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Research on the extraction of bitumen from oil sand treated by ultrasound irradiation

超音波照射を用いたオイルサンドからのビチューメン抽出に関する研究

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1. Introduction

Deposits of oil sands exist throughout the world and the majorities are present in Alberta (Canada) and Orinoco (Venezuela). Oil sands are the mixture of bitumen (heavy oil) and siliceous materials (sand, sandstone). 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. The objective of the present work is to study the extraction of bitumen from oil sands using ultrasound irradiation [1-3] combined with hot water treatment, and remove the use of chemical agents, thereby reducing the environmental burden.

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 sample of oil sand from Alberta, in Canada was used in this experiment. The suspension of oil sand was prepared by mixing oil sand (3 g) with distilled hot water (60ml, 60 - 90 °C) in a flask and sonicating it at 28 kHz. Then the suspension was treated by hot water while being stirred (750 RPM). After the hot water treatment, the extracted bitumen floating on the water surface was collected and weighed after drying. Total time for 28 kHz sonication and stirring in hot water was 15 min. After these treatments, the suspension was sonicated at 200 kHz, and the pH value and the particle dispersion in the solution were observed. 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.

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3. Results and Discussion

The TGA plot of the oil sands is shown in **Fig. 1**. The decrease in the weight started at 150 °C and continued through the temperature sweep up to 680 °C. The weight change became insignificant when the temperature increased further to 800 °C. The total loss of the weight was 12.3 %, which is mainly due to the resolution of bitumen in and around the sands. This percentage is close to reported bitumen weight percentages in oil sands [4,5]. 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.

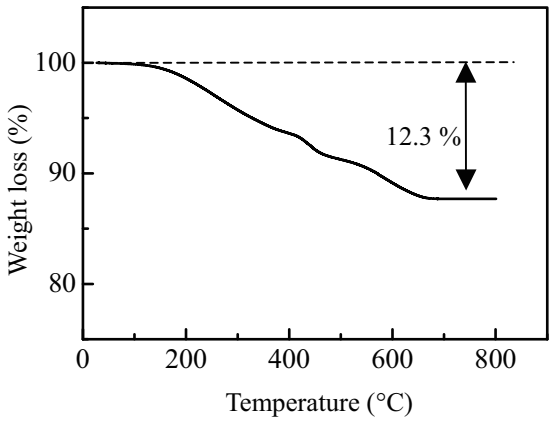

Fig.1 Thermo-gravimetric analysis for the oil sand in Ar at the heating rate of 5 °C min^{-1}.

Fig. 2 shows the bitumen extraction rate α (= M / Mo; Mo is the mass of bitumen in the original mixture (12.3 wt.%)) and the contamination rate of fine sands in the extracted bitumen β (= Ms / M). The results suggest that sonication at 28 kHz before the hot water treatment can effectively extract bitumen from oil sands. This will be partly because the ultrasound irradiation increased the surface area of oil sand particles and increased the contact with water. The critical factor was the water temperature during the process because the bitumen extraction rate α was remarkably reduced when the sonication was conducted at 60 °C. The contamination rate of fine sands in the extracted bitumen β was decreased by using 28 kHz sonication for 10 min. The reason could be because the particle size of oil sand relates to β. This extraction process without using chemical agents, however, needs further improvements since the chemical agents can achieve the β value under 0.1.

Fig. 3 shows the changes in the pH of oil sand suspensions during 3 hours of sonication at 200 kHz. It is clear that sonication caused the solution more acidic. Precipitation of the sands of siliceous material occurred (**Fig.4**) because it has the zero Zeta-potential region at the pH around 2 to 4.

4. Conclusions

The result of TGA indicated that the bitumen content in the oil sand was 12.3 wt.%. We applied ultrasound irradiation in combination with hot water treatment, and successfully extracted 60 % of the bitumen content. After this extraction process, fine particles of sands in the suspension were precipitated by sonication at 200 kHz without addition of any precipitant. Thus, our bitumen extraction process does not require chemical agents and reduces environmental burden.

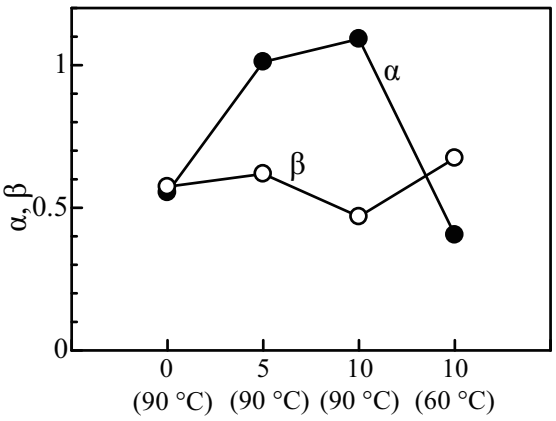

Fig. 2 The bitumen extraction rate α and the contamination rate of fine sands in the extracted bitumen β under various conditions (Total time for 28kHz sonication at 60 °C or 90 °C and stirring in hot water at 90 °C was 15min).

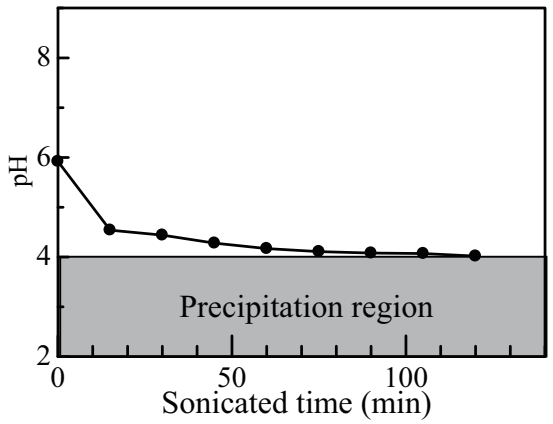

Fig. 3 Variation in the pH of the oil sand suspension treated by sonication at 200kHz for 120min.

Fig.4 Transparent appearance of the oil sand suspension stood for 24 h following 120 min sonication.

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