Thermographic experiments and modeling of thermal dispersion effects on temperature distributions in saturated porous media

Muhammad Imran[1], Ruud J. Schotting[1] and Kleingeld P. J[1]

[1]*Environmental Hydrogeology group Utrecht University, 3508TA, Utrecht, Netherlands*

ABSTRACT: Geothermal energy is a clean, environment friendly (non-polluting) and renewable natural source of energy that emerges from the original formation of the planet and is continuously produced inside the earth as a result of the decay of radioactive material. Heat transfer in a geothermal reservoir is a fascinating research area and is becoming increasingly important owing to the use of groundwater for thermal applications, oil crisis, depletion of fossil fuel resources, high inflation rates and increased focus on the environment. The earth is a hotbed of geothermal energy**.** Temperature below the earth's surface increases generally at a rate of 30C^0 per 1000m depth. Hydrothermal energy from geothermal reservoirs is utilized by pumping the hot water from deeper formations to the surface by production wells. Once the heat is extracted, the cooled water is injected back to the geological formations by injection wells concurrently for the maintenance of hydraulic regime, to avoid subsidence and long term utilization of geothermal potential of the reservoir. Experiments have shown that all the hydrodynamic effects are not accurately accounted by mere inclusion of convective term in the energy equation. The effects of pore level velocity non-uniformity on the temperature distributions are taken into account by unsteady and irreversible thermal dispersion coefficients.

The present work is devoted to study the impact of both longitudinal and transverse thermal dispersion coefficients on heat transfer characteristics in mixed convective flow in homogeneous porous media (sand and glass beads). 2D lab experiments are performed by using a non-intrusive method (IR thermography) with varioscan 3022 IR camera. IR thermography is based on the detection of thermal radiations with a specific intensity emitting from a surface to be measured. Emission of IR radiations is proportion to the temperature of the object. It (radiation) carries information for the temperature distributions of the object under observation. Quantitative analysis of thermal images (thermographs) obtained in real time during experiments is performed by an IR image processing software (IRBIS plus 2.2 thermographic system).

Experimental results are compared with numerical simulations to investigate the effects of thermal dispersion coefficients on temperature distributions by coupling energy conservation equation with fluid flow (Darcy law) in saturated porous media using Finite Element Method (FEM). One temperature model (OTM) equation describing the local thermal equilibrium between the solid and fluid phases has been used with volume averaging giving the macroscopic temperature and velocity fields. An important step is to specify the distance between the production and injection wells to avoid the entry of cold water into the production well. Convective heat transfer in a homogeneous porous media provides a theoretical basis for fundamental understanding of heat transfer mechanisms, aquifer thermal energy storage (ATES). We found that thermal dispersion enhanced temperature value at a point and it helped in the provision of water at a desired temperature from given geothermal systems. Transverse thermal dispersion coefficient has pronounced effects on temperature distributions as compared to longitudinal dispersion coefficients in saturated porous media flow. It plays a significant role in determining the life span of a geothermal reservoir and in providing a hot water to the production wells.