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Development of a new simple hydrostatic equilibrium model for sustainable evaluation in geothermal energy

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Abstract

Geothermal energy is a renewable energy, that is, the energy removed from the geothermal reservoir is continuously replaced on time scales similar to those required for energy removal. Replacement energy to the geothermal reservoir is supplied by fluid of natural recharge and injection. Sustainable geothermal utilization is the ideal condition of the applied production system to sustain the stable production level over long times. It is very important to manage the mass balance between production, injection and natural recharge in the geothermal reservoir to maintain sustainability during exploitation. A new simple hydrostatic equilibrium model is developed by this mass balance model of geothermal reservoir.

This paper builds up a new simple hydrostatic equilibrium model to consider hydrostatic connection between recharged reservoir and discharged reservoir. Principle of fluid-pressure transmission states that pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions. Hydrostatic equilibrium occurs when compression due to gravity is balanced by a pressure gradient force in the opposite direction. Mass changes data in this hydrostatic equilibrium model is estimated by gravity changes from repeat gravity measurement method. The equation result between production, injection and mass change rate calculates recharge factor from discharged reservoir. This model also assessed a relatively constant of entered mass flow rate from the surface that continues working during the production and injection well activity. This new simple hydrostatic equilibrium model is applied in Kamojang Geothermal Field, the geothermal reservoir with limited natural recharge.

Keywords: Hydrostatic equilibrium model; Recharge factor; geothermal energy ;

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1. Introduction

1.1. Background

Geothermal energy is renewable energy but it should be good maintained to reach sustainability. Renewable describes an attribute of the energy resource, i.e. the energy removed from a resource is continuously replaced by more energy on time scales similar to those required for energy removal and those typical of technological/societal systems (30-300 years), rather than geological times [1][2]. Sustainability is the doctrine that economic growth and development must take place and be maintained for long time [3]. Sustainable geothermal utilization should refer to how geothermal energy is utilized and Axelsson et al. [4] discussed this for 100-300 years utilization.

One of some important factors in order to achieve the sustainable geothermal utilization is maintaining the stable production and recharge rate to the reservoir. Balancing between production and total recharge rate is significant to avoid depletion. Production rates that persistently exceed the rate of total recharge will eventually lead to reservoir depletion, thus will stopping economic production. Sustainable geothermal utilization will occur if production rate is same or less than total recharge rate. Axelsson explained that the main modes of sustainable geothermal utilization are following some criteria [5].In this paper, sustainable geothermal utilization will be evaluated by new simple hydrostatic equilibrium model. The objective of model development in this paper is to simplify a fluid movement in the subsurface.

Axelsson et al. [6] discussed some examples of equilibrium model in some geothermal fields between production rate and recharge rate. Increased production rate was followed by decrease of water level. According to similar idea, we also build two reservoirs in the subsurface that are production and recharge reservoir for this model. Mass balance between production and recharge reservoir is tied by hydrostatic equilibrium law. Initial condition in the hydrostatic equilibrium model between these two reservoirs is has same pressure. Regarding to high mass extraction from some production wells, the pressure of production reservoir will decline. The pressure difference between these two reservoirs can cause a fluid movement from recharge reservoir to production reservoir. The final condition when increased fluid mass recharge balances the discharge mass acquires a new hydrostatic equilibrium.

1.2. Conceptual model

There are two kinds of geothermal systems, liquid and vapour dominated system. Liquid dominated system has higher pressure than vapour. The reservoir pressure is also influenced by temperature and depth of system. According to high pressure of geothermal system, fluid discharge from geothermal reservoir naturally about 0.05 (liquid dominated system) to 0.5 (vapour dominated system) million tons per year [7]. On the other hand, the gravity weight of surface water can enter to reservoir.

The simple conceptual model of hydrostatic equilibrium in this paper is developed with two reservoirs. Reservoir 1 is a production reservoir of geothermal system and reservoir 2 is a fluid source reservoir for the recharge. Between reservoir 1 that has pressure 1 (P_1) and reservoir 2 that has pressure 2 (P_2) is tied by a hydrostatic equilibrium model. The simple conceptual of hydrostatic equilibrium model for this paper can be seen in Figure 1. This equilibrium model overlooked some factors for quite simplification.

The Figure 1 shows a hydrostatic equilibrium between reservoir 1 and reservoir 2. The fluids flow from reservoir 2 to reservoir 1 or opposite direction depend on pressure difference between them. For the example, if $P_2 > P_1$, then fluid rate will flow from reservoir 2 to reservoir 1, and also the opposite way if $P_1 > P_2$. (*P*), initial word of production rate, is an amount of exerted mass from production well per year. (*I*), an initial word of injection rate, is an amount of entered mass from injection well per year. (*S*), an initial word of surface rate, is an amount of fluid flow per year naturally from the surface to reservoir and