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A new methodology for numerical simulation of geothermal down-hole heat exchangers

A. Carotenuto, N. Massarotti*, A. Mauro

Dipartimento per le Tecnologie (DiT), Università degli Studi di Napoli "Parthenope", Centro Direzionale, Isola C4, 80143 Napoli, Italy

HIGHLIGHTS

- Thermo-fluidynamic field in a down-hole heat exchanger and geothermal well system is simulated.
- The generalized model for heat and fluid flow through porous media is employed.
- The proposed approach uses single domain approach for down-hole heat exchanger, well and aquifer.
- Numerical results are validated against experimental data available for a geothermal convector.
- The procedure is an excellent tool for geothermal down-hole heat exchangers optimization.

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ABSTRACT

This paper presents a numerical procedure for the simulation of heat and fluid flow in a heat exchange system for exploitation of low enthalpy geothermal reservoirs. The authors employ for the first time the generalised model for the mathematical description of heat and fluid flow through saturated porous media in order to study down-hole heat exchanger, well and aquifer, using a single domain approach. Steady state operation of the system is considered and the results obtained are validated against experimental data collected for a geothermal convector prototype installed in an existing geothermal well on the island of Ischia in southern Italy. The comparison shows that the proposed procedure can be successfully used for the simulation of this type of problems, and represents an excellent tool for down-hole heat exchangers optimization. The results of the present model are employed here to analyse the approximate boundary conditions that were previously developed for the simulation of a simplified aquifer model.

1. Introduction

The growth of the world's energy demand needs to be increasingly satisfied through energy sources alternative to fossil fuels. Among these, geothermal energy is being increasingly used. Besides district heating, that has been employed for many years, geothermal heat pumps have represented the most significant new installation in the last decade in residential and commercial buildings throughout the world, and new uses have been considered for electric energy production. Low enthalpy geothermal energy can be successfully employed for building heating and cooling, with positive socio-economic and environmental impacts [1–5]. Ground-coupled heat pump systems have recently been extensively used and pile foundations as ground heat exchangers are currently under investigation in order to reduce installation costs [6,7]. Furthermore, electric energy production from geothermal sources is becoming attractive thanks to the use of Organic Rankine Cycle (ORC) technology combined with medium enthalpy geothermal reservoirs [8,9]. Comprehensive reviews of the research and developments of ground-coupled heat pumps and ground heat exchangers technology for applications in air-conditioning have been recently presented in scientific literature [10,11].

The use of geothermal heat pumps and binary cycles for electric energy production may substantially increase the economic potential of geothermal energy, extending its use to countries that have not exploited this source so far, due to the lack of high enthalpy geothermal reservoirs. In countries where geothermal energy is already used extensively, down-hole heat exchangers can solve the problem of re-introducing the geothermal fluid into the reservoir, as requested by environmental and legislative restrictions. However, the amount of heat withdrawn from the aquifer with down-hole heat exchangers may be limited due to the interaction between the heat exchanger, the well and the aquifer. In fact,

* Corresponding author. Tel.: +39 081 5476735; fax: +39 081 5476780.
E-mail address: massarotti@uniparthenope.it (N. Massarotti).

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