Understanding bilinear flow in fractured reservoirs by numerical hydraulic modelling

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Abstract

Understanding the different flow regimes in fractured reservoirs has always been key in the interpretation and evaluation of hydraulic well tests as well as in the production optimization of reservoirs. In particular, hydraulic stimulation of pre-existing vertical fractures has been the subject of numerous analytical and numerical investigations. Numerical modelling provides a quantitative understanding of hydraulic wellbore stimulations and makes it possible the derivation of important aquifer properties such as fracture conductivity, formation permeability and storage capacity of the fracture and the matrix, respectively. Specially, the distribution of these hydraulic parameters has a major impact on the heat transfer in geothermal reservoirs. An in-depth description of the behavior of multiple flow regimes in fractures is extremely important in order to master the physics behind the modelling and simulation, and hence to reliably interpret the results. This investigation concentrates on the specific flow regime known as bilinear flow, which considers a longitudinal flow in the fracture and a perpendicular flow from the fracture to the formation. There has been considerable research on the bilinear flow behavior of vertical fractures, mainly under two different conditions (I) fluid injection/production at constant pressure in the well and (II) fluid injection/production at constant flow rate in the well. In this work, the advance speed of the isobars along the fracture and the formation is computed and examined during the bilinear flow regime in the case of injecting fluid in the well at constant pressure.

Numerical hydraulic modelling and simulation has been conducted in this work with the software COMSOL MULTIPHYSICS. Darcy's flow has been considered to describe the fluid flow in porous and fractured geologic media. The model setup consists of a 2D vertical fracture, embedded in a matrix, where water is pumped into the reservoir. The hydraulic boundary conditions, which have been placed far enough from the stimulated vertical fracture to avoid influence, have been set according to analytical models (no flow and constant pressure boundary conditions) to be able to reliably compare numerical with analytical results. Hence, the entire model setup fulfills all the geophysical requirements needed for the simulation of the theoretical behavior of bilinear flow in vertical fractures. Several simulation tests have been performed by modelling fluid injection in the fracture while keeping a constant pressure in the well. Subsequently, numerical computations have been conducted to obtain the advance speed of the isobars along the fracture and the formation. Previously, it has been extensively studied the advance speed of the isobars along the fracture and the formation during the bilinear flow regime when the flow rate in the well is set constant. This work focusses on similar investigations, however, instead of considering a constant flow rate in the well, a constant pressure in the well is considered. An advance speed of the isobars along the fracture and the formation proportional to the fourth root of time and to the second root of time is expected to be obtained, respectively.

This work addresses the challenging task of gaining a quantitative understanding of bilinear flow in fractured reservoirs under constant pressure conditions in the well, requiring a multidisciplinary approach. Expanding the understanding of bilinear flow regime in fractured reservoirs leads to a more precise analysis and conclusions during well test stimulations. This, in turn, makes it possible to characterize an aquifer more accurately and consequently have more precise assessments of geothermal reservoir behavior and production optimization during operation.