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Pore-scale modelling of non-isothermal reactive transport based on the micro-continuum approach: application to coke combustion in a matrix-fracture system

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Non-isothermal reactive transport in complicated porous media is diverse in nature and industrial applications. This study focuses on coke combustion during in situ crude oil combustion techniques, which is an advanced recovery technique to exploit heavy oil in the fractured reservoir. There are challenges in modelling the multiple thermal and physicochemical processes in the multiscale matrix-fracture system, which contains nanometer-range coke pores, micrometer-range matrix pores, and a sub-millimeter-range natural fracture. In the present study, a pore-resolved micro-continuum approach was used to couple the weakly compressible gas flow, species transport, conjugate heat transfer, heterogeneous coke oxidation kinetics and structural evolution. Image-based simulations were implemented on synthetic geological models, mimicking coke deposition habits based on tomography images. The sub-resolution nanoporous coke region was treated as a continuum, for which the random pore model, permeability model and species diffusivity model were integrated as sub-grid models to account for the unresolved reactive surface area, Darcy flow, and Knudsen diffusion, respectively. Combustion regime diagrams for coke combustion in the unfractured fractured media were mapped with axes of the ignition temperature and the air flux. They were compared to address the influence of the natural fracture on the oxygen transport and burning temperature. The oxygen diffusion mechanism was found to dominate the oxygen transport from the fracture into the matrix and lead to desirable smoudering combustion temperature regardless of the air injection rate. Effects of fracture geometries were quantified to demonstrate tortuous and discrete fractures, and well-matched air injection rates with fracture apertures can effectively suppress the air channeling risk. Possible discrepancies between lab measurements and field operations were demonstrated due to the inconsistent air flux so that the misinterpretation of experimental results for field applications can be avoided. The present pathway from tomography image to synthetic image and to numerical simulation extends the "image and compute"technique to solve multiscale and non-isothermal reactive transport.

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References

Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

Online

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