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Estimation of Thermal Properties of Methane Hydrate Sediment

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Abstract

Thermal conductivity of real hydrate-layer sand grain, which was recovered from the sediment under sea bottom near Japan, was measured with hot-disc transient method. That of Toyoura standard sand was also measured for comparison. Thermal conductivity of natural methanehydrate-layer sand was 3.8 ~ 5.8 [W/mK] at measured condition (263K~283K, 0.1MPa). This value was lower than that of Toyoura standard sand (8.6 ~ 9.4 [W/mK]) at the same condition. Thermal conductivities of the natural hydrate-layer sand grain and artificial methane hydrate (MH) mixtures were also measured at the condition that imitated the real circumstances of sediment under sea bottom (278K, 10MPa,water saturated). The value was remarkably decreased with the increase of MH concentration at 0vol% ~40vol%. While, it was not so much changed at higher than 40vol%. Estimation of thermal conductivity of natural sand-MH-water three component mixtures was carried out. As a result, the series-parallel conjugation model with varying the contribution parameter reproduced measured values correctly. This is consistent with the idea that structure of measured sand-MH mixed samples should be changed around 40vol% of MH.

INTRODUCTION

Gas hydrate is a clathrate compound that is composed of guest gas molecules and host water cages[1]. Recently, it becomes well known that there are huge amount of methane hydrate in the sediment under sea floor as same as land areas of permafrost regions. Since this gas hydrate contains large quantity of methane gas, it is considered as one of the substantial future energy resources. Thus, the investigation to recover it from the sea bottom near Japan was launched. In this investigation, thermal properties such as thermal conductivity, heat of dissociation and heat capacity of gas hydrate sediment are very important to evaluate economy of gas hydrate recovery. However, there is not enough experimental data for those thermal properties. Especially, very few data is reported for thermal conductivity of methane hydrate with soil and water[2, 3]. In this paper, thermal conductivity of natural hydrate-layer sand grain was determined by comparing the measured apparent thermal conductivity of water-saturated samples and that of estimated values with mixing model. Thermal conductivities of the natural sand grain and artificial methane hydrate (MH) mixtures were measured at the condition that imitates the real circumstances of sediment under sea bottom. Estimation of thermal conductivity of natural sand-MH-water three component mixtures was also carried out.

Experiment

Principle of hot-disc transient method

Figure 1 shows the principle of hot-disc transient method[4]. In this method, electric pulse is supplied to the sample materials and mitigation of temperature (ΔT_{avg}) around censor probe with passing time (t) is acquired. This ΔT_{avg} can be expressed theoretically as following formula;

$$\Delta T_{ave}(\tau)=P_0/\pi^{3/2}r\lambda\times D(\tau) \quad \bullet\bullet\bullet\bullet\bullet\bullet\bullet\bullet(1)$$

Here, P_0 is the electric power that is supplied to the sensor probe [W], λ is the apparent thermal conductivity of sample [W/mK], r is the radius of sensor probe (mm), D (τ) is the function of the non-dimensional parameter τ, which is expressed