ENAC – School of Architecture, Civil and Environmental Engineering
SGC – Civil Engineering Section
LMS – Soil Mechanics Laboratory
lms.epfl.ch

Pre-study and Master Thesis
Fall Semester 2023
–

Modelling, analysis, and optimization of a hydronic system: coaxial borehole heat exchanger

Supervisor: Professor Lyesse Laloui
Assistant : Dr. Elena Ravera

Motivation of the project

Transforming the global energy supply landscape towards a decarbonized, secure, and resilient energy system needs holistic system solutions. Sustainable renewable heating will continue to play a key role in the coming years, based on technologies with limited environmental impact. Geothermal energy systems such as geothermal heat pumps (GSHP) are positioned as reliable systems whose main purpose today is to cover part of the energy demands for heating and cooling in different countries. These systems exchange heat with the surrounding ground by means of a borehole heat exchanger (BHE). Among the different types of BHE, the U-pipe configuration has dominated the geothermal market for many years. More recent designs such as the coaxial pipe configuration show some interesting advantages over the U-pipe design: much lower pressure losses and in some cases also lower borehole thermal resistance. However, these systems are still poorly implemented in practice.
The objective of this study is to model, analyze and optimize the performance of a coaxial borehole heat exchanger. The study is based on thermo-hydraulic numerical simulations that will have to be compared with available analytical models. Sensitivity analyses should be performed to identify the dominant parameters on the performance for different practical scenarios. The purpose is to provide a summary and the range of these parameters (e.g., borehole length, pipe diameter and thickness, flow rate, circulating fluid…) and to critically analyze their effects. The final output should include guidelines that may be used for engineers when dealing in practice with such technology. These guidelines must also consider environmental and economic impacts to design an energy system considering the optimization of the whole system, the related performance, cost, and environmental impact.

Keywords

Coaxial borehole heat exchanger, fluid dynamics, geothermal energy, ground shallow heat pump, heat transfer, parametrical studies, renewable energy

References

Beier, R. A., Acuña, J., Mogensen, P., & Palm, B. (2013). Borehole resistance and vertical temperature profiles in coaxial borehole heat exchangers. Applied energy, 102, 665-675.
Pan, S., Kong, Y., Chen, C., Pang, Z., & Wang, J. (2020). Optimization of the utilization of deep borehole heat exchangers. Geothermal Energy, 8(1), 1-20.
2
Raymond, J., Mercier, S., & Nguyen, L. (2015). Designing coaxial ground heat exchangers with a thermally enhanced outer pipe. Geothermal Energy, 3(1), 1-14.

Giménez Polo, E. (2020). Coaxial Borehole Heat Exchanger: Modeling, Thermal and Hydronic Analysis (Master thesis, Industriales UPM).

Goal of the project

By the end of the project, the student is expected to be able to:

- Model an analyze the thermo-hydraulic behavior of a coaxial borehole heat exchanger
- Perform numerical sensitivity analyses
- Identify the dominant parameters on the performance for different relevant practical scenarios
- Provide guidelines when dealing in practice with such technology
- Critically assess and present the results

Tasks and work to carry out

- Literature review
- Building the numerical model
- Comparison of the numerical analyses with available analytical models
- Identification of the parameters of interest for sensitivity analyses
- Representation of the results in a consistent and effective manner
- Compose a project report in written form
- Presenting a project orally

Deliverables

- Report

The student will have to prepare a technical report containing the introduction and motivation for the project, the description of the accomplished work and related results as well as conclusions. The technical report will have to be prepared in an electronic format and send to the supervisor and the responsible of the project by the end of the semester.

- Final Presentation

The student will have to present his work during a presentation at the end of the semester. The day and the place of the presentation will be communicated to the student.

Planning

- Meetings and presentations

A weekly meeting (on Friday pm) with the assistant is suggested to discuss the progress of the project. One meeting per month will be organised with Prof. Laloui (dates will be communicated to the student). During the meetings with the assistant, the student will have to present (i) the progress of the work, (ii) possible questions and remarks and (iii) a summary of the next steps for the project. During these meetings, the supervisors may vary the foreseen goals of the project, if necessary. The student will have to prepare all the possible questions before the meeting in written form and a summary of each meeting for the next fixed meeting.

- Report

The report will be written in English. Graphs will be built with the Grapher software, Matlab, or with the aid of Microsoft Excel. Particular attention will be given to the writing up of the report. In the document, the student will have to clearly introduce the topic, to highlight the hypotheses made, to present the considered methodology, to discuss the obtained results and to draw the related conclusions.

- **Electronic files**

At the end of the project, the student will have to send to the supervisors a folder containing a clear classification of all the electronic files developed during the project, including those related to the reports, obtained data, presentations, poster and graphs.

Grading

The final grade will be assigned considering the following proportions of contribution:

- Technical report 70%
- Oral presentation 30%

The evaluation will also consider the work methodology, discipline and resourcefulness of the student.

General rules of the project

The schedule of the project is defined by the EPFL Academic Calendar:
https://memento.epfl.ch/academic-calendar/?period=180

The student signature on the submitted report certifies that the work is original and developed by him/herself. This work is property of the EPFL and cannot be disseminated without the approval of the considered Institution.

Contacts

Responsible: Elena Ravera
elena.ravera@epfl.ch
GC D0 424
Tel.: +41 2169 32353

Professor: Lyesse Laloui
lyesse.laloui@epfl.ch
Tel.: [+41 2169] 32314