Development of Prediction Model of CO\textsubscript{2} Hydrate Film Thickness for CCS

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ABSTRACT

The purpose of the present study is to develop the prediction model of CO\textsubscript{2} hydrate film thickness. Especially the influence of flow around the hydrate on the forming and growing is studied experimentally. We apply the experimental results of film thickness to the presented film thickness model, and compare it to the experimental results. By using these experimental data, H\textsubscript{2}O permeation coefficient is estimated. And to use permeation coefficient of H\textsubscript{2}O, the mass flux that water molecule through hydrate is estimated to predict CO\textsubscript{2} hydrate film forming and growing under the condition with water flow.

KEY WORDS: Global warming; CCS; CO\textsubscript{2} hydrate; Mass transfer;

NOMENCLATURE

- $A$: superficial area of a hydrate film [m\textsuperscript{2}]
- $C$: mass concentration [kg/m\textsuperscript{3}]
- $D$: diffusion coefficient [m\textsuperscript{2}/s]
- $g$: gravitational acceleration [m/s\textsuperscript{2}]
- $Gr$: Grashof number [-]
- $J$: mass flux [kg/(m\textsuperscript{2}·s)]
- $K$: mass transfer coefficient [m/s]
- $L$: characteristic length [m]
- $l$: distance between hydrate film and screen [m]
- $M$: number of interference fringes [-]
- $M_{CO2}$: CO\textsubscript{2} molecular mass [kg/mol]
- $M_{H2O}$: H\textsubscript{2}O molecular mass [kg/mol]
- $m_{CO2}$: amount of CO\textsubscript{2} dissolution [kg/m\textsuperscript{2}]
- $n$: hydration number [-]
- $n_e$: index of refraction of CO\textsubscript{2} hydrate [-]
- $n_w$: index of refraction of water [-]
- $Sc$: Schmidt number [-]
- $Sh$: Sherwood number [-]
- $SO_{CO2}$: saturated solubility of CO\textsubscript{2} in water [-]
- $Re$: Reynolds number [-]
- $T$: temperature [°C]
- $t$: time [s]
- $u$: flow velocity [m/s]
- $V$: volume of a test chamber [m\textsuperscript{3}]
- $V_{CO2}$: molar volume of CO\textsubscript{2} [m\textsuperscript{3}/mol]
- $V_d$: film displacement rate at the H\textsubscript{2}O side [m/s]
- $V_f$: film displacement rate at the CO\textsubscript{2} side [m/s]
- $\Delta y$: an interval of the interference fringes [m]
- $z$: distance from an interface [m]

Greek symbols

- $\alpha$: H\textsubscript{2}O permeation coefficient of H\textsubscript{2}O [m\textsuperscript{2}/s]
- $\beta$: coefficient of volumetric expansion [m\textsuperscript{3}/kg]
- $\delta$: CO\textsubscript{2} hydrate film thickness [m]
- $\delta_b$: CO\textsubscript{2} boundary layer thickness [m]
- $\eta_{H2O}$: viscosity of water [Pa·s]
- $\varphi$: association parameter [-]
- $\lambda$: laser wavelength [nm]
- $\nu$: kinematic viscosity of water [m\textsuperscript{2}/s]
- $\theta$: incidence angle of the laser light [-]
- $\rho$: density [kg/m\textsuperscript{3}]
- $\rho_{sat}$: density of CO\textsubscript{2} saturated water [kg/m\textsuperscript{3}]

Superscripts

- CO\textsubscript{2}: CO\textsubscript{2} side
- H: hydrate
- Hydrate: presence of the hydrate
- nohydrate: absence of the hydrate
- W: water side
- $\infty$: bulk

Subscripts

- CO\textsubscript{2}: liquid CO\textsubscript{2}
- H\textsubscript{2}O: water

INTRODUCTION

Carbon dioxide (CO\textsubscript{2}) is considered as greenhouse gas to global warming of the earth. Carbon dioxide capture and storage (CCS) of ocean sequestration is expected as one of the effective options to mitigate the global warming. In the CCS, CO\textsubscript{2} is planning to store at deep seafloor. At deep seafloor, temperature condition of sea water is around 4 °C and pressure condition can be thought over 10 MPa deeper than 1000 m. In this region, CO\textsubscript{2} exist as liquid phase. On the other hand,