Reproduction of complicated scale form in pipe systems from hydrodynamic perspectives

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Scale precipitation seriously damages all equipment in oil, gas and geothermal power plants. There have been lots of predictive analyses on scale growth from chemical perspectives based on reaction kinetics. However, the formation process of scale is very complex and there are some phenomena which cannot be explained by simple chemical considerations. One of them is the local scale deposition at the joint of piping structure, and its visualization was attempted by the lattice Boltzmann method (LBM) for a microscopic analysis on silica particle motion in a flow of geothermal fluid based on fluid dynamics. The Brownian motion and re-entrainment of fine particles have, however, not been taken into account in the dynamics and there remained the instability in the calculation at the early stage of scale growth in the overall macroscopic analysis. Although the previous work was a novel approach, it is clear that the completeness in the dynamics to silica particles has to be considered in the physical analysis of scaling phenomena. We therefore have introduced more elaborative calculation over the spatial scale from micrometers to millimeters with the Brownian random motion to dynamically describe the behavior of silica particles under the distribution in the sizes in fluid for both the adhesion to and the exfoliation from the wall surface.
In this study, we first demonstrate the result of the new elaborative calculation to show how the Brownian motion influences the kinematic behavior of silica particles that lead us to a new expression of the scale deposition rate as a function of flow velocity. Next, as in the previous study, we attempted to visualize a time sequence of the scale shape in a pipe with the macroscopic analysis using LBM coupled with the microscopic calculation. At this time, in order to increase the stability of the crystal growth, we introduced a calculation that automatically complements the cavity grids due to random scale generation. Furthermore, the holding effect on silica particles by the normal flow to the wall was also taken into consideration.
As a result of these modifications, we succeeded not only to describe the process of pipe clogging due to scale deposition stably, but also to reproduce the complicated scale development protruding into the flow due to the influence from flow properties in the field. Our simulation proved that an approach based on physics works effective for the analysis of scale deposition and could be extended as a hybrid model that accommodate chemical parameters such as pH and temperature for further improvement.

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