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The use of ultrasound irradiation for extracting bitumen from oil sand at low temperature

超音波照射を用いたオイルサンドからのビチューメンの低温抽出

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1. Introduction

Oil sands are the mixture of bitumen (heavy oil), siliceous materials (sand, sandstone) and connate water. Deposits of oil sands exist throughout the world and the majorities are present in Alberta (Canada) and Orinoco (Venezuela). The bitumen content of oil sands is 10-15 wt%. For bitumen to be used as fuel energy, it must be extracted from oil sands and collected. Main industrial processes to extract bitumen from oil sands need treatment with hot water and steam. The addition of chemical agents (alkaline reagents, surfactants) has been investigated to improve the yield of bitumen and to reduce the energy of extraction process. Sadeghi et al. reported that hydrogen peroxide plays a positive role in the separation of bitumen from tar sand grains during ultrasound irradiation of 40 kHz [1]. The objective of the present work is to study the extraction of bitumen from oil sands using ultrasound irradiation and hydrogen peroxide combined with warm or hot water treatment, and removes the use of surfactants and agents, thereby reducing the environmental burden [2-6]. Especially, we focused on 200 kHz ultrasound irradiation which generates hydogen peroxide by collapse of cavities and prevents particle reduction of its weak viblation motion [2-4, 7].

2. Experimental

The sonication was performed with an ultrasonic generators (TA-4021; KAIJO) and submersible transducers (28 kHz and 200 kHz; KAIJO). The outputs of these devices were adjusted to 200 W. A flat-bottom flask was used as a reactor which is able to control the solution temperature by a circulation system. Air was flowed at 100 ml/min. The experimental apparatus is shown in **Fig.1**. A sample of oil sand from Alberta, in Canada was used in this experiment. The sample size of the oil sand was 3-5 mm (**Fig.2**). The suspension of oil sand was prepared by mixing oil sand (2.97 g) and sodium hydroxide (0.03 g) with distilled warm water (60 ml, 45 °C) or distilled hot water (60 ml, 85 °C) in a flask. Then the suspensions were treated by hot or warm water while being sonicated (28 kHz, 200 kHz) or stirred (750 RPM) for 15min. After the treatment, the extracted bitumen floating on the water surface was collected and weighed after drying. Oil sand and the recovered bitumen were analyzed with a thermo-gravimetric analyzer (TG-8120; Rigaku) under Ar flow. The TGA spectra were acquired in the temperature ranging from 30 to 800 °C with the heating rate of 5 °C min^{-1}. Experiments at individual conditions were conducted over twice.

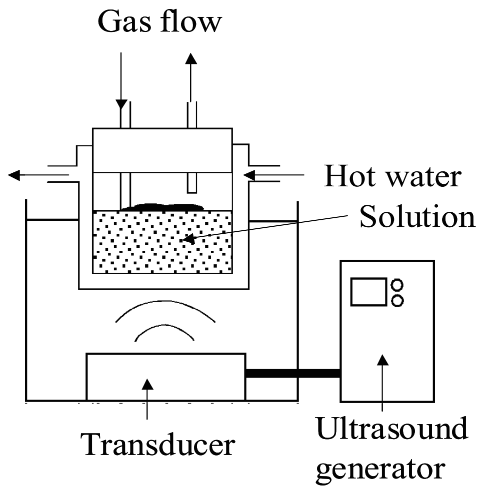

Fig.1 Schematic design of the experimental apparatus.

Fig.2 Photograph of the oil sand particles.

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3. Results and Discussion

The bitumen content of oil sands was 12.3 %, which was analyzed by the TGA plot of the oil sands. This percentage is close to reported bitumen weight percentages in oil sands [1,7]. The mass of bitumen rising to the water surface (M) by the treatment is total of the mass of bitumen itself (M_b) and the mass of entrapped solid particles of sands (M_s); $M = M_b + M_s$. TGA was used to measure the weight of M_b. The bitumen extraction rate (= M_b / Mo × 100; Mo is the mass of bitumen in the original mixture (12.3 wt%)) and purity, the without contamination ratio of fine sands in the extracted bitumen, (= M_b / M) were calculated by the results of TGA. **Table I** shows results of purities and extraction rates at various conditions (treatment time was 15 min, oil sand 2.97 g, NaOH 0.03 g). The results suggest that high temperature (85 °C) is easier to extract bitumen from oil sand than low temperature (45 °C). Sonication of 200 kHz is well known to generate OH radical and hydrogen peroxide (H_2O_2). Sadeghi et al. reported that hydrogen peroxide plays a positive role in the separation of bitumen from tar sand grains during ultrasound irradiation. However, the bitumen extraction rate of 200 kHz was 0 % at 45 °C. We thought that the amount of generated H_2O_2 was very low (7 ppm at 45 °C) and generated H_2O_2 did not work enough for separation of bitumen. And then we confirmed the role of H_2O_2 for the separation of oil sand. A large amount of H_2O_2 (100, 1000 ppm; SANTOKU) was added to the solution (85 °C) during ultrasound irradiation or stirring and the results shown in **Fig.3**. At stirring condition, the bitumen extraction rate was not changed when H_2O_2 was added. However, at 28 kHz sonication condition, the bitumen extraction rate was remarkably increased when H_2O_2 was added. By applying sonication and H_2O_2 simultaneously, the vesicles were generated at the surface of bitumen. The vesicles made the oil sand rise more easily to the surface of the solution.

4. Conclusions

It was clear that a large amount of H_2O_2 (>100 ppm) plays a positive role in the separation of bitumen from oil sand grains during ultrasound irradiation. By applying sonication and H_2O_2 simultaneously, the vesicles were generated at the surface of bitumen. The vesicles made the oil sand rise more easily to the surface of the solution. In the future, we will examine the extraction of bitumen using 200 kHz sonication and H_2O_2 simultaneously at low temperature.

Table I Bitumen extraction ratio from oil sand at various conditions

	temp. (℃)	purity	extraction ratio (%)
28kHz	45	0.69	17.8
	85	0.91	41.6
200kHz	45	−	0
	85	0.91	57.6
stirring	45	−	0
	85	0.88	5.82

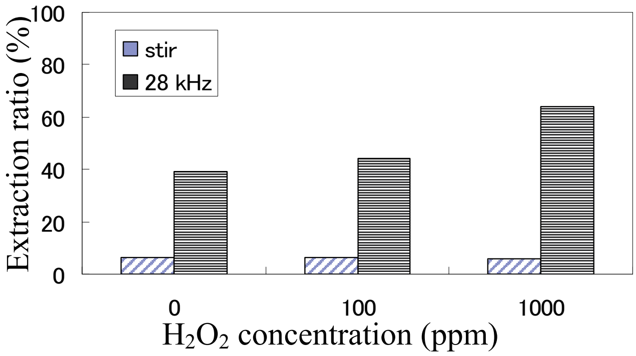

Fig.3 Variations in the extraction ratio of bitumen from the oil sand treated by H_2O_2 addition (0, 100, 1000 ppm) and sonicaton (28 kHz) or stirring (750 RPM) for 15 min.

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