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A Fundamental Study of Applying Ultrasonic Waves in 20 kHz Band Frequency to the Method of Preheating the Oil Sand

オイルサンド予熱手法への 20kHz 帯超音波の適用に関する基礎研究

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1. Introduction

Currently, the mainstream to produce heavy oil bitumen is open pit mining. In 2004, bitumen production from Canada oil sands were about 90 million barrels per day. Two-thirds of the 90 million bbl of bitumen has been developed by open pit mining. However, there are approximately 80% of 170 billion bbl of remaining recoverable reserves of bitumen in oil sand that is deeper than tens of m. It is necessary to collect most of bitumen to develop oil sands. One of the in-site collection method called SAGD(Steam Assisted Gravity Drainage) is an effective means to develop the oil sands located in the underground. In SAGD, the hot steam is injected into the underground to fluidize the heavy oil bitumen. And perform the recovery of the bitumen from oil sand layer. At present, the preheating time of oil sand layer injected with hot steam is too long, and it costs significant investment to development the oil sands. Therefore, it is necessary to reduce the running costs to reduced through the preheating time of heavy oil.

In recent years, the use of ultrasonic waves in the process of extracting bitumen recovered by open pit mining, etc. have been reported on the extraction efficiency[1~4)]. However, the study that is apply the ultrasonic waves to directly SAGD are not reported. Therefore, aim of this study is to apply the SAGD method, made basic study of heavy oil thermal conductivity of the sand belt use ultrasonic 20kHz frequency band.

2. Experimental Methods

Fig. 1 shows schematic view of the experimental setup. The ultrasonic sonication was performed by Langevin type transducer (FUJI CERAMICS CORPORATION, 28 kHz resonant frequency). The output of this device was adjusted to 700mVpp by function generator (Agilent Technologies). This signal was amplified 100times with bipolar power supply (HSA4011; NF). The aim of experiment is measuring the temperature rising of sand layer, conducted to evaluate relation between ultrasonic sonication and temperature rising. Drying sand was filled up into 3L PP beaker. The sand layer was made with Toyoura sand. Toyoura sand is natural silica sand. Particle size is adjusted to arrangement from 0.1mm to 0.3mm. φ80 Rubber heater (watt density:1W/cm^2) that can bake up to about 200℃ placed on the bottom of beaker. The temperature was measured with thermocouples type K that is Teflon-type mold. This is known as resin FEP whose heat resistance is a wide range of 0 ~ 200℃. And, resin FEP has chemical resistance, flame resistance and excellent adhesion to low-wear. This sensor was needed to measure temperature in the sand layer. The temperature measurement has performed 4000s. Temperature of a room was kept constant. Langevin type transducer was attached at the bottom of beaker to transfer to the vibration in the sand directly. Sensor setup is shown in Fig.1, too. At side of heater, TC was set from heater surface to beaker depth at 5mm intervals (Gr1). At center of heater, TC was set from heater surface to beaker depth at 5mm intervals (Gr2).

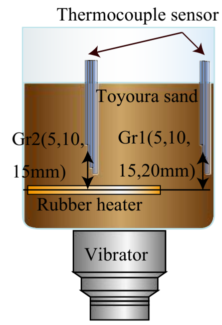

Fig.1 Schematic view of the experimental setup. Sensor at side of heater is G1. Sensor at center of heater is G2.

Applied Fourier's law to calculate thermal conductivity is indicated by **eq. (1).**

$$q = -\lambda \frac{\partial T}{\partial x} = \lambda \frac{(T_H - T_C)}{d} \quad \cdots (1)$$

$$\lambda = \frac{0.86P}{2A} \frac{d}{T_H - T_C} \quad ^{6)}$$

Here, q is thermal flux (W/m^2). d is distance from heater (m). λ is thermal conductivity(W/(m・

K)). T_H is steady-state temperature on surface of heater (K). T_C is steady-state temperature measured with sensor (K). A is heater superficial area (m^2). P is electricity (W). Steady state method is used with other research[6]. It was thought that this method can be applied to a powdery state as the drying sands to estimate thermal conductivity. P is estimated by currency and voltage value which was read constant-voltage source. Compared non ultrasonic sonication to ultrasonic sonication, the rising temperature trend was analyzed.

3. Results and Discussion

Fig. 2 shows an example of results of temperature measurement. It shows from 4000s to 6400s, sand temperature was just about steady state. Steady temperature is needed to calculate thermal conductivity. **Fig. 3** shows relation between thermal conductivity and ultrasonic frequency. Calculated thermal conductivity value is from 0.075 to 0.16. To determine the validity, results were compared with previous studies and some materials[5~7]. **Table I** indicates thermal conductivity of varied material[7]. These values are close to proposal. And some

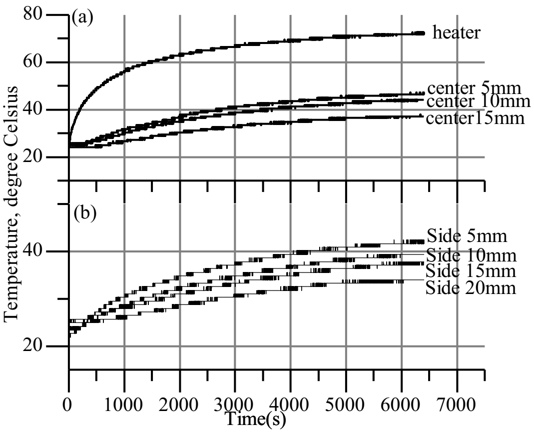

Fig.2 An example of results of temperature measurement. (a) is measured with G1 sensors. (b) is measured with G2 sensors.

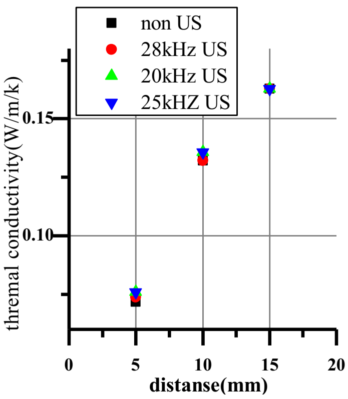

Fig.3 Relation between thermal conductivity and ultrasonic frequency. Ultrasonic frequency is used at 20 kHz, 25 kHz and 28 kHz.

reports show thermal conductivity of sand is from situation, thermal conductivity is twice the difference[5]. So it can be said that proposal was considered reasonable and proper.

Fig.3 indicates when distance from heater to sensor is 15mm, relation between thermal conductivity and ultrasonic frequency is little. By contrast, in the situation of distance of 10mm and 5mm, a trend shows low frequency is higher thermal conductivity than high frequency.

Table I Thermal conductivity(W/m/K) of various material[7]

Material	sand	air	clay
λ(W/m/K)	0.2408	0.026	0.946
Material	soil(in gravel)	drying soil	wet soil
λ(W/m/K)	0.387	0.0946	0.4902

4. Conclusions

To apply ultrasonic waves in 20 kHz frequency band to method of preheating oil sand, relation between thermal conductivity and ultrasonic frequency is investigated. It is clear that thermal conductivity of Toyoura sand layer can be calculated with steady state method. Proposal thermal conductivity is close to previous studies etc. If distance from heater is far, relation between thermal conductivity and ultrasonic frequency is little. And if distance from heater is near, relation between thermal conductivity and ultrasonic frequency is more.

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