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Heat exchanger optimization for geothermal district heating systems: A fuel saving approach

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Abstract

One of the most commonly used heating devices in geothermal systems is the heat exchanger. The output conditions of heat exchangers are based on several parameters. The heat transfer area is one of the most important parameters for heat exchangers in terms of economics. Although there are a lot of methods to optimize heat exchangers, the method described here is a fairly easy approach. In this paper, a counter flow heat exchanger of geothermal district heating system is considered and optimum design values, which provide maximum annual net profit, for the considered heating system are found according to fuel savings. Performance of the heat exchanger is also calculated. In the analysis, since some values are affected by local conditions, Turkey's conditions are considered.

Keywords: Heat exchanger; Geothermal; Optimization; Heat transfer area; District heating

1. Introduction

A geothermal resource that produces geofluid at 150 °C or less is called a "low temperature geothermal resource" [1]. Most of the existing geothermal resources in the world are low temperature geothermal resources. These resources are used for space and district heating, greenhouse heating, fish farming, process heating and balneological purposes. Since geothermal waters have considerable dissolved solids, indirect systems are used for heating processes. That is, the heat of the geothermal brine is transferred to fresh circulating water by means of a heat exchanger. The most commonly used heat exchanger

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Nomenclature

ε	effectiveness of the heat exchanger
$\dot{Q}$	heat transfer rate from geothermal brine to circulating water [W]
$\dot{Q}_{max}$	maximum heat transfer rate in the heat exchanger [W]
C_p	specific heat [J/kg ^{0}C]
C_h	thermal capacity of geothermal brine [W/^{0}C]
Cc	thermal capacity of circulating water [W/^{0}C]
$\dot{m}_s$	mass flow rate of circulating water [kg/s]
$\dot{m}_{geo}$	mass flow rate of geothermal brine [kg/s]
$LMTD$	log-mean temperature difference [^{0}C]
T_{hi}	input temperature of geofluid into heat exchanger [^{0}C]
T_{ho}	output temperature of geofluid from heat exchanger [^{0}C]
T_{ci}	input temperature of circulating water into heat exchanger [^{0}C]
T_{co}	output temperature of circulating water from heat exchanger [^{0}C]
U	overall heat transfer coefficient of heat exchanger [W/m^2 K]
A	heat transfer area of heat exchanger [m^2]
C_a	annual investment cost [$/year]
I_c	investment cost of unit plate heat exchanger area [$/m2]
CRF	cost recovery factor
i	interest rate
n	heat exchanger life-time [year]
H_u	lower heating value of fuel [kJ/kg]
η_k	boiler efficiency [%]
H	operational hours of the plant [h/year]
b_e	specific fuel consumption [kg/kWh]
B_e	specific fuel consumption [kg/kW year]
B	total fuel consumption [kg/year]
YPT	annual money savings [$/year]
F	fuel cost [$/kg]
NK	annual net profit [$/year]

type for this purpose is the counter flow plate heat exchanger (Fig. 1). There are two main reasons to use a counter flow plate heat exchanger in a geothermal heating system. Firstly, clean and less corrosive heating fluid circulates in the heating cycle and, secondly they have high heat transfer performance [2]. The heat transfer performance of a heat exchanger is very important for geothermal systems because geothermal reservoirs are not fully ‘‘renewable’’. If geothermal reservoirs are fed by hot groundwater, they may be renewable. For this purpose, the utilized geothermal fluid must be reinjected to the reservoir. However, some important points should be considered in the reinjection application, for example the distance between the reinjection and the production wells (usually >1 km). Otherwise the reinjected ‘‘cold’’ water ($T_{ho}<T_{hi}$) may reach the production well soon after the start of operation. From that moment on the geothermal fluid production temperature will decrease; the lower T_{ho}, the stronger is the effect. This means geothermal reservoirs should be used as effectively as possible.