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Energy exploitation analysis of natural gas hydrate depressurization dissociation in porous media

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As a kind of clean and potential energy resource, large quantities of gas hydrates have been proved to exist widely in the permafrost and in deep marine environments with high pressure and low temperature conditions favorable for their formation. Recently, how to develop and exploit the natural gas hydrate reservoir efficiently is one of the critical issues in the energy resource R&D in 21st century. However, gas hydrate dissociation is an endothermic process and the researches on the heat analysis of dissociation process is not enough and the results are often various.
Base on the research findings about the mechanism of gas hydrate dissociation, this study develops the mathematical model including mass conservation, energy conservation, chemical reaction kinetics and geomechanic equation and conducts the numerical simulation of gas hydrate dissociation in porous media. Three cases have been simulated in a cylindrical reactor adopting a vertical well in the center with the production well bottom pressure Pin=3.1, 2.5, 2.1 Mpa, respectively. All these cases are well matched with the experiment on the gas recovery factor of methane hydrate in porous of the Konno et al(2014) using the unique apparatus referred to as High-pressure Giant Unit for Methane-hydrate Analyses (HiGUMMA). Both of those Cases (1 to 3) are not dissociated completely in 200 mins because of the higher initial gas hydrate in the porous media. The experiment and the numerical simulation indicate obviously the existence of a "freezing stage" in case of Pin=2.1(Case 3). Four phases of gas, liquid, ice, and hydrate are observed to coexist in the reactor in this freezing stage. Compared with other two cases, the hydrate dissociation in Case 3 is promoted by three kinds of heat: the reservoir sensible heat Qr-sen, the conducted heat from the boundaries Qsur , and the latent heat from ice transition Qi-lat. Meanwhile, the discussions of various heat consumption in Case 3 are represented in detail. It could be conclude that Qr-sen and Qi-lat act as an essential role in inducing the rapid gas production rate in two peaks, which also means the faster dissociation rate of natural gas hydrate in porous media. Furthermore, the entropy of dissociation process is calculated specially according to the second law of thermodynamics. Based on above analysis, the rate of pressure reduction is optimized and the energy efficiency is enhanced. Although the formed ice may cause flow blockage for the gas and water, the released latent heat is still remarkably attractive for the fast hydrate dissociation. In this work, the basic reservoir unit of conceptual model is established and developed, which provides theoretical guidance for the exploitation of the actual hydrate reservoir in the future. Hereafter, the various reservoir conditions would be conducted to explore the transformation patterns of the energy exploitation and entropy.

References

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