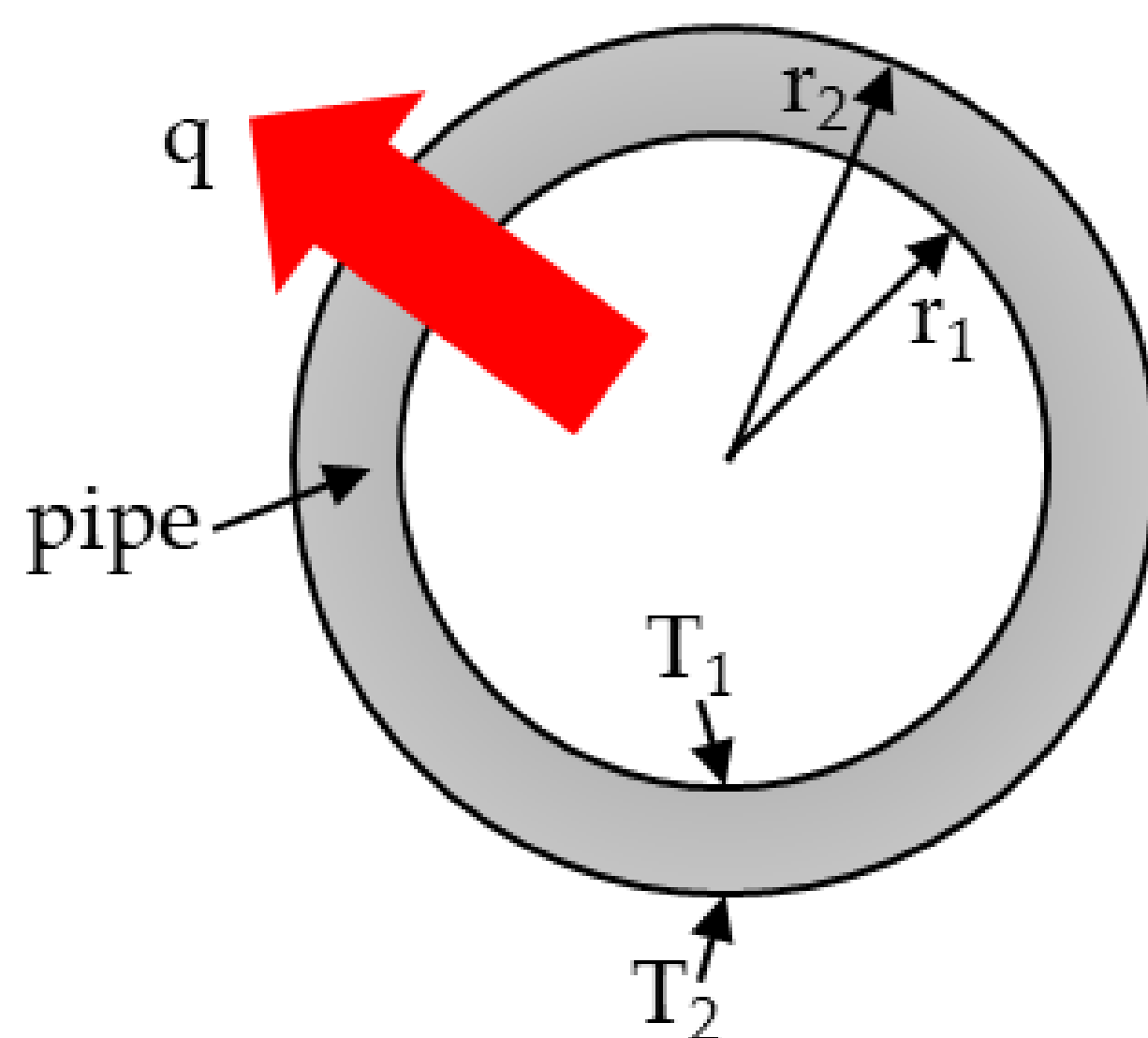


Introduction

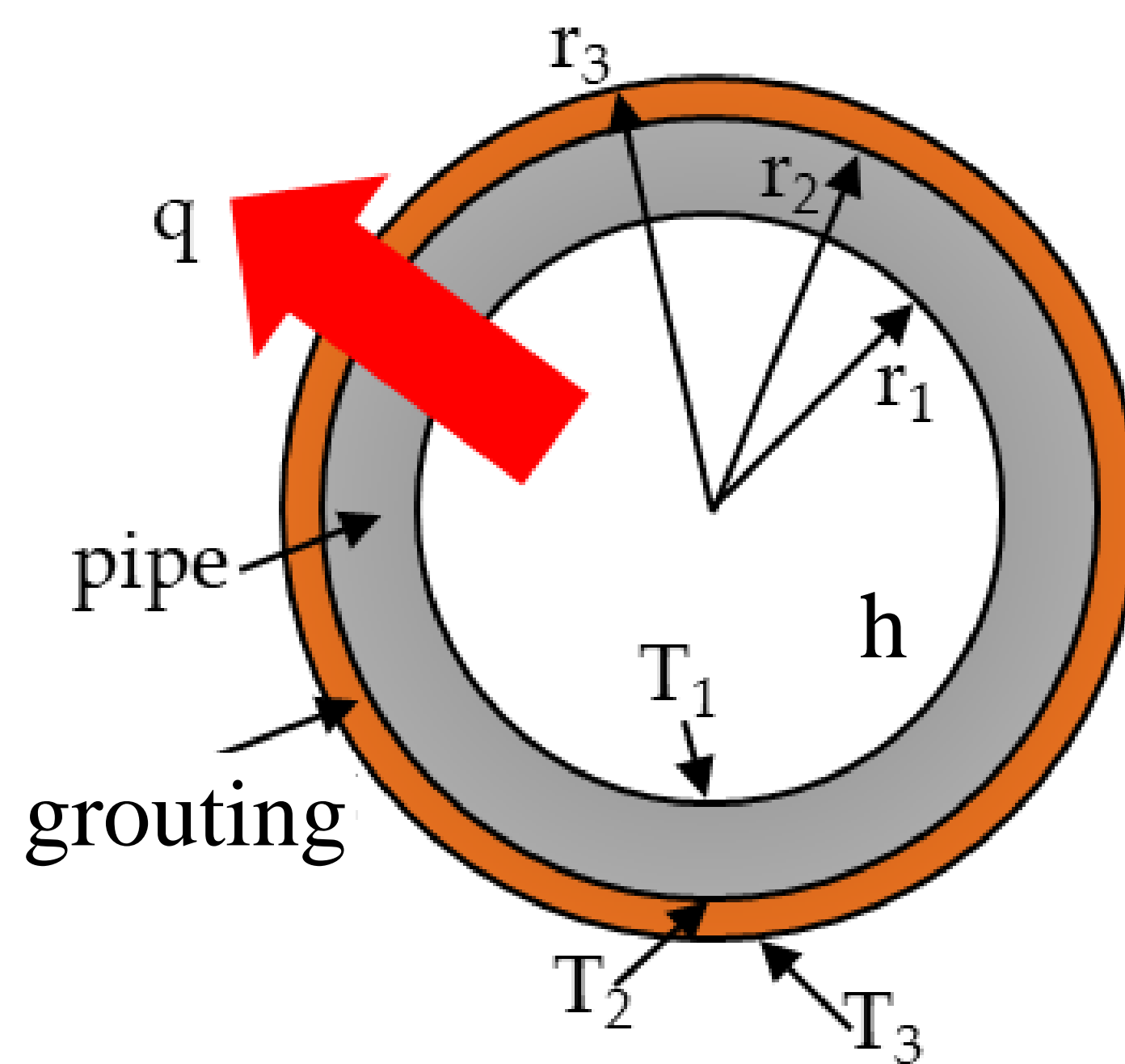
UngROUTED GHE

$$q = -2\pi\lambda \frac{\partial T}{\partial r} \quad R_{pipe} = \frac{\ln(\frac{r_2}{r_1})}{L2\pi\lambda}$$



Multiple layers, i.e. grouted GHE

$$R_{total} = R_{fluid} + R_{pipe} + R_{grout} = \frac{1}{Lh2\pi r_1} + \frac{\ln(\frac{r_2}{r_1})}{L2\pi\lambda_{pipe}} + \frac{\ln(\frac{r_3}{r_2})}{L2\pi\lambda_{grout}}$$



PRELIMINARY FINDINGS IN THE ASSESSMENT OF THE CRITICAL RADIUS OF GROUND HEAT EXCHANGERS: A FACTORIAL DESIGN APPROACH

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Keywords : ground heat exchanger, pipe materials, grout materials, thermophysical properties, design of experiment.

Abstract

In closed-loop shallow geothermal, there are many reasons to prefer a specific pipe size and configuration of the vertical ground heat exchanger, which can be related to very practical issues such as drilling equipment or installation methods. However, a correct design should also consider the heat exchange between the heat-carrier fluid and the surrounding subsoil [1-4]. Determining the radius of grouted and non-grouted exchangers is critical to enhance the thermal performance [5]. In cylindrical coordinates, adding grout or increasing the diameter of the exchanger could change the thickness of the grouting, which influence the borehole-resistance. Furthermore, it may happen that a decrease in thermal resistance due to the change in the thickness of the pipe or of the grouting layers can lead to a lower thermal resistance compared to a higher thermal conductivity of the materials.[6]. Although well-known analytical equations exist that independently define the different phenomena involved from the physical standpoint, their application as a whole is intricate and cannot describe all the interaction between the variables that contribute to the overall thermal performance. In a simplified form, such variables are the operating temperatures, the thermophysical properties, the radii and thickness of pipe and grout, as well as the thermal properties of the subsoil. In this research, a different approach based on statistical modeling is proposed, which takes into account the abovementioned variables organized as a factorial design [7]. Each variable takes on analytically calculated levels to obtain responses. Then, through multiple linear regression it is possible to mathematically describe the problem through coefficients allowing to make predictions for whatever chosen exchanger configuration. Furthermore, it is possible to select or screen out the few important main variables from the many less important ones, and this is essential for improving or designing new types of exchangers.

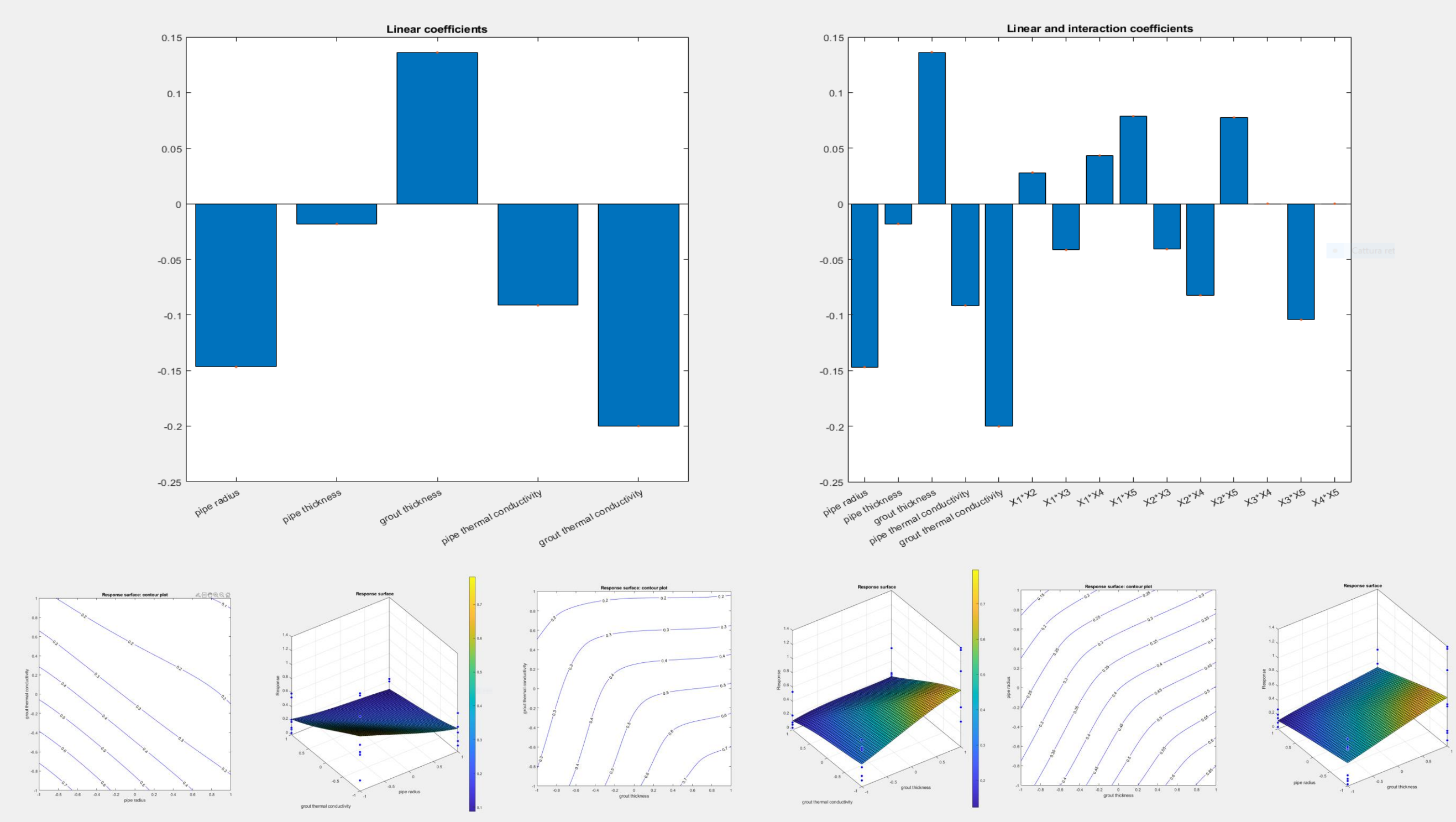
Methods

Goal: reduction of the overall thermal resistance given by the pipe and the surrounding grout.
Response: Thermal resistance [m·K·W⁻¹]
Factors:

Variable	Parameter	Min level (-1)	Max level (+1)
X1	Inner pipe radius [m]	0,02	1
X2	Pipe wall thickness [m]	0,002	0,008
X3	Grout thickness [m]	0,02	0,1
X4	Pipe thermal conductivity [W/mK]	0,5	75
x5	Grout thermal conductivity [W/mK]	0,2	1,5

- Experimental design: 2⁵ factorial design.
- 5 independent variables,
- 2 levels of each variable.
- 32 Experiments.

Results



References

[1] Noorollahi, Y., Saeidi R., Mohammadi M., Amiri A., Hosseinzadeh, M. 2018: The effects of ground heat exchanger parameters changes on geothermal heat pump performance – A review, Applied Thermal Engineering, Volume 129.
[2] Remund, C.P. Borehole thermal resistance: Laboratory and field studies. ASHRAE Trans. 1999, 105, 439.
[3] Lee, C. Thermal performance evaluation of a vertical closed-loop ground heat exchanger according to rock type in Korea. Energy Build. 2019, 183, 184–194.
[4] Acuña, J.; Palm, B. A novel coaxial borehole heat exchanger: Description and first distributed thermal response test measurements. In Proceedings of the World Geothermal Congress, Bali, Indonesia, 25–30 April 2010; p. 7.
[5] Luo, J.; Rohn, J.; Bayer, M.; Priess, A. Thermal efficiency comparison of borehole heat exchangers with different drillhole diameters. Energies 2013, 6, 4187–4206.
[6] Carslaw, H.S. & Jaeger, J.C. 1959: Conduction of Heat in Solids, Oxford University Press, New York, 2nd ed.
[7] Box, G. E.; Hunter, W. G.; Hunter, J. S. 2005: Statistics for Experimenters: Design, Innovation, and Discovery (2nd ed.). Wiley.