Numerical Description of Flow Channel in Pipe Conduits Considering Solid-fluid Phase Shift with Lattice Boltzmann Method

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It is an essential task to secure the stable flow in metallic pipes for efficient energy production of fluid resources such as oil, gas and geothermal brine. One of the main obstacles to the efficient extraction of fluid is silica scaling which causes pipe clogging due to the precipitation of inorganic salts dissolved in geothermal fluid. Mineral deposition is observed not only in geothermal power plants but also in heat transfer systems of nuclear power plants. Moreover, the precipitation of asphaltenes and the hydrate formation in petroleum or gas pipelines, which are problems similar to silica scaling, deteriorate fluid motion through . As countermeasures against the scaling, pH adjustment for suppressing high molecular polymerization of dissolved silicates has been conducted, but it’ s still in a stage of trial and error. Although lots of experimental researches on scaling prediction have been done based on kinematical analysis on the chemical reaction in the process of silica deposition, the case where the polymerization rate of silicates is independent of temperature has also been confirmed and the limit of chemical approach has been pointed out.

Besides silica scaling, pipe thinning can be cited as a serious issue threatening the stable operation of energy production. This relates a phenomenon in which the piping loses its original function of fluid transport due to the alternation, wear or rupture as a result of interaction between metallic pipe and surrounding environment. Most of the past experimental works on pipe corrosion have focused on pH as a dominant factor of chemical reaction in the wall vicinity. However, it has been said to be difficult to accurately reproduce the actual reduction of pipe thickness in the case of complicated conduits such as elbow piping or downstream of orifice plates since hydrodynamic influence induced by the complicated flow field becomes dominant over the chemical melting effect.

In this research, we combine microscopic and macroscopic analyses which reflect the physical influence over a wide area on silica scaling and pipe thinning. As the simulation method of flow calculation and reactive boundaries between solid and fluid, we use the lattice Boltzmann method (LBM), which has advantages in parallel computation and arbitrary boundary settings. In the process of sequential calculation in the solid-fluid boundaries with LBM, an analogical algorithm of random selection and volume fractions for crystal growth is utilized. Both results of scale visualization and corrosion simulation showed good agreement with real data with high numerical stability. Our research suggested that applications of LBM is effective with regards to various flow analyses in pipe conduits with complex phase shift.

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