Quantitative simulation of silica scale deposition from physical kinematics perspectives

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Silica scaling restricts the heat extraction and deteriorates the power generation efficiency in geothermal systems. Although drug injection and pH adjustment are practiced in various fields as a countermeasure against this problem, they are still in a stage where trial and error are repeated. The main obstacle of this problem is that the mechanism of silica scaling has not been revealed yet.

In order to predict silica scale precipitation and establish an effective countermeasure means, it is indispensable to construct a numerical calculation model. However, scale deposition phenomenon consists of some processes in which a wide variety of physical and chemical elements are intertwined complicatedly, so that the way to find a method leading to elucidation of its mechanism is extremely steep. There have been a large number of studies on silica scale deposition rate, but order of magnitude difference is pointed out between experimental data and predicted value gained from simple chemical kinetics. Several other contradictions are reported when we analyze the scale deposition process from a chemical point of view, so detailed analysis incorporating new elements is required.

As a part of a novel initiative, Mizushima *et al.* (2016) proposed a scale precipitation prediction method that took physical factors into account, and reproduced the increase of local scale deposition depending on fluid flow velocity.

In our research, we propose a complementary method which enables more accurate prediction of silica scale deposition by introducing several physical actions which were not completely considered in the simulation method constructed by Mizushima *et al.* (2016). We regard the silica involved in scale deposition as spherical colloidal particles and evaluate the mechanical balance in the process where the silica particles flowing in the medium fluid adhere to the wall surface and the condition in which the particles once attached to the wall surface peel off again. We perform direct numerical simulations by making discretized motion equation for individual particles in fluid and the equation considering the rotational moment balance for the particles on the wall surface. With this direct numerical analysis, it is possible to track the particle behavior stably without any restriction due to the grid intervals.

We applied all possible physical kinematic effects to a fine particle including drag force by fluid, gravity, buoyancy force, Van der Waals attractive force, electrostatic repulsive force, and Brownian motion, which is dominant in the diffusive behavior of particles. We set a 2D parallel plate channel with and without the slip flow condition. In the process of particle adhesion to the wall, we calculate particle motion by setting particle arrangement. Particles are moved in the fluid by diffusive effect mainly based on Brownian motion till they reach the wall vicinity where adhesive force is dominant. In the process of particle detachment from the wall, we evaluate the moment balance with random elements and count the number of particles peeling off the wall. The final scale deposition rate per unit surface area was given by using 100,000 realizations.

Our simulation results of silica deposition rate show good agreement with the experimental data (Hosoi and Imai,1982). Furthermore, our analysis of the shear flow effect on the detachment of deposited particles makes it possible to explain the trend of field observation (Mercado *et al.*, 1989). It is a remarkable achievement in this research that we elucidate once again the necessity to incorporate the physical process into the prediction of scale deposition. Since our quantitative simulation has wide expandability, the proposed method can be a novel tool to evaluate the influence of particle deposition in not only geothermal systems but also oil and gas fields.

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