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Experimental investigation of heat transport through single synthetic fractures

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Abstract

A laboratory physical model has been set up to analyze heat transport dynamics through single synthetic fractures. The Synfrac program together with a 3d printer have been used to build several fracture planes having different geometrical characteristics that have been moulded to generate concrete porous fractured blocks. The tests regard the observation of the thermal breakthrough curves obtained through a continuous flow injection in correspondence of eight thermocouples located uniformly on one of the fractured blocks.
The physical model developed permits to reproduce and understand adequately some features of heat transport dynamics in fractured media

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Keywords: heat transport; fractured media; physical model

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1. Introduction

In fractured geothermal reservoirs, heat transport is highly influenced by the presence of the fractures, so appropriate knowledge of heat transport behavior in fractured aquifers is essential for accurate prediction of the heat dissipation and recovery from geothermal reservoirs.

Nomenclature

b	half aperture of the fracture (L)
B	half fracture spacing (L)
c_w	specific heat capacity of the water ($L^2T^2K^{-1}$)
c_m	specific heat capacity of the matrix ($L^2T^2K^{-1}$)
δ	Thickness boundary layer (L)
D_f	Thermal dispersion coefficient (L^2T^{-1})
k_e	Effective thermal conductivity of the matrix ($MLT^{-2}K^{-1}$)
L	Length of fractures (L)
ρ_w	Density of the water (ML^{-3})
ρ_m	Density of the matrix (ML^{-3})
Re	Reynolds number
t	time (T)
T_f	Temperature of fracture (K)
T_m	Temperature of matrix (K)
TRA_{eq}	Equivalent transmissivity (L^2T^{-1})
u_f	Thermal convective velocity (LT^{-1})
x	Coordinate parallel to the axis of fractures (L)
z	Coordinate perpendicular to the axis of fractures (L)

The study of heat transfer in fractured media is challenging. The presence of highly localized flow pattern and heat diffusion in the matrix has a significant effect on heat recovery or dissipation in both space and time. These processes influence the late time tailing of heat dissipation and recovery deviating from the classical conceptual model such as the equivalent porous media or the parallel plate model.

Many numerical and experimental investigations have been carried out to study heat transfer dynamics in fractured media.

[1] studied the effect of flow channeling on heat transfer in fractured rocks and they showed how the heat recovery in geothermal tests may be controlled by the fracture geometry.

[2] found a dynamic heat transfer coefficient between rock walls and the flowing fluid dependent on the fracture aperture.

[3] showed an experimental study of heat transport in fractured media. They concluded that at the laboratory scale the heat transport in fracture network has a dual porosity behaviour and the thermal dispersion played an important role on heat transfer dynamics.

On the basis of the laboratory experiment on heat transport in fractured media, [4] affirmed that it is not efficient to store thermal energy in rocks with high fracture density because the fracture are surrounded by a matrix with a more limited capability to store heat.

The present study is aimed at setting up a physical model to study heat transport dynamics in fractured media with parallel fractures varying the roughness, the aperture distribution and the fracture spacing. For this purpose the heat transport in a thermally isolated fractured block having a synthetic single fracture with known geometry has been investigated.

The observed behaviour has been compared with the one dimensional analytical solution for semi-infinite equally spaced parallel fractures embedded in a porous matrix [5]. The analytical model represented adequately the observed data and heat transport parameters. The effect of flow channeling and the fracture – matrix interaction is evident giving rise to an asymmetric distribution of the probability of residence time with a pronounced long tailing effect.