Geophysical Research Abstracts
Vol. 15, EGU2013-10770, 2013
EGU General Assembly 2013

Evolution of a gas bubble in porous matrix filled by methane hydrate

Kirill Tsiberkin (1), Dmitry Lyubimov (1), Tatyana Lyubimova (2), and Oleg Zikanov (3)

(1) Theoretical Physics Department, Perm State University, Perm, Russian Federation, (2) Institute of Continuous Media Mechanics, Perm, Russian Federation, (3) Department of Mechanical Engineering, University of Michigan-Dearborn, Dearborn, Michigan, USA

Behavior of a small isolated hydrate-free inclusion (a bubble) within hydrate-bearing porous matrix is studied analytically and numerically.

An infinite porous matrix of uniform properties with pores filled by methane hydrates and either water (excessive water situation) or methane gas (excessive gas situation) is considered. A small spherical hydrate-free bubble of radius R_0 exists at initial moment within the matrix due to overheating relative to the surrounding medium.

There is no continuing heat supply within the bubble, so new hydrate forms on its boundary, and its radius decreases with time. The process is analysed in the framework of the model that takes into account the phase transition and accompanying heat and mass transport processes and assumes spherical symmetry. It is shown that in the case of small ($\sim 10^{-2}$-10^{-1} m) bubbles, convective fluxes are negligible and the process is fully described by heat conduction and phase change equations.

A spherically symmetric Stefan problem for purely conduction-controlled evolution is solved analytically for the case of equilibrium initial temperature and pressure within the bubble. The self-similar solution is verified, with good results, in numerical simulations based on the full filtration and heat transfer model and using the isotherm migration method. Numerical simulations are also conducted for a wide range of cases not amenable to analytical solution.

It is found that, except for initial development of an overheated bubble, its radius evolves with time following the self-similar formula:

$$\frac{R(t)}{R_0} = \left(1 - \frac{t}{t_m}\right)^{1/2}, \tag{1}$$

where t_m is the life-time of bubble (time of its complete freezing). The analytical solution shows that t_m follows

$$t_m \sim (R_0/\Gamma)^2, \tag{2}$$

where Γ is a constant determined by the temperature difference ΔT between the bubble's interior and far field.

We consider implications for natural hydrate deposits. As an example, for a bubble with $R_0 = 4$ cm and $\Delta T = 0.001$ K, we find $t_m \sim 5.7 \cdot 10^6$ s (2 months) in a water excess system, and $\sim 2.9 \cdot 10^7$ s (11 months) in a gas excess system.

Motion of the bubble is not considered in our study, but it can be estimated that at the typical velocity of buoyancy-driven transport, a small bubble does not move a significant distance over its life-time and, thus, cannot survive filtration through the hydrate stability zone.

Work was financially supported by the Civilian Research and Development Foundation (Grant RUP1-2945-PE-09) and the Russian Foundation for Basic Research (Grant 09-01-92505).